

STC89C51RC/RD+系列单片机器件手册

STC89C51RC,	STC89LE51RC
STC89C52RC,	STC89LE52RC
STC89C53RC,	STC89LE53RC
STC89C54RD+,	STC89LE54RD+
STC89C58RD+,	STC89LE58RD+
STC89C510RD+,	STC89LE510RD+
STC89C512RD+,	STC89LE512RD+
STC89C514RD+,	STC89LE514RD+
STC89C516RD+,	STC89LE516RD+

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第1章 STC89系列单片机总体介绍

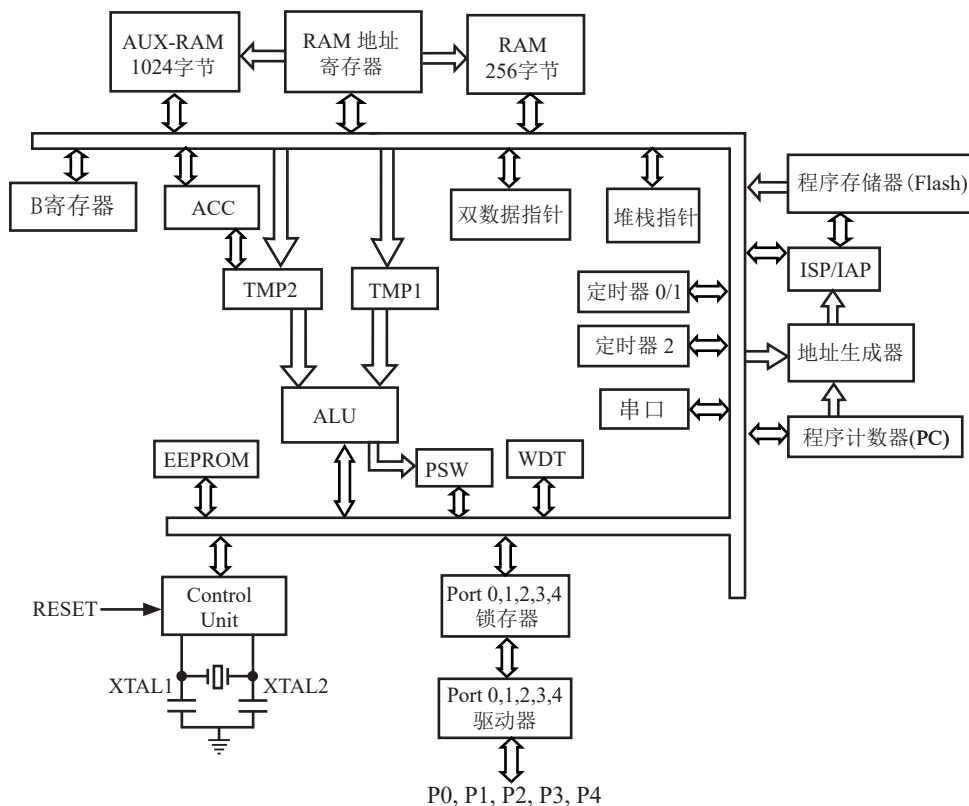
1.1 STC89C51RC/RD+系列单片机简介

STC89C51RC/RD+系列单片机是宏晶科技推出的新一代高速/低功耗/超强抗干扰的单片机，指令代码完全兼容传统8051单片机，12时钟/机器周期和6时钟/机器周期可以任意选择，HD版本和90C版本内部集成MAX810专用复位电路。

1. 增强型8051单片机，6时钟/机器周期和12时钟/机器周期可任意选择，指令代码完全兼容传统8051
 2. 工作电压：5.5V - 3.3V (5V单片机) / 3.8V - 2.0V (3V单片机)
 3. 工作频率范围：0~40MHz，相当于普通8051的 0~80MHz，实际工作频率可达48MHz.
 4. 用户应用程序空间：4K / 8K / 13K / 16K / 32K / 64K字节
 5. 片上集成1280字节或512字节RAM
 6. 通用I/O口(35/39个)，复位后为：P1/P2/P3/P4是准双向口/弱上拉(普通8051传统I/O口)；P0口是开漏输出，作为总线扩展用时，不用加上拉电阻，作为I/O口用时，需加上拉电阻。
 7. ISP（在系统可编程）/ IAP（在应用可编程），无需专用编程器，无需专用仿真器，可通过串口（RxD/P3.0, TxD/P3.1）直接下载用户程序，数秒即可完成一片
 8. 有EEPROM功能
 9. 看门狗
 10. 内部集成MAX810专用复位电路(HD版本和90C版本才有)，外部晶体20M以下时，可省外部复位电路。
 11. 共3个16位定时器/计数器，其中定时器0还可以当成2个8位定时器使用。
 12. 外部中断4路，下降沿中断或低电平触发中断，Power Down模式可由外部中断低电平触发中断方式唤醒。
 13. 通用异步串行口(UART)，还可利用定时器软件实现多个UART
 14. 工作温度范围：-40~+85℃(工业级) / 0~75℃(商业级)
 15. 封装：LQFP-44,PDIP-40,PLCC-44,PQFP-44. 如选择STC89系列, 请优先选择LQFP-44封装.
- 温馨提示：推荐优先选择采用最新第六代加密技术的宏晶STC11/10xx系列单片机取代全球各厂家均已被解密的89系列单片机。

1.2 STC89C51RC/RD+系列单片机的内部结构

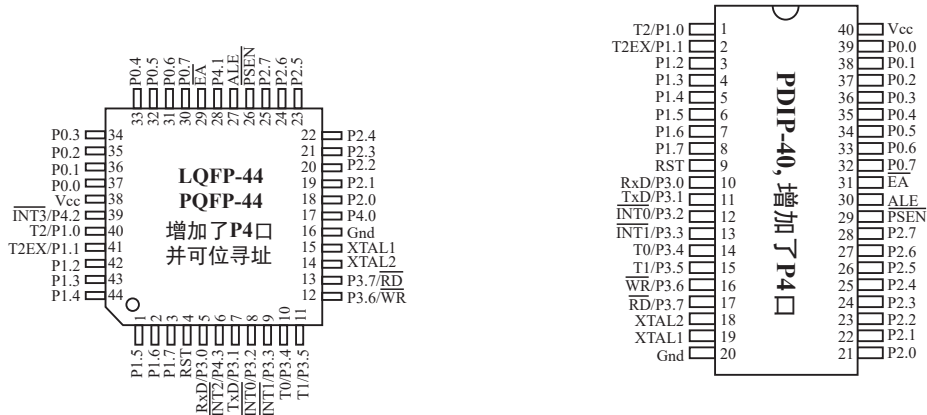
STC89C51RC/RD+系列单片机的内部结构框图如下图所示。STC89C51RC/RD+单片机中包含中央处理器(CPU)、程序存储器(Flash)、数据存储器(SRAM)、定时/计数器、UART串口、I/O接口、EEPROM、看门狗等模块。STC89C51RC/RD+系列单片机几乎包含了数据采集和控制中所需的所有单元模块，可称得上一个片上系统。



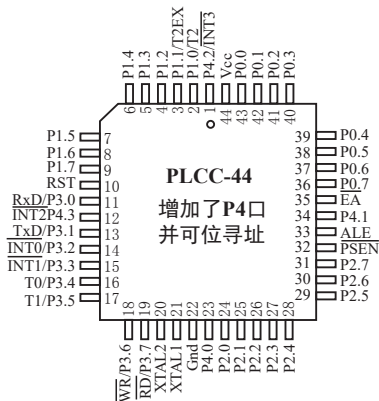
STC89C51RC/RD+系列内部结构框图

1.3 STC89C51RC/RD+系列单片机管脚图

1.3.1 STC89C51RC/RD+系列HD版本的管脚图



HD版本无P4.6/P4.5/P4.4口



关于编译器/ 汇编器:

1. 任何老的编译器/汇编器均可使用Keil C51 中: Device选择标准的Intel8052头文件包含标准的 <reg52.h>
2. 新增特殊功能寄存器如要用到, 则用“sfr”及“sbit”声明地址即可
3. 汇编中用“data”, 或“EQU”声明地址

关于仿真及仿真器:

1. 任何老的仿真器均可使用
2. 老的仿真器仿真他可仿真的基本功能
3. 新增特殊功能用ISP直接下载程序看结果即可
5. 其实现在大部分STC用户不用仿真器, 用ISP就可调通64K程序

关于工作电压/时钟频率:RC/RD+系列是真正的6T单片机, 兼容普通的12 时钟/机器周期

内核实际6T	现有HD版本5V单片机, 单倍速工作将外部时钟频率除以2, 降频工作					
工作电压	外部时钟	单倍速 相当于 普通8052	实际内核 运行时钟	双倍速 相当于 普通8052	实际内核 运行时钟	IAP/ISP可以
5.5V - 4.5V	0 - 44MHz	0 - 44MHz	0 - 20MHz	0 - 80MHz	0 - 40MHz	读, 编程, 擦除
5.5V - 3.8V	0 - 33MHz	0 - 33MHz	0 - 16.5MHz	0 - 66MHz	0 - 33MHz	读, 编程, 擦除
5.5V - 3.6V	0 - 24MHz	0 - 24MHz	0 - 12MHz	0 - 48MHz	0 - 24MHz	读, 编程, 擦除
5.5V - 3.4V	0 - 20MHz	0 - 20MHz	0 - 10MHz	0 - 40MHz	0 - 20MHz	读(不要编程/擦除)

3V: 3.8 - 2.0V(可外部24MHz, 双倍速48MHz), 2.3 - 1.9V时不要进行IAP擦除/编程



1.4 STC89C51RC/RD+系列单片机选型一览表

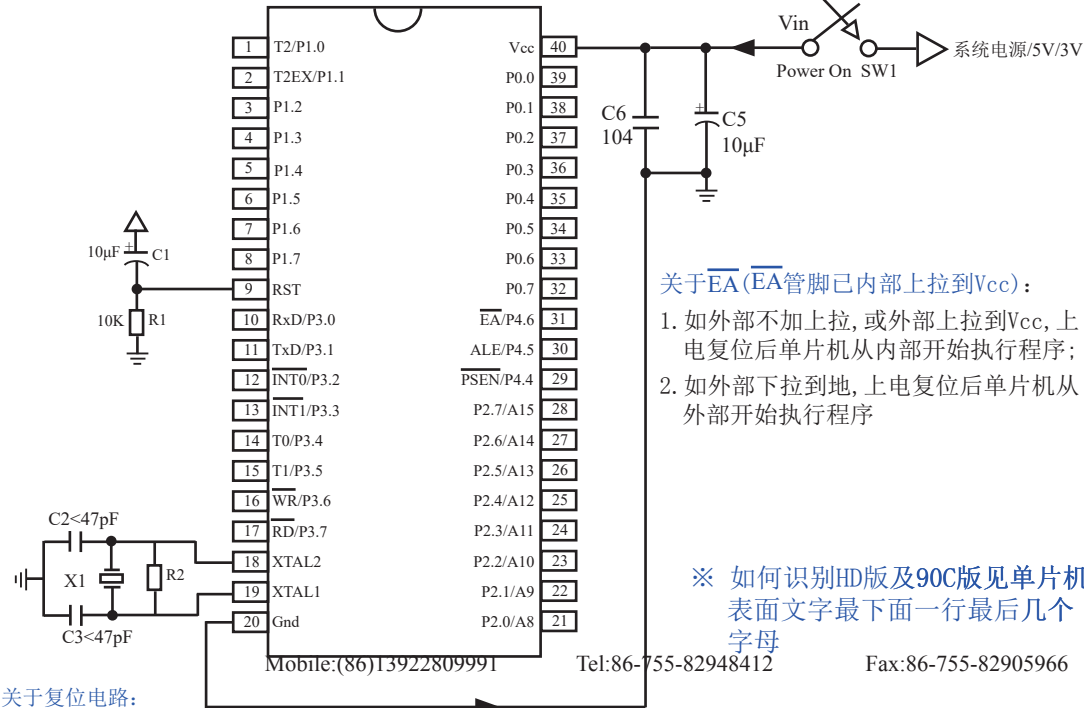
型号	工作电压 (V)	最高时钟频率 Hz		Flash 程序存储器 (字节)	SRAM 字节	定时器	UART 串口	D P T R	EEP ROM (字节)	看门狗	A/D	中断源	中断优先级	I/O	支持掉电唤醒外部中断	内置复位	封装 40-Pin	封装44-Pin
		5V	3V															
STC89C/LE51RC系列单片机选型一览																		
STC89C51RC	5.5 - 3.3	0-80M		4K	512	3	1个	2	4K	有	-	8	4	35/39	4个	有	PDIP	LQFP/PLCC
STC89C52RC	5.5 - 3.3	0-80M		8K	512	3	1个	2	4K	有	-	8	4	35/39	4个	有	PDIP	LQFP/PLCC
STC89C53RC	5.5 - 3.3	0-80M		13K	512	3	1个	2	-	有	-	8	4	35/39	4个	有	PDIP	LQFP/PLCC
STC89LE51RC	3.6 - 2.0		0-80M	4K	512	3	1个	2	4K	有	-	8	4	35/39	4个	有	PDIP	LQFP/PLCC
STC89LE52RC	3.6 - 2.0		0-80M	8K	512	3	1个	2	4K	有	-	8	4	35/39	4个	有	PDIP	LQFP/PLCC
STC89LE53RC	3.6 - 2.0		0-80M	13K	512	3	1个	2	-	有	-	8	4	35/39	4个	有	PDIP	LQFP/PLCC
STC89C/LE51RD+系列单片机选型一览																		
STC89C54RD+	5.5 - 3.3	0-80M		16K	1280	3	1个	2	45K	有	-	8	4	35/39	4个	有	PDIP	LQFP/PLCC
STC89C58RD+	5.5 - 3.3	0-80M		32K	1280	3	1个	2	29K	有	-	8	4	35/39	4个	有	PDIP	LQFP/PLCC
STC89C516RD+	5.5 - 3.3	0-80M		64K	1280	3	1个	2	-	有	-	8	4	35/39	4个	有	PDIP	LQFP/PLCC
STC89LE54RD+	3.6 - 2.0		0-80M	16K	1280	3	1个	2	45K	有	-	8	4	35/39	4个	有	PDIP	LQFP/PLCC
STC89LE58RD+	3.6 - 2.0		0-80M	32K	1280	3	1个	2	29K	有	-	8	4	35/39	4个	有	PDIP	LQFP/PLCC
STC89LE516RD+	3.6 - 2.0		0-80M	64K	1280	3	1个	2	-	有	-	8	4	35/39	4个	有	PDIP	LQFP/PLCC

STC89C51RC/RD+系列单片机44-pin的封装除LQFP44和PLCC44外，还有PFQP44，但是不推荐使用PLCC44和PFQP44封装，建议选用LQFP44的封装。

选用STC单片机的理由：降低成本，提升性能，原有程序直接使用，硬件无需改动。STC公司鼓励您放心大胆选用LQFP44小型封装单片机，使您的产品更小，更轻，功耗更低。
用STC提供的STC-ISP.exe 工具将您的2进制代码或16进制代码下载进STC相关的单片机即可。

RC/RD+系列为真正的看门狗，缺省为关闭(冷启动),启动后无法关闭，可放心省去外部看门狗。内部Flash擦写次数为10万次以上。

1.5 STC89C51RC/RD+系列单片机最小应用系统



关于复位电路:

晶振频率X1为4MHz时, C2、C3应为100pF; 晶振频率X1为6MHz时, C2、C3应为47pF~100pF; 晶振频率X1为12M~25MHz时, C2、C3应为47pF

- 1. 阻容复位时, 电容C1为10uF, 电阻R1为10K
- 2. RC/RD+系列单片机HD版本, RESET脚内部已有45K-100K下拉电阻

关于晶振电路:

OSCDN, 晶体振荡器增益控制 = full gain								
X1	4MHz	6MHz	12M-25MHz	26M-30MHz	31M-35MHz	36M-39MHz	40M-43MHz	44M-48MHz
C2, C3	= 100pF	47pF~100pF	= 47pF	<= 10pF	<= 10pF	<= 10pF	<= 10pF	<= 5pF
R1	不用	不用	不用	6.8K	5.1K	4.7K	3.3K	3.3K

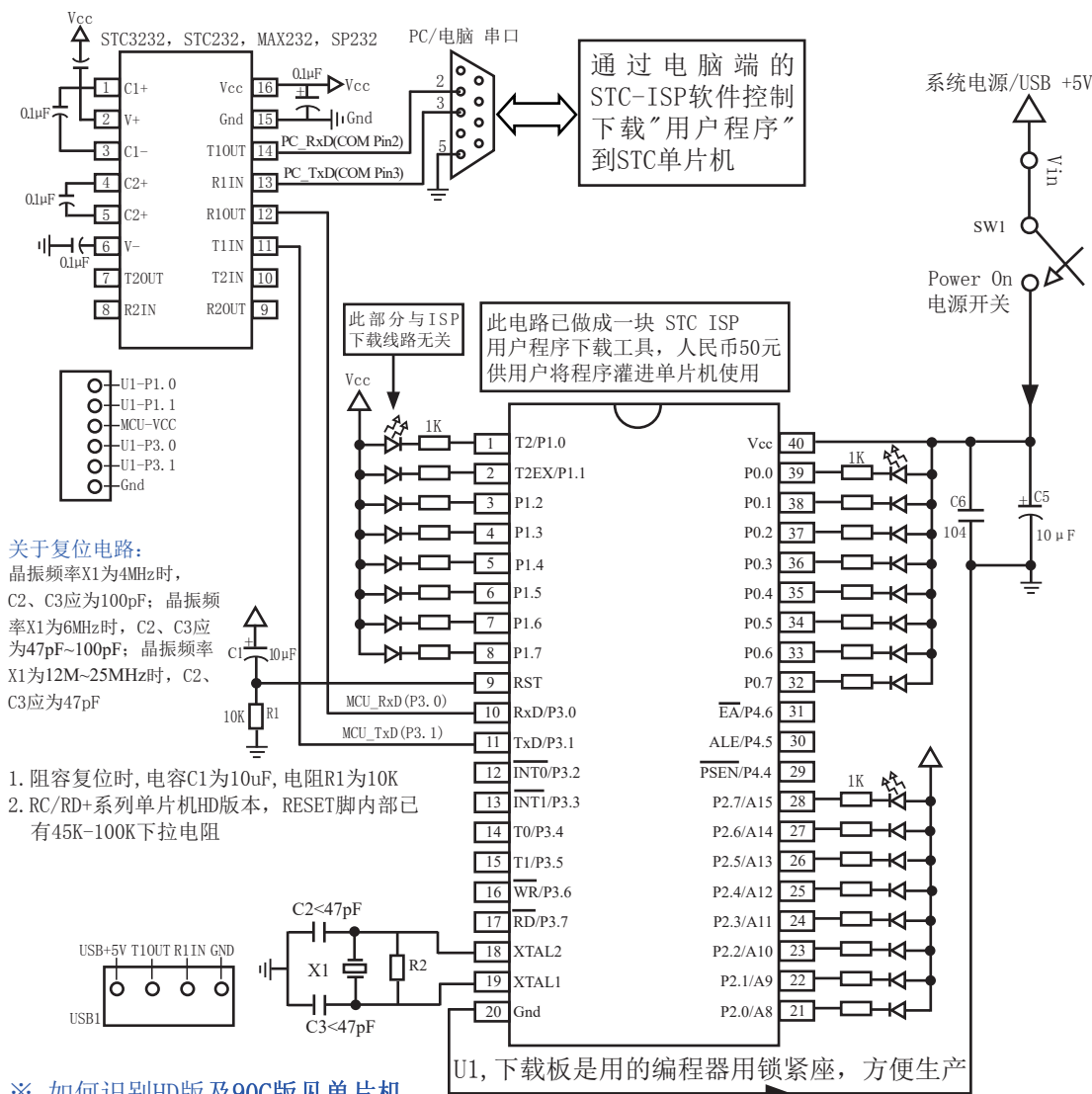
OSCDN(OSC Control), 晶体振荡器增益 = 1/2 gain								
X1	4MHz	6MHz	12M-25MHz	26M-30MHz	31M-35MHz	36M-39MHz	40M-43MHz	44M-48MHz
C2, C3	= 100pF	47pF~100pF	= 47pF	<= 10pF	不用	不用	不用	不用
R1	不用	不用	不用	6.8K	5.1K	4.7K	3.3K	3.3K

STC89系列HD版本的单片机正常工作时的时钟频率

推荐工作时钟频率(总线) STC单片机RC/RD+系列 (I/O方式可到40M/80M)	内部振荡器产生时钟, 外接晶体		外部时钟直接输入, 由XTAL1输入	
	12T模式	6T模式	12T模式	6T模式
5.0V单片机	2MHz - 48MHz	2MHz - 36MHz	2MHz - 48MHz	2MHz - 36MHz
3.3V单片机	2MHz - 48MHz	2MHz - 32MHz	2MHz - 36MHz	2MHz - 18MHz

1.6 STC89C51RC/RD+系列在系统可编程(ISP)典型应用线路图

STC 单片机在线编程线路, STC RS-232 转换器



※ 如何识别HD版及90C版见单片机表面文字最下面一行最后几个字母

关于EA (EA管脚已内部上拉到Vcc):

1. 如外部不加上拉, 或外部上拉到Vcc, 上电复位后单片机从内部开始执行程序;
2. 如外部下拉到地, 上电复位后单片机从外部开始执行程序

1.7 STC89C51RC/RD+系列管脚说明

管脚	管脚编号			说明	
	LQFP44	PDIP40	PLCC44		
P0.0 ~ P0.7	37-30	39-32	43~36	P0:P0口既可作为输入/输出口，也可作为地址/数据复用总线使用。当P0口作为输入/输出口时，P0是一个8位准双向口，上电复位后处于开漏模式。P0口内部无上拉电阻，所以作I/O口必须外接10K~4.7K的上拉电阻。当P0作为地址/数据复用总线使用时，是低8位地址线[A0~A7]，数据线的[D0~D7]，此时无需外接上拉电阻。	
P1.0/T2	40	1	2	P1.0	标准I/O口 PORT1[0]
				T2	定时器/计数器2的外部输入
P1.1/T2EX	41	2	3	P1.1	标准I/O口 PORT1[1]
				T2EX	定时器/计数器2捕捉/重装方式的触发控制
P1.2	42	3	4	标准I/O口 PORT1[2]	
P1.3	43	4	5	标准I/O口 PORT1[3]	
P1.4	44	5	6	标准I/O口 PORT1[4]	
P1.5	1	6	7	标准I/O口 PORT1[5]	
P1.6	2	7	8	标准I/O口 PORT1[6]	
P1.7	3	8	9	标准I/O口 PORT1[7]	
P2.0 ~ P2.7	18-25	21-28	24~31	Port2: P2口内部有上拉电阻，既可作为输入/输出口，也可作为高8位地址总线使用(A8 ~ A15)。当P2口作为输入/输出口时，P2是一个8位准双向口。	
P3.0/RxD	5	10	11	P3.0	标准I/O口 PORT3[0]
				RxD	串口1数据接收端
P3.1/TxD	7	11	13	P3.1	标准I/O口 PORT3[1]
				TxD	串口1数据发送端
P3.2/ $\overline{\text{INT0}}$	8	12	14	P3.2	标准I/O口 PORT3[2]
				$\overline{\text{INT0}}$	外部中断0, 下降沿中断或低电平中断
P3.3/ $\overline{\text{INT1}}$	9	13	15	P3.3	标准I/O口 PORT3[3]
				$\overline{\text{INT1}}$	外部中断1, 下降沿中断或低电平中断
P3.4/T0	10	14	16	P3.4	标准I/O口 PORT3[4]
				T0	定时器/计数器0的外部输入
P3.5/T1	11	15	17	P3.5	标准I/O口 PORT3[5]
				T1	定时器/计数器1的外部输入
P3.6/ $\overline{\text{WR}}$	12	16	18	P3.6	标准I/O口 PORT3[6]
				$\overline{\text{WR}}$	外部数据存储器写脉冲
P3.7/ $\overline{\text{RD}}$	13	17	19	P3.7	标准I/O口 PORT3[7]
				$\overline{\text{RD}}$	外部数据存储器读脉冲

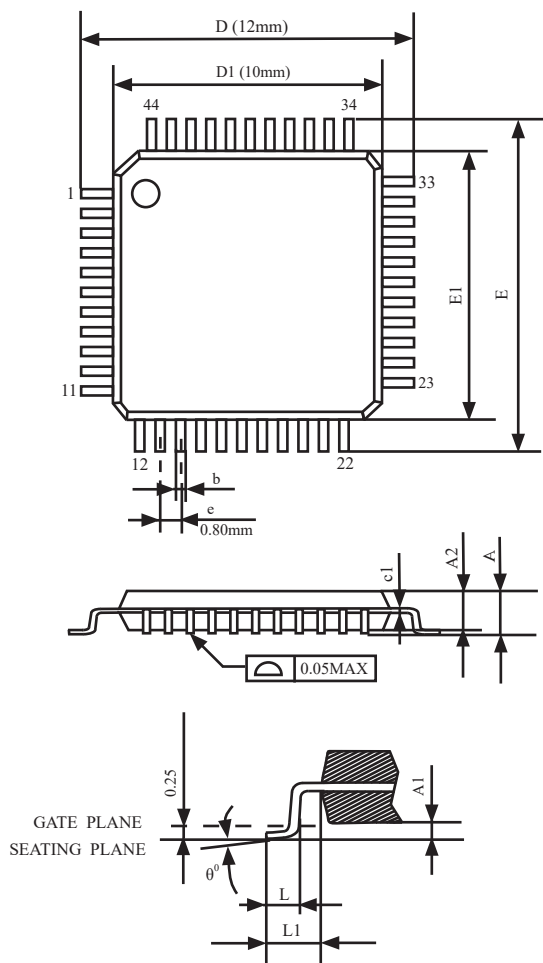
管脚	管脚编号			说明	
	LQFP44	PDIP40	PLCC44		
P4.0	17		23	P4.0	标准I/O口 PORT4[0]
P4.1	28		34	P4.1	标准I/O口 PORT4[1]
P4.2/ $\overline{\text{INT3}}$	39		1	P4.2	标准I/O口 PORT4[2]
				$\overline{\text{INT3}}$	外部中断3, 下降沿中断或低电平中断
P4.3/ $\overline{\text{INT2}}$	6		12	P4.3	标准I/O口 PORT4[3]
				$\overline{\text{INT3}}$	外部中断2, 下降沿中断或低电平中断
P4.4/ $\overline{\text{PSEN}}$	26	29	32	P4.4	标准I/O口 PORT4[4]
				$\overline{\text{PSEN}}$	外部程序存储器选通信号输出引脚
P4.5/ALE	27	30	33	P4.5	标准I/O口 PORT4[5]
				ALE	地址锁存允许信号输出引脚/编程脉冲输入引脚
P4.6/ $\overline{\text{EA}}$	29	31	35	P4.6	标准I/O口 PORT4[6]
				$\overline{\text{EA}}$	内外存储器选择引脚
RST	4	9	10	RST	复位脚
XTAL1	15	19	21	内部时钟电路反相放大器输入端, 接外部晶振的一个引脚。当直接使用外部时钟源时, 此引脚是外部时钟源的输入端。	
XTAL2	14	18	20	内部时钟电路反相放大器的输出端, 接外部晶振的另一端。当直接使用外部时钟源时, 此引脚可浮空, 此时XTAL2实际将XTAL1输入的时钟进行输出。	
VCC	38	40	44	电源正极	
Gnd	16	20	22	电源负极, 接地	

1.8 STC89C51RC/RD+系列单片机封装尺寸图

所有封装形式均满足欧盟RoHS要求

LQFP-44 封装尺寸图

LQFP-44 OUTLINE PACKAGE



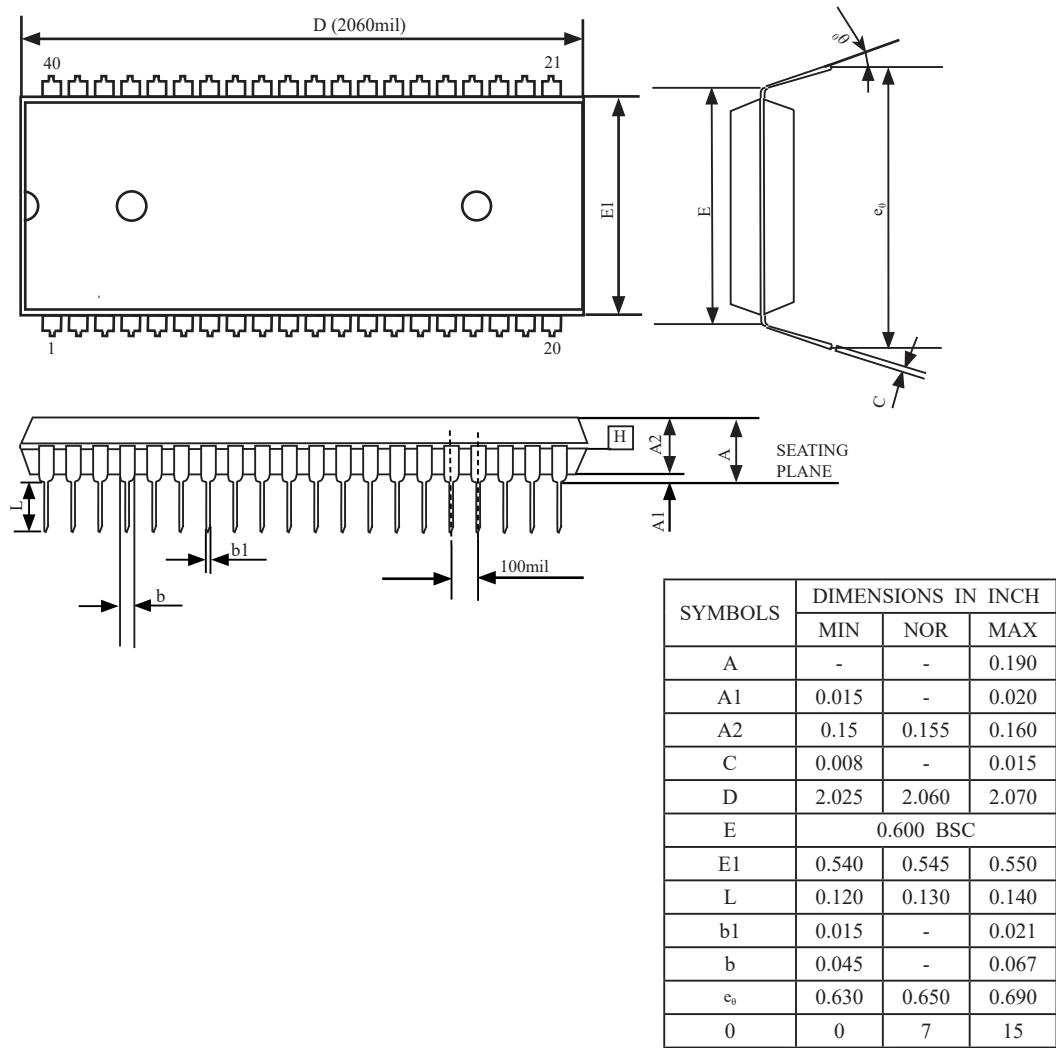
VARIATIONS (ALL DIMENSIONS SHOWN IN MM)

SYMBOLS	MIN.	NOM.	MAX.
A	-	-	1.60
A1	0.05	-	0.15
A2	1.35	1.40	1.45
c1	0.09	-	0.16
D	12.00		
D1	10.00		
E	12.00		
E1	10.00		
e	0.80		
b(w/o plating)	0.25	0.30	0.35
L	0.45	0.60	0.75
L1	1.00REF		
θ ⁰	0 ⁰	3.5 ⁰	7 ⁰



PDIP-40 封装尺寸图

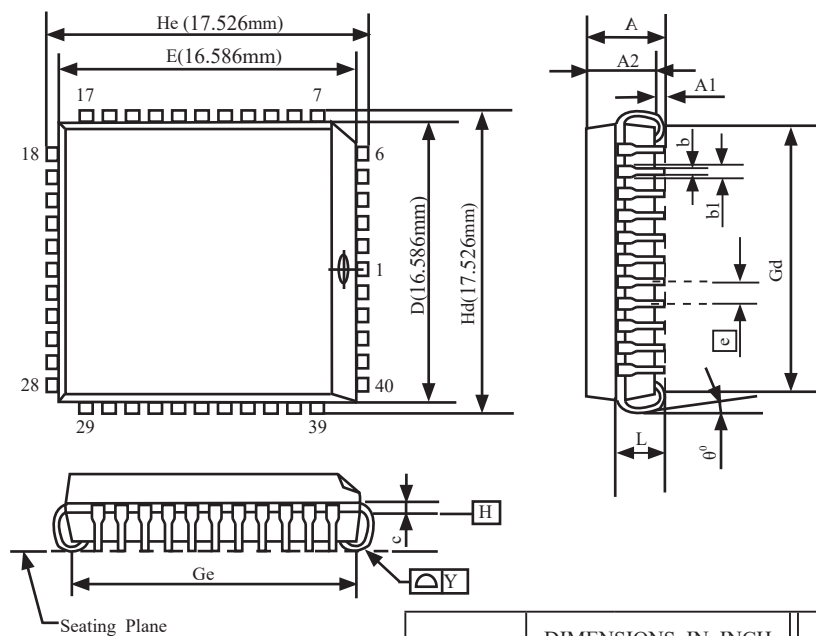
PDIP-40 OUTLINE PACKAGE



UNIT: INCH 1 inch = 1000mil

PLCC-44 封装尺寸图

PLCC-44 OUTLINE PACKAGE

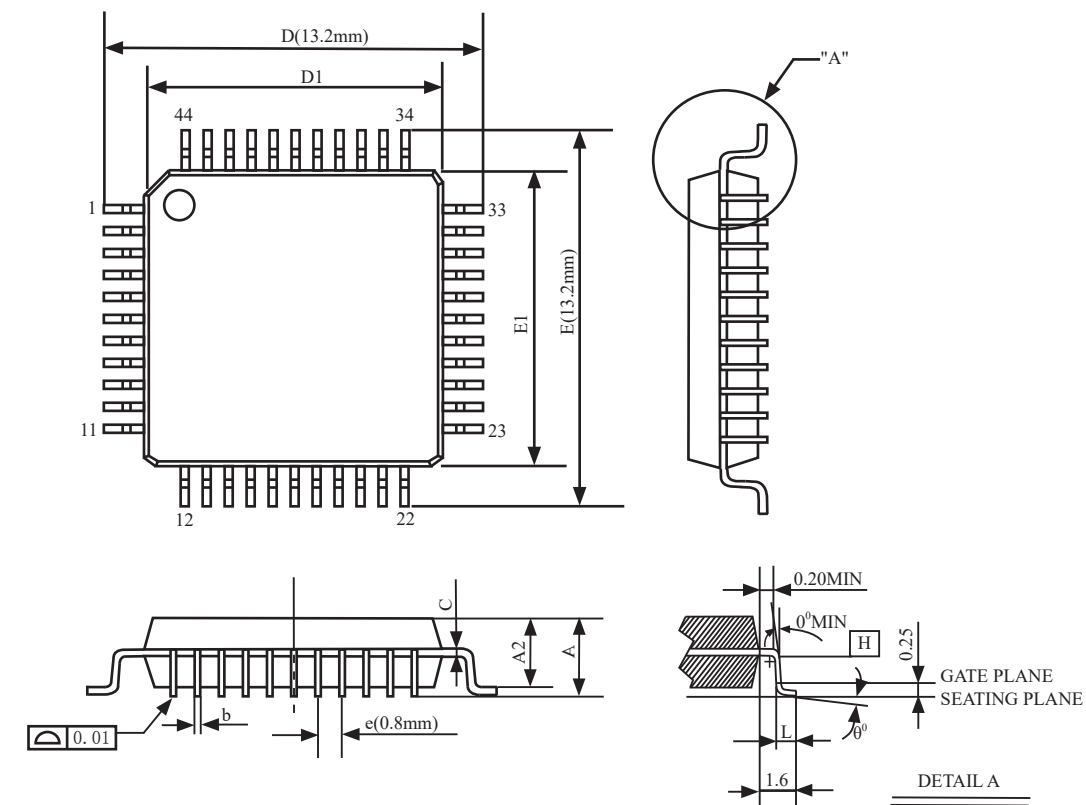


SYMBOLS	DIMENSIONS IN INCH			DIMENSIONS IN MILLIMETERS		
	MIN	NOM	MAX	MIN	NOM	MAX
A	0.165	-	0.180	4.191	-	4.572
A1	0.020	-	-	0.508	-	-
A2	0.147	-	0.158	3.734	-	4.013
b1	0.026	0.028	0.032	0.660	0.711	0.813
b	0.013	0.017	0.021	0.330	0.432	0.533
c	0.007	0.010	0.0013	0.178	0.254	0.330
D	0.650	0.653	0.656	16.510	16.586	16.662
E	0.650	0.653	0.656	16.510	16.586	16.662
e	0.050BSC			1.270BSC		
Gd	0.590	0.610	0.630	14.986	15.494	16.002
Ge	0.590	0.610	0.630	14.986	15.494	16.002
Hd	0.685	0.690	0.695	17.399	17.526	17.653
He	0.685	0.690	0.695	17.399	17.526	17.653
L	0.100	-	0.112	2.540	-	2.845
Y	-	-	0.004	-	-	0.102

1 inch = 1000 mil

PQFP-44 封装尺寸图

PQFP-44 OUTLINE PACKAGE



SYMBOLS	MIN.	NOM	MAX.
A	—	—	2.70
A1	0.25	—	0.50
A2	1.80	2.00	2.20
b(w/o plating)	0.25	0.30	0.35
D	13.00	13.20	13.40
D1	9.9	10.00	10.10
E	13.00	13.20	13.40
E1	9.9	10.00	10.10
L	0.73	0.88	0.93
e	0.80 BSC.		
θ°	0	—	7
C	0.1	0.15	0.2

UNIT:mm

NOTES:

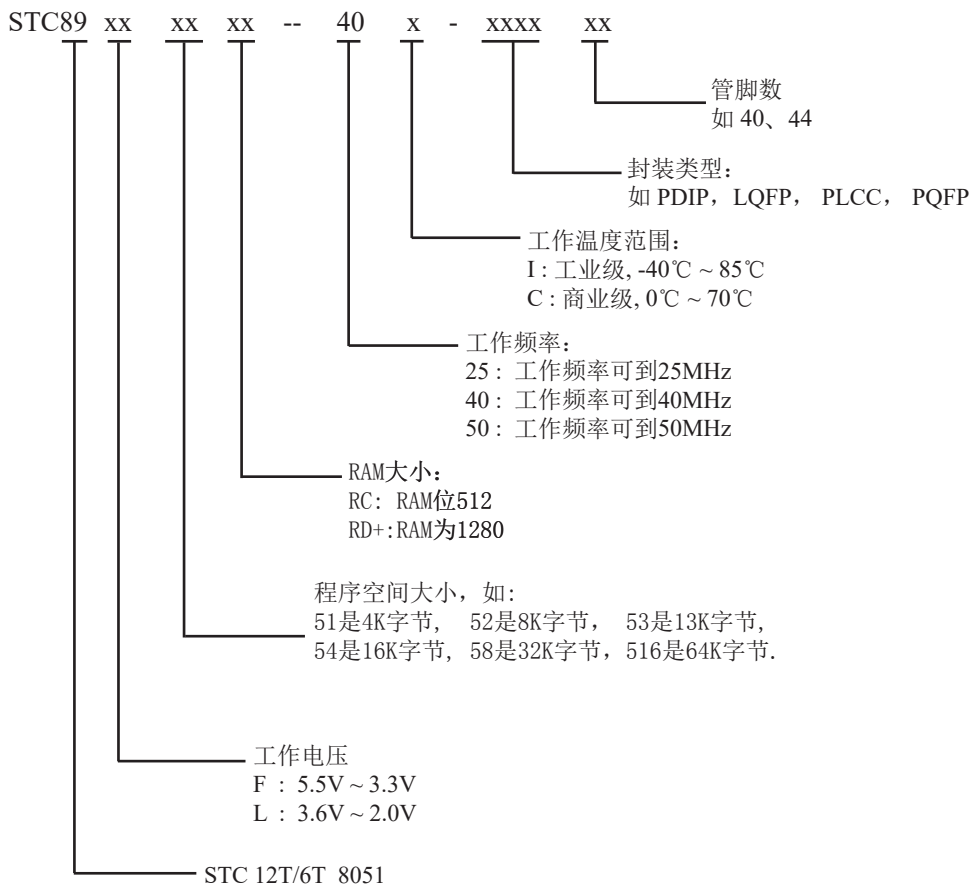
1.JEDEC OUTLINE:M0-108 AA-1

2.DATUM PLANE **[H]** IS LOCATED AT THE BOTTOM OF THE MOLD PARTING LINE COINCIDENT WITH WHERE THE LAED EXITS THE BODY.

3.DIMENSIONS D1 AND E1 D0 NOT INCLUDE MOLD PROTRUSION. ALLOWABLE PROTRUSION IS 0.25mm PER SIDE. DIMENSIONS D1 AND E1 D0 INCLUDE MOLD MISMATCH AND ARE DETRMINED AT DATUM PLANE **[H]**.

4.DIMENSION b DOES NOT INCLUDE DAMBAR PROTRUSION.

1.9 STC89C51RC/RD+系列单片机命名规则

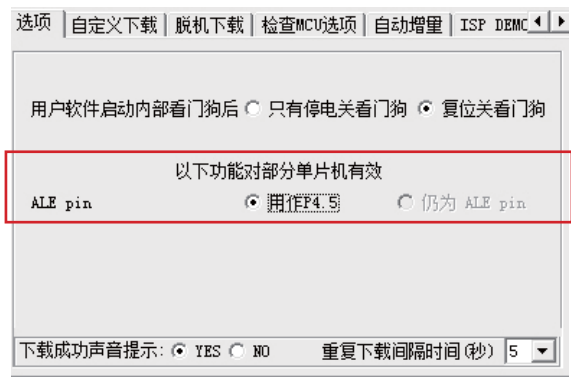


1.10 如何识别HD版及90C版本

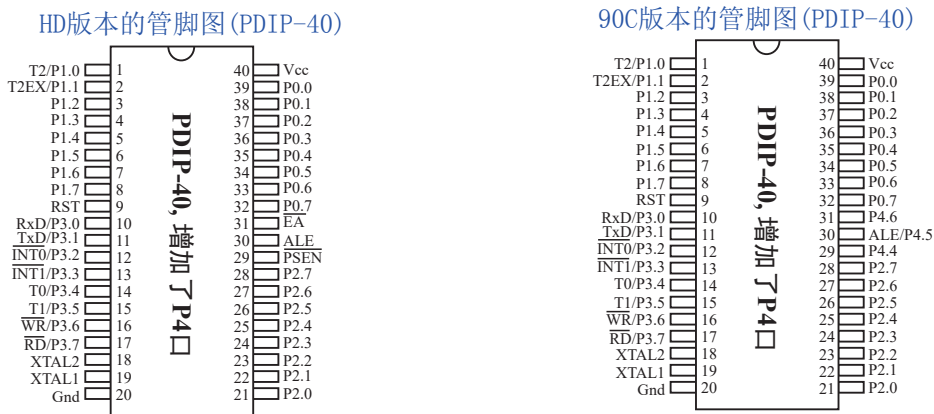
※ 如何识别HD版及90C版见单片机表面文字最下面一行最后几个字母

HD版本和90C版本内部都集成了MAX810专用复位电路，当时钟频率为6MHz时内部简单的MAX810专用复位电路是可靠的；当时钟频率为12MHz时勉强可用。在要求不高的情况下，可在复位脚外接电阻电容复位。

HD版有PSEN、ALE及EA管脚，无P4.4/P4.5/P4.6口。而90C版本有P4.4和P4.6管脚，无PSEN和EA。90C版本的ALE/P4.5管脚既可作I/O口P4.5使用，也可被复用作ALE管脚，默认是用作ALE管脚。如用户需用到P4.5口，只能选择90C版本的单片机，且需在烧录用户程序时在STC-ISP编程器中将ALE pin选择为用作P4.5，在烧录用户程序时在STC-ISP编程器中该管脚默认的是作为ALE pin。具体设置如下图所示：



下面是STC89系列单片机HD版和90C版本的管脚图，主要区别在P4.6/P4.5/P4.4三个管脚处。



1.11 降低单片机时钟对外界的电磁辐射(EMI)——三大措施

1. 禁止ALE信号输出，适用型号：

STC89C51RC, STC89C52RC, STC89C53RC, STC89LE51RC, STC89LE52RC, STC89LE53RC
STC89C54RD+, STC89C58RD+, STC89C516RD+, STC89LE54RD+, STC89LE58RD+, STC89LE516RD+

RC/RD+系列8051单片机 扩展RAM管理及禁止ALE输出 特殊功能寄存器(只写)

AUXR : Auxiliary Register(只写)

Mnemonic	Add	bit	B7	B6	B5	B4	B3	B2	B1	B0	Reset Value
AUXR	8EH	name	-	-	-	-	-	-	EXTRAM	ALEOFF	xxxx,xx00

禁止ALE信号输出(应用示例供参考, C 语言):

```
sfr AUXR = 0x8e;      /* 声明AUXR 寄存器的地址 */
```

```
AUXR = 0x01;
```

/* ALEOFF位置1, 禁止ALE信号输出, 提升系统的EMI性能, 复位后为0, ALE信号正常输出*/

禁止ALE信号输出(应用示例供参考, 汇编语言):

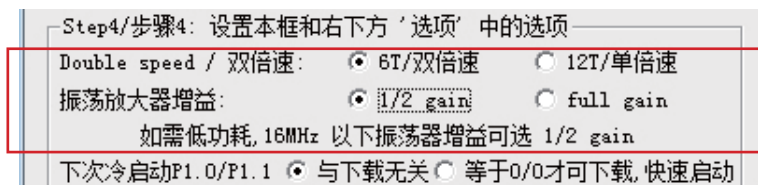
```
AUXR    EQU    8Eh          ;或AUXR    DATA    8Eh
```

```
MOV     AUXR,   #00000001B   ;ALEOFF位置“1”, 禁止ALE信号输出,
```

```
;提升了系统的EMI性能
```

2. 外部时钟频率降一半，6T模式：传统的8051为每个机器周期12时钟，如将STC的增强型8051单片机在ISP烧录程序时设为双倍速（及6T模式，每个机器周期6 时钟），则可将单片机外部时钟频率降低一半，有效的降低单片机时钟对外界的干扰

3. 单片机内部时钟振荡器增益降低一半：在ISP烧录程序时将OSCDN设为1/2gain可以有效的降低单片机时钟高频部分对外界的辐射, 但此时外部晶振频率尽量不要高于16MHz。单片机外部晶振频率<16MHz时，可将OSCDN设为1/2 gain, 有利于降低EMI，16M以上选择full gain。



1.12 超低功耗——STC89C51RC/RD+ 系列单片机

1. 掉电模式:

典型功耗 $< 0.1\mu\text{A}$ ，可由外部中断唤醒，中断返回后，继续执行原程序

2. 空闲模式（建议不要使用）:

典型功耗 2mA

3. 正常工作模式:

典型功耗 $4\text{mA} - 7\text{mA}$

4. 掉电模式可由外部中断唤醒，适用于水表、气表等电池供电系统及便携设备

第2章 省电模式及复位

2.1 STC89C51RC/RD+系列单片机的省电模式

STC89C51RC/RD+系列单片机可以运行2种省电模式以降低功耗，它们分别是：空闲模式和掉电模式。正常工作模式下，STC89C51RC/RD+系列单片机的典型功耗是4mA~7mA，而掉电模式下的典型功耗是<0.1uA，空闲模式(建议不要使用此模式)下的典型功耗是2mA。

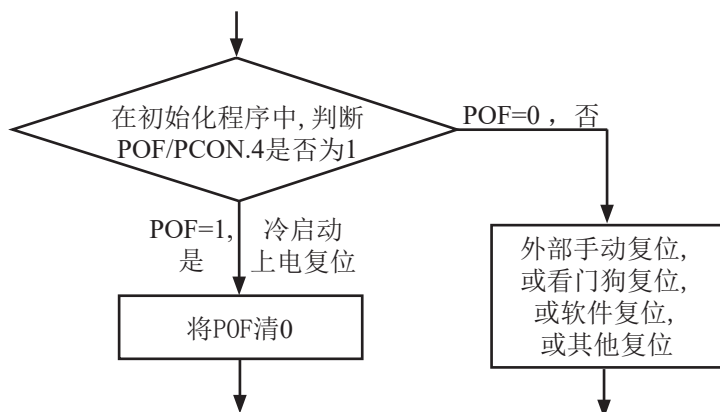
空闲模式和掉电模式的进入由电源控制寄存器PCON的相应位控制。PCON寄存器定义如下：

PCON (Power Control Register) (不可位寻址)

SFR name	Address	bit	B7	B6	B5	B4	B3	B2	B1	B0
PCON	87H	name	SMOD	SMOD0	-	POF	GF1	GF0	PD	IDL

POF：上电复位标志位，单片机停电后，上电复位标志位为1，可由软件清0。

实际应用：要判断是上电复位（冷启动），还是外部复位脚输入复位信号产生的复位，还是内部看门狗复位，还是软件复位或者其他复位，可通过如下方法来判断：



判断复位种类流程图

PD：将其置1时，进入Power Down模式，可由外部中断低电平触发或下降沿触发唤醒，进入掉电模式时，内部时钟停振，由于无时钟CPU、定时器、串行口等功能部件停止工作，只有外部中断继续工作。掉电模式可由外部中断唤醒，中断返回后，继续执行原程序。掉电模式也叫停机模式，此时功耗<0.1uA。

IDL：将其置1，进入IDLE模式(空闲)，除系统不给CPU供时钟，CPU不执行指令外，其余功能部件仍可继续工作，可由任何一个中断唤醒。

GF1,GF0：两个通用工作标志位，用户可以任意使用。

SMOD, SMOD0：与电源控制无关，与串口有关，在此不作介绍。

2.1.1 空闲模式(建议不要使用)

将IDL/PCON.0置为1, 单片机将进入IDLE(空闲)模式。在空闲模式下, 仅CPU无时钟停止工作, 但是外部中断、定时器、串行口等仍正常运行。而看门狗在空闲模式下是否工作取决于其自身有一个“IDLE”模式位: IDLE_WDT(WDT_CONTR.3)。当IDLE_WDT位被设置为“1”时, 看门狗定时器在“空闲模式”计数, 即正常工作。当IDLE_WDT位被清“0”时, 看门狗定时器在“空闲模式”时不计数, 即停止工作。在空闲模式下, RAM、堆栈指针(SP)、程序计数器(PC)、程序状态字(PSW)、累加器(A)等寄存器都保持原有数据。I/O口保持着空闲模式被激活前那一刻的逻辑状态。空闲模式下单片机的所有外围设备都能正常运行(除CPU无时钟不工作外)。当任何一个中断产生时, 它们都可以将单片机唤醒, 单片机被唤醒后, CPU将继续执行进入空闲模式语句的下一条指令。

有两种方式可以退出空闲模式。任何一个中断的产生都会引起IDL/PCON.0被硬件清除, 从而退出空闲模式。另一个退出空闲模式的方法是: 外部RST引脚复位, 将复位脚拉高, 产生复位。这种拉高复位引脚来产生复位的信号源需要被保持24个时钟加上10us, 才能产生复位, 再将RST引脚拉低, 结束复位, 单片机从用户程序的0000H处开始正常工作。

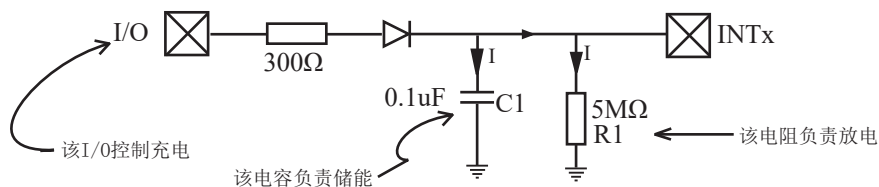
2.1.2 掉电模式/停机模式

将PD/PCON.1置为1, 单片机将进入Power Down(掉电)模式, 掉电模式也叫停机模式。进入掉电模式后, 内部时钟停振, 由于无时钟源, CPU、定时器、看门狗、串行口等停止工作, 外部中断继续工作。如果低压检测电路被允许可产生中断, 则低压检测电路也可继续工作, 否则将停止工作。进入掉电模式后, 所有I/O口、SFRs(特殊功能寄存器)维持进入掉电模式前那一刻的状态不变。

可将CPU从掉电模式唤醒的外部管脚有: $\overline{\text{INT0}}/\text{P3.2}$, $\overline{\text{INT1}}/\text{P3.3}$, $\overline{\text{INT2}}/\text{P4.3}$, $\overline{\text{INT3}}/\text{P4.2}$

另外, 外部复位也将MCU从掉电模式中唤醒, 复位唤醒后的MCU将从用户程序的0000H处开始正常工作。

当用户系统无外部中断源将单片机从掉电模式唤醒时, 下面的电路能够定时唤醒掉电模式。



控制充电的I/O口首先配置为推挽/强上拉模式并置高, 上面的电路会给储能电容C1充电。在单片机进入掉电模式之前, 将控制充电的I/O口拉低, 上面电路通过电阻R1给储能电容C1放电。当电容C1的电被放到小于0.8V时, 外部中断INTx会产生一个下降沿中断, 从而自动地将单片机从掉电模式中唤醒。


```

/*可由外部中断唤醒的掉电唤醒示例程序 -----*/
/*-----*/
/* --- STC MCU International Limited -----*/
/* --- 演示STC89xx 系列单片机由外部中断唤醒掉电模式 -----*/
/*如果要在程序中使用或在文章中引用该程序 -----*/
/*请在程序或文章中注明使用了宏晶科技的资料及程序 -----*/
/*-----*/

#include <reg51.h>
#include <intrins.h>
sbit    Begin_LED = P1^2;                //Begin-LED indicator indicates system start-up
unsigned char    Is_Power_Down = 0;      //Set this bit before go into Power-down mode
sbit    Is_Power_Down_LED_INT0          = P1^7; //Power-Down wake-up LED indicator on INT0
sbit    Not_Power_Down_LED_INT0         = P1^6; //Not Power-Down wake-up LED indicator on INT0
sbit    Is_Power_Down_LED_INT1          = P1^5; //Power-Down wake-up LED indicator on INT1
sbit    Not_Power_Down_LED_INT1         = P1^4; //Not Power-Down wake-up LED indicator on INT1
sbit    Power_Down_Wakeup_Pin_INT0      = P3^2; //Power-Down wake-up pin on INT0
sbit    Power_Down_Wakeup_Pin_INT1      = P3^3; //Power-Down wake-up pin on INT1
sbit    Normal_Work_Flashing_LED        = P1^3; //Normal work LED indicator

void Normal_Work_Flashing (void);
void INT_System_init (void);
void INT0_Routine (void);
void INT1_Routine (void);

void main (void)
{
    unsigned char    j = 0;
    unsigned char    wakeup_counter = 0;
                                //clear interrupt wakeup counter variable wakeup_counter
    Begin_LED = 0;              //system start-up LED
    INT_System_init ( );       //Interrupt system initialization
    while(1)
    {
        P2 = wakeup_counter;
        wakeup_counter++;
        for(j=0; j<2; j++)
        {
            Normal_Work_Flashing( ); //System normal work
        }
    }
}

```

```

        Is_Power_Down = 1;           //Set this bit before go into Power-down mode
        PCON    = 0x02;             //after this instruction, MCU will be in power-down mode
                                    //external clock stop

        _nop_();
        _nop_();
        _nop_();
        _nop_();
    }
}

void INT_System_init(void)
{
    IT0    = 0;                     /* External interrupt 0, low electrical level triggered */
//    IT0    = 1;                     /* External interrupt 0, negative edge triggered */
    EX0    = 1;                     /* Enable external interrupt 0
    IT1    = 0;                     /* External interrupt 1, low electrical level triggered */
//    IT1    = 1;                     /* External interrupt 1, negative edge triggered */
    EX1    = 1;                     /* Enable external interrupt 1
    EA     = 1;                     /* Set Global Enable bit
}

void INT0_Routine(void) interrupt 0
{
    if(Is_Power_Down)
    {
        //Is_Power_Down == 1;       /* Power-Down wakeup on INT0 */
        Is_Power_Down = 0;
        Is_Power_Down_LED_INT0 = 0;
                                    /*open external interrupt 0 Power-Down wake-up LED indicator */
        while (Power_Down_Wakeup_Pin_INT0 == 0)
        {
            /* wait higher */
        }
        Is_Power_Down_LED_INT0 = 1;
                                    /* close external interrupt 0 Power-Down wake-up LED indicator */
    }
    else
    {
        Not_Power_Down_LED_INT0 = 0; /* open external interrupt 0 normal work LED */
        while (Power_Down_Wakeup_Pin_INT0 == 0)
        {
            /* wait higher */
        }
        Not_Power_Down_LED_INT0 = 1; /* close external interrupt 0 normal work LED */
    }
}
}

```

```

void INT1_Routine (void) interrupt 2
{
    if (Is_Power_Down)
    {
        //Is_Power_Down ==1;    /* Power-Down wakeup on INT1 */
        Is_Power_Down = 0;
        Is_Power_Down_LED_INT1 = 0;
        /*open external interrupt 1 Power-Down wake-up LED indicator */
        while (Power_Down_Wakeup_Pin_INT1 == 0)
        {
            /* wait higher */
        }
        Is_Power_Down_LED_INT1 = 1;
        /* close external interrupt 1 Power-Down wake-up LED indicator */
    }
    else
    {
        Not_Power_Down_LED_INT1 = 0;    /* open external interrupt 1 normal work LED */
        while (Power_Down_Wakeup_Pin_INT1 == 0)
        {
            /* wait higher */
        }
        Not_Power_Down_LED_INT1 = 1;    /* close external interrupt 1 normal work LED */
    }
}

void delay (void)
{
    unsigned int    j = 0x00;
    unsigned int    k = 0x00;
    for (k=0; k<2; ++k)
    {
        for (j=0; j<=30000; ++j)
        {
            _nop_();
            _nop_();
            _nop_();
            _nop_();
            _nop_();
            _nop_();
            _nop_();
        }
    }
}

```

```
void Normal_Work_Flashing (void)
```

```
{
    Normal_Work_Flashing_LED = 0;
    delay ();
    Normal_Work_Flashing_LED = 1;
    delay ();
}
```

```
;通过外部中断从掉电模式唤醒单片机（汇编语言）
```

```
*****
```

```
;Wake Up Idle and Wake Up Power Down
```

```
*****
```

```
;/* --- STC MCU International Limited -----*/
```

```
;/* --- 演示STC89xx系列单片机由外部中断唤醒掉电模式 -----*/
```

```
;/*如果要在程序中使用或在文章中引用该程序 -----*/
```

```
;/*请在程序中或文章中注明使用了宏晶科技的资料及程序 -----*/
```

```
;/*-----*/
```

```
ORG    0000H
```

```
AJMP   MAIN
```

```
ORG    0003H
```

```
int0_interrupt:
```

```
CLR     P1.7
```

```
;open P1.7 LED indicator
```

```
ACALL  delay
```

```
;delay in order to observe
```

```
CLR     EA
```

```
;clear global enable bit, stop all interrupts
```

```
RETI
```

```
ORG     0013H
```

```
int1_interrupt:
```

```
CLR     P1.6
```

```
;open P1.6 LED indicator
```

```
ACALL  delay
```

```
;delay in order to observe
```

```
CLR     EA
```

```
;clear global enable bit, stop all interrupts
```

```
RETI
```

```
ORG     0100H
```

```
delay:
```

```
CLR     A
```

```
MOV     R0,    A
```

```
MOV     R1,    A
```

```
MOV     R2,    #02
```

```

main:
    MOV    R3,    #0                ;P1 LED increment mode changed
                                        ;start to run program

main_loop:
    MOV    A,     R3
    CPL    A
    MOV    P1,    A
    ACALL  delay
    INC    R3
    MOV    A,     R3
    SUBB   A,     #18H
    JC     main_loop
    MOV    P1,    #0FFH            ;close all LED, MCU go into power-down mode
    CLR    IT0                ;low electrical level trigger external interrupt 0
;    SETB   IT0                ;negative edge trigger external interrupt 0
;    SETB   EX0                ;enable external interrupt 0
    CLR    IT1                ;low electrical level trigger external interrupt 1
;    SETB   IT1                ;negative edge trigger external interrupt 1
    SETB   EX1                ;enable external interrupt 1
    SETB   EA                ;set the global enable
                                        ;if don't so, power-down mode cannot be wake up

;MCU will go into idle mode or power-down mode after the following instructions
    MOV    A,     PCON    ;Set PD bit, power-down mode (PD = PCON.1)
    ORL    A,     #02H
    MOV    PCON,  A
;    NOP
;    MOV    PCON,  #00000001B    ;Set IDL bit, idle mode (IDL = PCON.0)
    MOV    P1,    #0DFH    ;1101,1111
    NOP
    NOP
    NOP

WAIT1:
    SJMP   $                ;dynamically stop
    END

```

2.2 复位

STC89C51RC/RD+系列单片机有4种复位方式：外部RST引脚复位，软件复位，掉电复位/上电复位，看门狗复位。

2.2.1 外部RST引脚复位

外部RST引脚复位就是从外部向RST引脚施加一定宽度的复位脉冲，从而实现单片机的复位。将RST复位管脚拉高并维持至少24个时钟加10us后, 单片机会进入复位状态，将RST复位管脚拉回低电平后，单片机结束复位状态并从用户程序区的0000H处开始正常工作。

2.2.2 软件复位

用户应用程序在运行过程当中，有时会有特殊需求，需要实现单片机系统软复位（热启动之一），传统的8051单片机由于硬件上未支持此功能，用户必须用软件模拟实现，实现起来较麻烦。现STC新推出的增强型8051根据客户要求增加了ISP_CONTR特殊功能寄存器, 实现了此功能。用户只需简单的控制ISP_CONTR特殊功能寄存器的其中两位SWBS/SWRST就可以系统复位了。

ISP_CONTR: ISP/IAP 控制寄存器

SFR Name	SFR Address	bit	B7	B6	B5	B4	B3	B2	B1	B0
ISP_CONTR	E7H	name	ISPEN	SWBS	SWRST	-	-	WT2	WT1	WT0

ISPEN: ISP/IAP功能允许位。

0: 禁止ISP/IAP读/写/擦除Data Flash/EEPROM;

1: 允许ISP/IAP读/写/擦除Data Flash/EEPROM。

SWBS: 软件选择从用户应用程序区启动(0)，还是从ISP程序区启动(1)。要与SWRST直接配合才可以实现

SWRST: 0: 不操作；1: 产生软件系统复位，硬件自动清零。

;从用户应用程序区 (AP区) 软件复位并切换到用户应用程序区 (AP区) 开始执行程序

MOV ISP_CONTR, #00100000B ;SWBS = 0(选择AP区), SWRST = 1(软复位)

;从系统ISP监控程序区软件复位并切换到用户应用程序区 (AP区) 开始执行程序

MOV ISP_CONTR, #00100000B ;SWBS = 0(选择AP区), SWRST = 1(软复位)

;从用户应用程序区 (AP区) 软件复位并切换到系统ISP监控程序区开始执行程序

MOV ISP_CONTR, #01100000B ;SWBS = 1(选择ISP区), SWRST = 1(软复位)

;从系统ISP监控程序区软件复位并切换到系统ISP监控程序区开始执行程序

MOV ISP_CONTR, #01100000B ;SWBS = 1(选择ISP区), SWRST = 1(软复位)

本复位是整个系统复位，所有的特殊功能寄存器都会复位到初始值，I/O口也会初始化

2.2.3 上电复位/掉电复位

当电源电压VCC低于上电复位/掉电复位电路的检测门槛电压时，所有的逻辑电路都会复位。当VCC重新恢复正常电压时，HD版本的单片机延迟2048个时钟(90C版本单片机延迟32768个时钟)后，上电复位/掉电复位结束。进入掉电模式时，上电复位/掉电复位功能被关闭。

2.2.4 看门狗(WDT)复位

适用型号：

STC89C51RC, STC89C52RC, STC89C53RC, STC89LE51RC, STC89LE52RC, STC89LE53RC

STC89C54RD+, STC89C58RD+, STC89C516RD+, STC89LE54RD+, STC89LE58RD+, STC89LE516RD+

在工业控制/ 汽车电子/ 航空航天等需要高可靠性的系统中, 为了防止“系统在异常情况下, 受到干扰, MCU/CPU程序跑飞, 导致系统长时间异常工作”, 通常是引进看门狗, 如果MCU/CPU不在规定的时间内按要求访问看门狗, 就认为MCU/CPU处于异常状态, 看门狗就会强迫MCU/CPU复位, 使系统重新从头开始按规律执行用户程序。

STC89C51RC/RD+系列单片机内部也引进了此看门狗功能, 使单片机系统可靠性设计变得更加方便/简洁。为此功能, 我们增加如下特殊功能寄存器WDT_CONTR:

WDT_CONTR: 看门狗(Watch-Dog-Timer)控制寄存器

SFR name	Address	bit	B7	B6	B5	B4	B3	B2	B1	B0
WDT_CONTR	E1H	name	-	-	EN_WDT	CLR_WDT	IDLE_WDT	PS2	PS1	PS0

Symbol符号 Function功能

EN_WDT : Enable WDT bit. When set, WDT is started
看门狗允许位, 当设置为“1”时, 看门狗启动。

CLR_WDT : WDT clear bit. If set, WDT will recount. Hardware will automatically clear this bit.
看门狗清“0”位, 当设为“1”时, 看门狗将重新计数。硬件将自动清“0”此位。

IDLE_WDT : When set, WDT is enabled in IDLE mode. When clear, WDT is disabled in IDLE
看门狗“IDLE”模式位, 当设置为“1”时, 看门狗定时器在“空闲模式”计数
当清“0”该位时, 看门狗定时器在“空闲模式”时不计数

PS2,PS1,PS0 : Pre-scale value of Watchdog timer is shown as the bellowed table:

看门狗定时器预分频值, 如下表所示

PS2	PS1	PS0	Pre-scale 预分频	WDT overflow Time @20MHz
0	0	0	2	39.3 mS
0	0	1	4	78.6 mS
0	1	0	8	157.3 mS
0	1	1	16	314.6 mS
1	0	0	32	629.1 mS
1	0	1	64	1.25 S
1	1	0	128	2.5 S
1	1	1	256	5 S

The WDT period is determined by the following equation 看门狗溢出时间计算
看门狗溢出时间 = (12 x Pre-scale x 32768) / Oscillator frequency

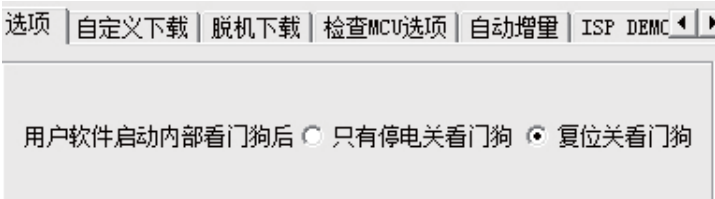
设时钟为12MHz:
看门狗溢出时间 = (12 × Pre-scale × 32768) / 12000000 = Pre-scale× 393216 / 12000000

PS2	PS1	PS0	Pre-scale 预分频	WDT overflow Time @12MHz
0	0	0	2	65.5 mS
0	0	1	4	131.0 mS
0	1	0	8	262.1 mS
0	1	1	16	524.2 mS
1	0	0	32	1.0485 S
1	0	1	64	2.0971 S
1	1	0	128	4.1943 S
1	1	1	256	8.3886 S

设时钟为11.0592MHz:
看门狗溢出时间= (12 x Pre-scale x 32768) / 11059200 = Pre-scale x 393216 / 11059200

PS2	PS1	PS0	Pre-scale	WDT overflow Time @11.0592MHz
0	0	0	2	71.1 mS
0	0	1	4	142.2 mS
0	1	0	8	284.4 mS
0	1	1	16	568.8 mS
1	0	0	32	1.1377 S
1	0	1	64	2.2755 S
1	1	0	128	4.5511 S
1	1	1	256	9.1022 S

当用户启动内部看门狗后，可在烧录用户程序时在STC-ISP编程器中对看门狗作如下所示的设置。



看门狗测试程序，在宏晶的下载板上可以直接测试

```

/*-----*/
/* --- STC MCU International Limited -----*/
/* --- 演示STC89xx系列单片机 看门狗及其溢出时间计算公式-----*/
/* 如果要在程序中使用或在文章中引用该程序， -----*/
/* 请在程序或文章中注明使用了宏晶科技的资料及程序 -----*/
/*-----*/

```

;本演示程序在STC-ISP Ver 4.86.PCB的下载编程工具上测试通过, 相关的工作状态在P1口上显示

;看门狗及其溢出时间 = $(12 * \text{Pre_scale} * 32768) / \text{Oscillator frequency}$

```
WDT_CONTR      EQU    0E1H          ;看门狗地址
```

```
WDT_TIME_LED    EQU    P1.5          ;用 P1.5 控制看门狗溢出时间指示灯,
```

;看门狗溢出时间可由该指示灯亮的时间长度或熄灭的时间长度表示

```
WDT_FLAG_LED    EQU    P1.7
```

;用P1.7控制看门狗溢出复位指示灯, 如点亮表示为看门狗溢出复位

```
Last_WDT_Time_LED_Status EQU 00H      ;位变量, 存储看门狗溢出时间指示灯的上一次状态位
```

;WDT复位时间(所用的Oscillator frequency = 18.432MHz):

```
;Pre_scale_Word      EQU    00111100B      ;清0, 启动看门狗, 预分频数=32,    0.68S
```

```
Pre_scale_Word      EQU    00111101B      ;清0, 启动看门狗, 预分频数=64,    1.36S
```

```
;Pre_scale_Word      EQU    00111110B      ;清0, 启动看门狗, 预分频数=128,  2.72S
```

```
;Pre_scale_Word      EQU    00111111B      ;清0, 启动看门狗, 预分频数=256,  5.44S
```

```
ORG    0000H
```

```
AJMP    MAIN
```

```
ORG    0100H
```

MAIN:

```
MOV     A,      WDT_CONTR          ;检测是否为看门狗复位
```

```
ANL     A,      #10000000B
```

```
JNZ     WDT_Reset          ;WDT_CONTR.7 = 1, 看门狗复位, 跳转到看门狗复位程序
```

;WDT_CONTR.7 = 0, 上电复位, 冷启动, RAM单元内容为随机值

```
SETB    Last_WDT_Time_LED_Status    ;上电复位,
```

;初始化看门狗溢出时间指示灯的状态位 = 1

```
CLR     WDT_TIME_LED          ;上电复位, 点亮看门狗溢出时间指示灯
```

```
MOV     WDT_CONTR,    #Pre_scale_Word    ;启动看门狗
```


2.2.5 冷启动复位和热启动复位

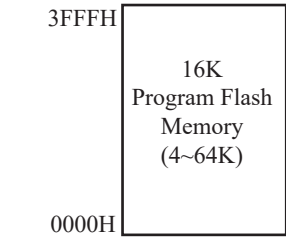
	复位源	现象
热启动复位	内部看门狗复位	会使单片机直接从用户程序区0000H处开始执行用户程序
	通过控制RESET脚产生的硬复位	会使系统 从用户程序区0000H处开始直接执行用户程序
	通过对ISP_CONTR寄存器送入20H产生的软复位	会使系统从用户程序区0000H处开始直接执行用户程序
	通过对ISP_CONTR寄存器送入60H产生的软复位	会使系统从系统ISP监控程序区开始执行程序，检测不到合法的ISP下载命令流后，会软复位到用户程序区执行用户程序
冷启动复位	系统停电后再上电引起的硬复位	会使系统从系统ISP监控程序区开始执行程序，检测不到合法的ISP下载命令流后，会软复位到用户程序区执行用户程序

第3章 片内存储器和特殊功能寄存器(SFRs)

STC89C51RC/RD+系列单片机的程序存储器和数据存储器是各自独立编址的. STC-89C51RC/RD+系列单片机除可以访问片上Flash存储器外，还可以访问64KB的外部程序存储器。STC89C54RD+系列单片机内部有1280字节的数据存储器，其在物理和逻辑上都分为两个地址空间:内部RAM(256字节)和内部扩展RAM(1024字节)。而STC89C51RC系列单片机内部有512字节的数据存储器，其在物理和逻辑上都分为两个地址空间:内部RAM(256字节)和内部扩展RAM(256字节)。另外，STC89C51RC/RD+系列单片机还可以访问在片外扩展的64KB外部数据存储器。现以STC89C54RD+系列单片机为例，分别介绍其程序存储器和数据存储器。

3.1 程序存储器

程序存储器用于存放用户程序、数据和表格等信息。STC89C51RC/RD+系列单片机内部集成了4K~64K字节的Flash程序存储器。STC89C51RC/RD+系列各种型号单片机的片内程序Flash存储器的地址如下表所示。



STC89C54RD+单片机程序存储器

Type	Program Memory
STC89C/LE51RC	0000H~0FFFH(4K)
STC89C/LE52RC	0000H~1FFFH(8K)
STC89C/LE53RC	0000H~3FFFH(13K)
STC89C/LE54RD+	0000H~3FFFH (16K)
STC89C/LE58RD+	0000H~7FFFH (32K)
STC89C/LE510RD+	0000H~9FFFH(40K)
STC89C/LE512RD+	0000H~BFFFH(48K)
STC89C/LE514RD+	0000H~DFFFH(56K)
STC89C/LE516RD+	0000H~FFFFH (64K)

单片机复位后，程序计数器(PC)的内容为0000H，从0000H单元开始执行程序。STC89C51RC/RD+单片机利用EA引脚来确定是访问片内程序存储器还是访问片外程序存储器。当EA引脚接高电平时，对于STC89C51RC/RD+单片机首先访问片内程序存储器，当PC的内容超过片内程序存储器的地址范围时，系统会自动转到片外程序存储器。以STC89C54RD+单片机为例，当若EA引脚接高电平，单片机首先从片内程序存储器的0000H单元开始执行程序，当PC的内容超过3FFFH时系统自动转到片外程序存储器中取指令。此时外部程序存储器的地址从4000H开始。

另外中断服务程序的入口地址(又称中断向量)也位于程序存储器单元。在程序存储器中，每个中断都有一个固定的入口地址，当中断发生并得到响应后，单片机就会自动跳转到相应的中断入口地址去执行程序。外部中断0的中断服务程序的入口地址是0003H，定时器/计数器0中断服务程序的入口地址是000BH, 外部中断1的中断服务程序的入口地址是0013H，定时器/计数器1的中断服务程序的入口地址是001BH等。更多的中断服务程序的入口地址(中断向量)见单独的中断章节。由于相邻中断入口地址的间隔区间(8个字节)有限，一般情况下无法保存完整的中断服务程序，因此，一般在中断响应的地址区域存放一条无条件转移指令，指向真正存放中断服务程序的空间去执行。

程序Flash存储器可在线反复编程擦写10万次以上，提高了使用的灵活性和方便性。

3.2 数据存储器(SRAM)

STC89C54RD+系列单片机内部集成了1280字节RAM，可用于存放程序执行的中间结果和过程数据。内部数据存储器在物理和逻辑上都分为两个地址空间：内部RAM(256字节)和内部扩展RAM(1024字节)。此外，STC89C51RC/RD+系列单片机还可以访问在片外扩展的64KB外部数据存储器。

3.2.1 内部RAM

内部RAM共256字节，可分为3个部分：**低128字节RAM(与传统8051兼容)**、**高128字节RAM(Intel在8052中扩展了高128字节RAM)**及特殊功能寄存器区。低128字节的数据存储器既可直接寻址也可间接寻址。高128字节RAM与特殊功能寄存器区貌似共用相同的地址范围，都使用80H~FFH, 地址空间虽然貌似重叠，但物理上是独立的，使用时通过不同的寻址方式加以区分。高128字节RAM只能间接寻址，特殊功能寄存器区只可直接寻址。

内部RAM的结构如下图所示，地址范围是00H~FFH。



低128字节RAM也称通用RAM区。通用RAM区又可分为工作寄存器组区，可位寻址区，用户RAM区和堆栈区。工作寄存器组区地址从00H~1FH共32B(字节)单元，分为4组(每一组称为一个寄存器组)，每组包含8个8位的工作寄存器，编号均为R0~R7，但属于不同的物理空间。通过使用工作寄存器组，可以提高运算速度。R0~R7是常用的寄存器，提供4组是因为1组往往不够用。程序状态字PSW寄存器中的RS1和RS0组合决定当前使用的工作寄存器组。见下面PSW寄存器的介绍。可位寻址区的地址从20H~2FH共16个字节单元。20H~2FH单元既可向普通RAM单元一样按字节存取，也可以对单元中的任何一位单独存取，共128位，所对应的地址范围是00H~7FH。位地址范围是00H~7FH，内部RAM低128字节的地址也是00H~7FH；从外表看，二者地址是一样的，实际上二者具有本质的区别；位地址指向的是一个位，而字节地址指向的是一个字节单元，在程序中使用不同的指令区分。内部RAM中的30H~FFH单元是用户RAM和堆栈区。一个8位的堆栈指针(SP)，用于指向堆栈区。单片机复位后，堆栈指针SP为07H，指向了工作寄存器组0中的R7，因此，用户初始化程序都应对SP设置初值，一般设置在80H以后的单元为宜。

PSW：程序状态字寄存器(可位寻址)

SFR name	Address	bit	B7	B6	B5	B4	B3	B2	B1	B0
PSW	D0H	name	CY	AC	F0	RS1	RS0	OV	F1	P

CY：标志位。进行加法运算时，当最高位即B7位有进位，或执行减法运算最高位有借位时，CY为1；反之为0

AC：进位辅助位。进行加法运算时，当B3位有进位，或执行减法运算B3有借位时，AC为1；反之为0。设置辅助进位标志AC的目的是为了便于BCD码加法、减法运算的调整。

F0：用户标志位0。

RS1、RS0: 工作寄存器组的选择位。如下表

RS1	RS0	当前使用的工作寄存器组(R0~R7)
0	0	0组(00H~07H)
0	1	1组(08H~0FH)
1	0	2组(10H~17H)
1	1	3组(18H~1FH)

OV：溢出标志位。

B1：保留位

F1：用户标志位1。

P：奇偶标志位。该标志位始终体现累加器ACC中1的个数的奇偶性。如果累加器ACC中1的个数为奇数，则P置1；当累加器ACC中的个数为偶数(包括0个)时，P位为0

堆栈指针(SP):

堆栈指针是一个8位专用寄存器。它指示出堆栈顶部在内部RAM块中的位置。系统复位后，SP初始化位07H，使得堆栈事实上由08H单元开始，考虑08H~1FH单元分别属于工作寄存器组1~3，若在程序设计中用到这些区，则最好把SP值改变为80H或更大的值为宜。STC89C51RC/RD+系列单片机的堆栈是向上生长的，即将数据压入堆栈后，SP内容增大。

3.2.2 内部扩展RAM(物理上是内部，逻辑上是外部，用MOVX访问)

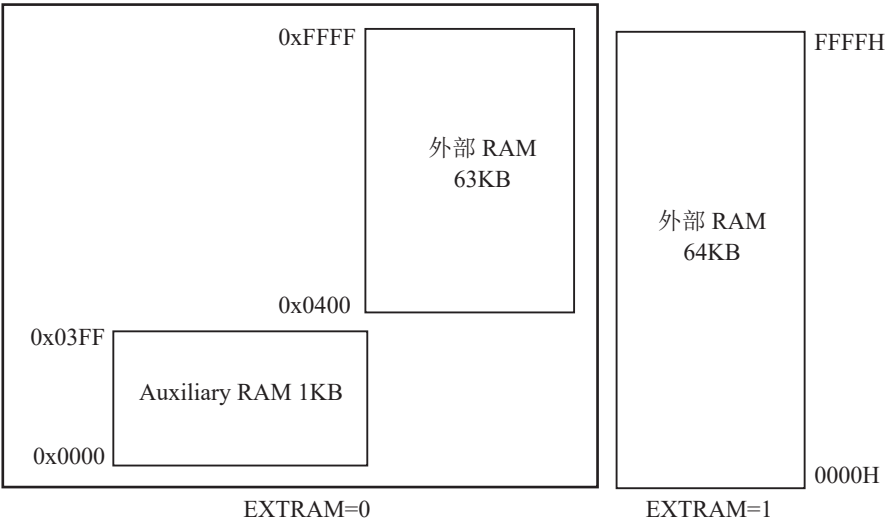
STC89C54RD+单片机片内除了集成256字节的内部RAM外，还集成了1024字节的扩展RAM，地址范围是0000H~03FFH. 访问内部扩展RAM的方法和传统8051单片机访问外部扩展RAM的方法相同，但是不影响P0口、P2口、P3.6、P3.7和ALE。在汇编语言中，内部扩展RAM通过MOVX指令访问，即使用“MOVX @DPTR”或者“MOVX @Ri”指令访问。在C语言中，可使用xdata声明存储类型即可，如“unsigned char xdata i=0;”。

单片机内部扩展RAM是否可以访问受辅助寄存器AUXR(地址为8EH)中的EXTRAM位控制。

STC89C51RC/RD+/AD/PWM系列单片机8051单片机 扩展RAM管理及禁止ALE输出 特殊功能寄存器

Mnemonic	Add	Name	7	6	5	4	3	2	1	0	Reset Value
AUXR	8EH	Auxiliary Register	-	-	-	-	-	-	EXTRAM	ALEOFF	xxxx,xx00

- EXTRAM: Internal/External RAM access 内部/外部RAM存取
- 0: 内部扩展的EXT_RAM可以存取.
- RD+系列单片机
- 在00H到3FFH单元(1024字节), 使用MOVX @DPTR指令访问, 超过400H的地址空间总是访问外部数据存储器(含400H单元)，MOVX @Ri 只能访问00H到FFH单元
- RC 系列单片机
- 在00H到FFH单元(256字节), 使用MOVX @DPTR指令访问, 超过100H的地址空间总是访问外部数据存储器(含100H单元)，MOVX @Ri 只能访问00H到FFH单元
- 1: External data memory access. 外部数据存储器存取
- 外部数据存储器存取, 禁止访问内部扩展RAM, 此时MOVX @DPTR / MOVX @Ri的使用同普通8052单片机



ALEOFF: Disable/enable ALE.

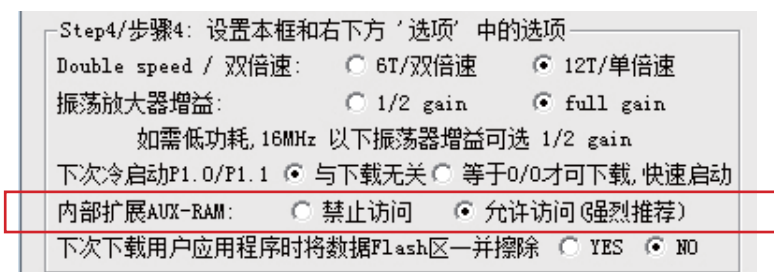
0: ALE is emitted at a constant rate of 1/3 the oscillator frequency in 6 clock mode, 1/6 fosc in 12 clock mode

ALE脚输出固定的1/6晶振频率信号在12时钟模式时, 在6时钟模式时输出固定的1/3晶振频率信号.

1: ALE is active only during a MOVX or MOVC instruction.

ALE脚仅在执行MOVX or MOVC指令时才输出信号, 好处是: 降低了系统对外界的EMI

另外, 在访问内部扩展RAM之前, 用户还需在烧录用户程序时在STC-ISP编程器中设置允许内部扩展AUX-RAM访问, 如下图所示



应用示例供参考（汇编）：

访问内部扩展的EXTRAM

；新增特殊功能寄存器声明(汇编方式)

```
AUXR          DATA          8EH;           或者用    AUXR EQU 8EH    定义
MOV           AUXR, #00000000B; EXTRAM位清为"0"，其实上电复位时此位就为"0"。
               ;MOVX A, @DPTR / MOVX @DPTR, A指令可访问内部扩展的EXTRAM
               ;RD+ 系列为(00H - 3FFH, 共1024 字节)
               ;RC 系列为(00H - FFH, 共256 字节)
               ;MOVX A, @Ri / MOVX A, @Ri 指令可直接访问内部扩展的EXTRAM
               ;使用此指令 RD+ 系列 只能访问内部扩展的EXTRAM(00H - FFH, 共256 字节)；
```

写芯片内部扩展的EXTRAM

```
MOV           DPTR, #address
MOV           A, #value
MOVX          @DPTR, A
```

；读芯片内部扩展的EXTRAM

```
MOV           DPTR, #address
MOVX A, @DPTR
```

RD+ 系列

； 如果 #address < 400H，则在EXTRAM 位为"0"时，访问物理上在内部，逻辑上在外部的此EXTRAM

； 如果 #address >= 400H，则总是访问物理上外部扩展的RAM 或I/O 空间（400H—FFFFH）

RC 系列

； 如果 #address < 100H，则在EXTRAM 位为"0"时，访问物理上在内部，逻辑上在外部的此EXTRAM

； 如果 #address >= 100H，则总是访问物理上外部扩展的RAM 或I/O 空间（100H—FFFFH）

禁止访问内部扩展的EXTRAM，以防冲突

MOV AUXR, #00000010B; EXTRAM控制位设置为"1"，禁止访问EXTRAM, 以防冲突
有些用户系统因为外部扩展了I/O 或者用片选去选多个RAM 区, 有时与此内部扩展的EXTRAM逻辑地址上有冲突，将此位设置为"1"，禁止访问此内部扩展的EXTRAM就可以了。

大实话：

其实不用设置AUXR 寄存器即可直接用MOVX @DPTR 指令访问此内部扩展的EXTRAM, 超过此RAM空间, 将访问片外单元. 如果系统外扩了SRAM, 而实际使用的空间小于1024/256 字节, 则可直接将此SRAM 省去, 比如省去STC62WV256, IS62C256, UT6264 等. 另外尽量用 MOVX A, @Ri / MOVX @Ri, A 指令访问此内部扩展的EXTRAM, 这样只能访问256字节的扩展EXTRAM, 但可与很多单片机兼容。

应用示例供参考（C 语言）：

```
/* 访问内部扩展的EXTRAM */
/* RD+ 系列为(00H - 3FFH, 共1024 字节扩展的EXTRAM) */
/* RC 系列为(00H - FFH, 共256 字节扩展的EXTRAM) */
/* 新增特殊功能寄存器声明(C 语言方式) */
sfr  AUXR = 0x8e      /*如果不需设置AUXR就不用声明AUXR */
AUXR = 0x00;          /*0000, 0000 EXTRAM位清0, 其实上电复位时此位就为0 */
unsigned char xdata sum, loop_counter, test_array[128];
/* 将变量声明成 xdata 即可直接访问此内部扩展的EXTRAM*/

/* 写芯片内部扩展的EXTRAM */
    sum      =      0;
    loop_counter  =      128;
    test_array[0] =      5;
/* 读芯片内部扩展的EXTRAM */
    sum      =      test_array[0];
/* RD+ 系列:
    如果 #address < 400H, 则在EXTRAM 位为” 0” 时, 访问物理上在内部, 逻辑上在外部
    的此EXTRAM
    如果#address>=400H, 则总是访问物理上外部扩展的RAM 或I/O空间 (400H-FFFFH)

RC 系列:
    如果 #address < 100H, 则在EXTRAM 位为” 0” 时, 访问物理上在内部, 逻辑上在外部
    的此EXTRAM
    如果#address>=100H, 总是访问物理上外部扩展的RAM 或I/O空间 (100H--FFFFH)

*/
```

禁止访问内部扩展的EXTRAM, 以防冲突

```
AUXR  = 0x02;      /* 0000, 0010, EXTRAM位设为” 1”, 禁止访问EXTRAM, 以防冲突*/
    有些用户系统因为外部扩展了I/O 或者用片选去选多个RAM 区, 有时与此内部扩展的
    EXTRAM逻辑上有冲突, 将此位设置为” 1”, 禁止访问此内部扩展的EXTRAM就可以了.
```

AUXR是只写寄存器

所谓只写, 就是直接用“MOV AUXR, #data”去写, 而不要用含读的操作如“或, 与, 入栈”因为他不让你读, 如去读, 读出的数值不确定, 用含读的操作如“或, 与, 入栈”, 会达不到需要的效果。

单片机HD版本和以前版本的区别(关于内部扩展RAM)

传统的8051，内部无扩展RAM，而STC89C51RC/RD+系列单片机内部均已扩展了RAM, 少数客户的老产品P0/P2是作为总线用的而不是作为普通I/O口用，有些需要用软件关闭此内部扩展RAM。而客户的源程序早已遗失，或开发工程师早已离职，所以STC89C51RC/RD+系列单片机为了解决此问题，推出HD版本以供用户在ISP下载程序时就可选择关闭此内部扩展RAM，以达到完全兼容以前的老产品的目的。

一般不要在ISP下载程序时就选择关闭此内部扩展RAM，因为流行用法是复位后缺省是允许访问扩展RAM, 复位后AUXR. 1/AUXR. EXTRAM = 0, 选择关闭此内部扩展RAM, 则本来是：

	在ISP下载程序时选择 “允许访问内部扩展RAM”	在ISP下载程序时选择 “禁止访问内部扩展RAM”
AUXR. 1/AUXR. EXTRAM = 0	是允许访问内部扩展RAM	是禁止访问内部扩展RAM
AUXR. 1/AUXR. EXTRAM = 1	是禁止访问内部扩展RAM	是允许访问内部扩展RAM

另STC89C51RC/RD+系列单片机C版本以前的单片机“AUXR寄存器是只写特性”，现HD版本及以后的版本将都是既可以读又可以写。

STC89C51RC/RD+系列单片机内部扩展RAM演示程序

```
;/* --- 演示 STC89C51RC/RD+系列单片机 MCU 内部扩展RAM演示程----- */
;/* --- 本演示程序在STC-ISP Ver 3.0A.PCB的下载编程工具上测试通过 ----- */
;/* --- 如果要在程序中使用该程序,请在程序中注明使用了宏晶科技的资料及程序 --- */
;/* --- 如果要在文章中引用该程序,请在文章中注明使用了宏晶科技的资料及程序 --- */

#include <reg52.h>
#include <intrins.h>          /* use _nop_() function */

sfr AUXR = 0x8e;
sfr AUXR1 = 0xa2;

sfr P4 = 0xe8;
sfr XICON = 0xc0;

sfr IPH = 0xb7;

sfr WDT_CONTR = 0xe1;
sfr ISP_DATA = 0xe2;
sfr ISP_ADDRH = 0xe3;
sfr ISP_ADDRL = 0xe4;
sfr ISP_CMD = 0xe5;
sfr ISP_TRIG = 0xe6;
sfr ISP_CONTR = 0xe7;

sbit ERROR_LED = P1^5;
sbit OK_LED = P1^7;

void main()
{
    unsigned int array_point = 0;

    /* 测试数组 Test_array_one[512],Test_array_two[512]*/
    unsigned char xdata Test_array_one[512] =
    {
        0x00,    0x01,    0x02,    0x03,    0x04,    0x05,    0x06,    0x07,
        0x08,    0x09,    0x0a,    0x0b,    0x0c,    0x0d,    0x0e,    0x0f,
        0x10,    0x11,    0x12,    0x13,    0x14,    0x15,    0x16,    0x17,
```

0x18,	0x19,	0x1a,	0x1b,	0x1c,	0x1d,	0x1e,	0x1f,
0x20,	0x21,	0x22,	0x23,	0x24,	0x25,	0x26,	0x27,
0x28,	0x29,	0x2a,	0x2b,	0x2c,	0x2d,	0x2e,	0x2f,
0x30,	0x31,	0x32,	0x33,	0x34,	0x35,	0x36,	0x37,
0x38,	0x39,	0x3a,	0x3b,	0x3c,	0x3d,	0x3e,	0x3f,
0x40,	0x41,	0x42,	0x43,	0x44,	0x45,	0x46,	0x47,
0x48,	0x49,	0x4a,	0x4b,	0x4c,	0x4d,	0x4e,	0x4f,
0x50,	0x51,	0x52,	0x53,	0x54,	0x55,	0x56,	0x57,
0x58,	0x59,	0x5a,	0x5b,	0x5c,	0x5d,	0x5e,	0x5f,
0x60,	0x61,	0x62,	0x63,	0x64,	0x65,	0x66,	0x67,
0x68,	0x69,	0x6a,	0x6b,	0x6c,	0x6d,	0x6e,	0x6f,
0x70,	0x71,	0x72,	0x73,	0x74,	0x75,	0x76,	0x77,
0x78,	0x79,	0x7a,	0x7b,	0x7c,	0x7d,	0x7e,	0x7f,
0x80,	0x81,	0x82,	0x83,	0x84,	0x85,	0x86,	0x87,
0x88,	0x89,	0x8a,	0x8b,	0x8c,	0x8d,	0x8e,	0x8f,
0x90,	0x91,	0x92,	0x93,	0x94,	0x95,	0x96,	0x97,
0x98,	0x99,	0x9a,	0x9b,	0x9c,	0x9d,	0x9e,	0x9f,
0xa0,	0xa1,	0xa2,	0xa3,	0xa4,	0xa5,	0xa6,	0xa7,
0xa8,	0xa9,	0xaa,	0xab,	0xac,	0xad,	0xae,	0xaf,
0xb0,	0xb1,	0xb2,	0xb3,	0xb4,	0xb5,	0xb6,	0xb7,
0xb8,	0xb9,	0xba,	0xbb,	0xbc,	0xbd,	0xbe,	0xbf,
0xc0,	0xc1,	0xc2,	0xc3,	0xc4,	0xc5,	0xc6,	0xc7,
0xc8,	0xc9,	0xca,	0xcb,	0xcc,	0xcd,	0xce,	0xcf,
0xd0,	0xd1,	0xd2,	0xd3,	0xd4,	0xd5,	0xd6,	0xd7,
0xd8,	0xd9,	0xda,	0xdb,	0xdc,	0xdd,	0xde,	0xdf,
0xe0,	0xe1,	0xe2,	0xe3,	0xe4,	0xe5,	0xe6,	0xe7,
0xe8,	0xe9,	0xea,	0xeb,	0xec,	0xed,	0xee,	0xef,
0xf0,	0xf1,	0xf2,	0xf3,	0xf4,	0xf5,	0xf6,	0xf7,
0xf8,	0xf9,	0xfa,	0xfb,	0xfc,	0xfd,	0xfe,	0xff,
0xff,	0xfe,	0xfd,	0xfc,	0xfb,	0xfa,	0xf9,	0xf8,
0xf7,	0xf6,	0xf5,	0xf4,	0xf3,	0xf2,	0xf1,	0xf0,
0xef,	0xee,	0xed,	0xec,	0xeb,	0xea,	0xe9,	0xe8,
0xe7,	0xe6,	0xe5,	0xe4,	0xe3,	0xe2,	0xe1,	0xe0,
0xdf,	0xde,	0xdd,	0xdc,	0xdb,	0xda,	0xd9,	0xd8,
0xd7,	0xd6,	0xd5,	0xd4,	0xd3,	0xd2,	0xd1,	0xd0,
0xcf,	0xce,	0xcd,	0xcc,	0xcb,	0xca,	0xc9,	0xc8,
0xc7,	0xc6,	0xc5,	0xc4,	0xc3,	0xc2,	0xc1,	0xc0,

```
    0xbf,    0xbe,    0xbd,    0xbc,    0xbb,    0xba,    0xb9,    0xb8,
    0xb7,    0xb6,    0xb5,    0xb4,    0xb3,    0xb2,    0xb1,    0xb0,
    0xaf,    0xae,    0xad,    0xac,    0xab,    0xaa,    0xa9,    0xa8,
    0xa7,    0xa6,    0xa5,    0xa4,    0xa3,    0xa2,    0xa1,    0xa0,
    0x9f,    0x9e,    0x9d,    0x9c,    0x9b,    0x9a,    0x99,    0x98,
    0x97,    0x96,    0x95,    0x94,    0x93,    0x92,    0x91,    0x90,
    0x8f,    0x8e,    0x8d,    0x8c,    0x8b,    0x8a,    0x89,    0x88,
    0x87,    0x86,    0x85,    0x84,    0x83,    0x82,    0x81,    0x80,
    0x7f,    0x7e,    0x7d,    0x7c,    0x7b,    0x7a,    0x79,    0x78,
    0x77,    0x76,    0x75,    0x74,    0x73,    0x72,    0x71,    0x70,
    0x6f,    0x6e,    0x6d,    0x6c,    0x6b,    0x6a,    0x69,    0x68,
    0x67,    0x66,    0x65,    0x64,    0x63,    0x62,    0x61,    0x60,
    0x5f,    0x5e,    0x5d,    0x5c,    0x5b,    0x5a,    0x59,    0x58,
    0x57,    0x56,    0x55,    0x54,    0x53,    0x52,    0x51,    0x50,
    0x4f,    0x4e,    0x4d,    0x4c,    0x4b,    0x4a,    0x49,    0x48,
    0x47,    0x46,    0x45,    0x44,    0x43,    0x42,    0x41,    0x40,
    0x3f,    0x3e,    0x3d,    0x3c,    0x3b,    0x3a,    0x39,    0x38,
    0x37,    0x36,    0x35,    0x34,    0x33,    0x32,    0x31,    0x30,
    0x2f,    0x2e,    0x2d,    0x2c,    0x2b,    0x2a,    0x29,    0x28,
    0x27,    0x26,    0x25,    0x24,    0x23,    0x22,    0x21,    0x20,
    0x1f,    0x1e,    0x1d,    0x1c,    0x1b,    0x1a,    0x19,    0x18,
    0x17,    0x16,    0x15,    0x14,    0x13,    0x12,    0x11,    0x10,
    0x0f,    0x0e,    0x0d,    0x0c,    0x0b,    0x0a,    0x09,    0x08,
    0x07,    0x06,    0x05,    0x04,    0x03,    0x02,    0x01,    0x00
};
```

```
unsigned char xdata Test_array_two[512] =
{
    0x00,    0x01,    0x02,    0x03,    0x04,    0x05,    0x06,    0x07,
    0x08,    0x09,    0x0a,    0x0b,    0x0c,    0x0d,    0x0e,    0x0f,
    0x10,    0x11,    0x12,    0x13,    0x14,    0x15,    0x16,    0x17,
    0x18,    0x19,    0x1a,    0x1b,    0x1c,    0x1d,    0x1e,    0x1f,
    0x20,    0x21,    0x22,    0x23,    0x24,    0x25,    0x26,    0x27,
```

0x28,	0x29,	0x2a,	0x2b,	0x2c,	0x2d,	0x2e,	0x2f,
0x30,	0x31,	0x32,	0x33,	0x34,	0x35,	0x36,	0x37,
0x38,	0x39,	0x3a,	0x3b,	0x3c,	0x3d,	0x3e,	0x3f,
0x40,	0x41,	0x42,	0x43,	0x44,	0x45,	0x46,	0x47,
0x48,	0x49,	0x4a,	0x4b,	0x4c,	0x4d,	0x4e,	0x4f,
0x50,	0x51,	0x52,	0x53,	0x54,	0x55,	0x56,	0x57,
0x58,	0x59,	0x5a,	0x5b,	0x5c,	0x5d,	0x5e,	0x5f,
0x60,	0x61,	0x62,	0x63,	0x64,	0x65,	0x66,	0x67,
0x68,	0x69,	0x6a,	0x6b,	0x6c,	0x6d,	0x6e,	0x6f,
0x70,	0x71,	0x72,	0x73,	0x74,	0x75,	0x76,	0x77,
0x78,	0x79,	0x7a,	0x7b,	0x7c,	0x7d,	0x7e,	0x7f,
0x80,	0x81,	0x82,	0x83,	0x84,	0x85,	0x86,	0x87,
0x88,	0x89,	0x8a,	0x8b,	0x8c,	0x8d,	0x8e,	0x8f,
0x90,	0x91,	0x92,	0x93,	0x94,	0x95,	0x96,	0x97,
0x98,	0x99,	0x9a,	0x9b,	0x9c,	0x9d,	0x9e,	0x9f,
0xa0,	0xa1,	0xa2,	0xa3,	0xa4,	0xa5,	0xa6,	0xa7,
0xa8,	0xa9,	0xaa,	0xab,	0xac,	0xad,	0xae,	0xaf,
0xb0,	0xb1,	0xb2,	0xb3,	0xb4,	0xb5,	0xb6,	0xb7,
0xb8,	0xb9,	0xba,	0xbb,	0xbc,	0xbd,	0xbe,	0xbf,
0xc0,	0xc1,	0xc2,	0xc3,	0xc4,	0xc5,	0xc6,	0xc7,
0xc8,	0xc9,	0xca,	0xcb,	0xcc,	0xcd,	0xce,	0xcf,
0xd0,	0xd1,	0xd2,	0xd3,	0xd4,	0xd5,	0xd6,	0xd7,
0xd8,	0xd9,	0xda,	0xdb,	0xdc,	0xdd,	0xde,	0xdf,
0xe0,	0xe1,	0xe2,	0xe3,	0xe4,	0xe5,	0xe6,	0xe7,
0xe8,	0xe9,	0xea,	0xeb,	0xec,	0xed,	0xee,	0xef,
0xf0,	0xf1,	0xf2,	0xf3,	0xf4,	0xf5,	0xf6,	0xf7,
0xf8,	0xf9,	0xfa,	0xfb,	0xfc,	0xfd,	0xfe,	0xff,
0xff,	0xfe,	0xfd,	0xfc,	0xfb,	0xfa,	0xf9,	0xf8,
0xf7,	0xf6,	0xf5,	0xf4,	0xf3,	0xf2,	0xf1,	0xf0,
0xef,	0xee,	0xed,	0xec,	0xeb,	0xea,	0xe9,	0xe8,
0xe7,	0xe6,	0xe5,	0xe4,	0xe3,	0xe2,	0xe1,	0xe0,
0xdf,	0xde,	0xdd,	0xdc,	0xdb,	0xda,	0xd9,	0xd8,
0xd7,	0xd6,	0xd5,	0xd4,	0xd3,	0xd2,	0xd1,	0xd0,
0xcf,	0xce,	0xcd,	0xcc,	0xcb,	0xca,	0xc9,	0xc8,
0xc7,	0xc6,	0xc5,	0xc4,	0xc3,	0xc2,	0xc1,	0xc0,

```

    0xbf,    0xbe,    0xbd,    0xbc,    0xbb,    0xba,    0xb9,    0xb8,
    0xb7,    0xb6,    0xb5,    0xb4,    0xb3,    0xb2,    0xb1,    0xb0,
    0xaf,    0xae,    0xad,    0xac,    0xab,    0xaa,    0xa9,    0xa8,
    0xa7,    0xa6,    0xa5,    0xa4,    0xa3,    0xa2,    0xa1,    0xa0,
    0x9f,    0x9e,    0x9d,    0x9c,    0x9b,    0x9a,    0x99,    0x98,
    0x97,    0x96,    0x95,    0x94,    0x93,    0x92,    0x91,    0x90,
    0x8f,    0x8e,    0x8d,    0x8c,    0x8b,    0x8a,    0x89,    0x88,
    0x87,    0x86,    0x85,    0x84,    0x83,    0x82,    0x81,    0x80,
    0x7f,    0x7e,    0x7d,    0x7c,    0x7b,    0x7a,    0x79,    0x78,
    0x77,    0x76,    0x75,    0x74,    0x73,    0x72,    0x71,    0x70,
    0x6f,    0x6e,    0x6d,    0x6c,    0x6b,    0x6a,    0x69,    0x68,
    0x67,    0x66,    0x65,    0x64,    0x63,    0x62,    0x61,    0x60,
    0x5f,    0x5e,    0x5d,    0x5c,    0x5b,    0x5a,    0x59,    0x58,
    0x57,    0x56,    0x55,    0x54,    0x53,    0x52,    0x51,    0x50,
    0x4f,    0x4e,    0x4d,    0x4c,    0x4b,    0x4a,    0x49,    0x48,
    0x47,    0x46,    0x45,    0x44,    0x43,    0x42,    0x41,    0x40,
    0x3f,    0x3e,    0x3d,    0x3c,    0x3b,    0x3a,    0x39,    0x38,
    0x37,    0x36,    0x35,    0x34,    0x33,    0x32,    0x31,    0x30,
    0x2f,    0x2e,    0x2d,    0x2c,    0x2b,    0x2a,    0x29,    0x28,
    0x27,    0x26,    0x25,    0x24,    0x23,    0x22,    0x21,    0x20,
    0x1f,    0x1e,    0x1d,    0x1c,    0x1b,    0x1a,    0x19,    0x18,
    0x17,    0x16,    0x15,    0x14,    0x13,    0x12,    0x11,    0x10,
    0x0f,    0x0e,    0x0d,    0x0c,    0x0b,    0x0a,    0x09,    0x08,
    0x07,    0x06,    0x05,    0x04,    0x03,    0x02,    0x01,    0x00
};
ERROR_LED = 1;
OK_LED = 1;
for(array_point=0; array_point<512; array_point++)
{
    if(Test_array_one[array_point]!=Test_array_two [array_point]){
        ERROR_LED = 0;
        OK_LED = 1;
        break;
    }
    else{
        OK_LED = 0;
        ERROR_LED = 1;
    }
}
while(1);
}

```

3.2.3 可外部扩展64K Bytes (字节) 数据存储器

STC89C51RC/RD+系列单片机具有扩展64KB外部数据存储器和I/O口的能力。访问外部数据存储器期间， $\overline{WR}$ 或 $\overline{RD}$ 信号要有效。

当MOVX指令访问物理上在内部，逻辑上在外部的片内扩展的1024字节EXTRAM时，以上设置均被忽略，以上设置只是在访问真正的片外扩展器件时有效。

助记符	功能说明	字节数	STC89C51RC/RD+系列单片机所需时钟
MOVX A,@Ri	逻辑上在外部的片内扩展RAM, (8位地址)送入累加器	1	12
MOVX A,@DPTR	逻辑上在外部的片内扩展RAM, (16位地址)送入累加器	1	12
MOVX @Ri,A	累加器送逻辑上在外部的片内扩展RAM(8位地址)	1	12
MOVX @DPTR,A	累加器送逻辑上在外部的片内扩展RAM(16位地址)	1	12

3.3 特殊功能寄存器(SFRs)

特殊功能寄存器 (SFR) 是用来对片内各功能模块进行管理、控制、监视的控制寄存器和状态寄存器，是一个特殊功能的RAM区。STC89C51RC/RD+系列单片机内的特殊功能寄存器 (SFR) 与内部高128字节RAM貌似共用相同的地址范围，都使用80H~FFH, 但特殊功能寄存器 (SFR) 必须用直接寻址指令访问。

STC89C51RC/RD+系列单片机的特殊功能寄存器名称及地址映象如下表所示

	0/8	1/9	2/A	3/B	4/C	5/D	6/E	7/F	
0F8H									0FFH
0F0H	B 0000,0000								0F7H
0E8H	P4 xxxx,1111								0EFH
0E0H	ACC 0000,0000	WDT_CONR xx00,0000	ISP_DATA 1111,1111	ISP_ADDRH 0000,0000	ISP_ADDRL 0000,0000	ISP_CMD 1111,1000	ISP_TRIG xxxx,xxxx	ISP_CONTR 000x,x000	0E7H
0D8H									0DFH
0D0H	PSW 0000,0000								0D7H
0C8H	T2CON 0000,0000	T2MOD xxxx,xx00	RCAP2L 0000,0000	RCAP2H 0000,0000	TL2 0000,0000	TH2 0000,0000			0CFH
0C0H	XICON 0000,0000								0C7H
0B8H	IP xx00,0000	SADEN 0000,0000							0BFH
0B0H	P3 1111,1111							IPH 0000,0000	0B7H
0A8H	IE 0x00,0000	SADDR 0000,0000							0AFH
0A0H	P2 1111,1111		AUXR1 xxxx,0xx0					Don't use	0A7H
098H	SCON 0000,0000	SBUF xxxx,xxxx							09FH
090H	P1 1111,1111								097H
088H	TCON 0000,0000	TMOD 0000,0000	TL0 0000,0000	TL1 0000,0000	TH0 0000,0000	TH1 0000,0000	AUXR xxxx,xx00		08FH
080H	P0 1111,1111	SP 0000,0111	DPL 0000,0000	DPH 0000,0000				PCON 00x1,0000	087H
	0/8	1/9	2/A	3/B	4/C	5/D	6/E	7/F	

↑
可位寻址

不可位寻址

注意：寄存器地址能够被8整除的才可以进行位操作，不能够被8整除的不可以进行位操作

符号	描述	地址	位地址及符号								复位值
			MSB				LSB				
P0	Port 0	80H	P0.7	P0.6	P0.5	P0.4	P0.3	P0.2	P0.1	P0.0	1111 1111B
SP	堆栈指针	81H									0000 0111B
DPTR	DPL	数据指针(低)									0000 0000B
	DPH	数据指针(高)									0000 0000B
PCON	电源控制寄存器	87H	SMOD	SMOD0	-	POF	GF1	GF0	PD	IDL	00x1 0000B
TCON	定时器控制寄存器	88H	TF1	TR1	TF0	TR0	IE1	IT1	IE0	IT0	0000 0000B
TMOD	定时器工作方式寄存器	89H	GATE	C/T	M1	M0	GATE	C/T	M1	M0	0000 0000B
TL0	定时器0低8位寄存器	8AH									0000 0000B
TL1	定时器1低8位寄存器	8BH									0000 0000B
TH0	定时器0高8位寄存器	8CH									0000 0000B
TH1	定时器1高8位寄存器	8DH									0000 0000B
AUXR	辅助寄存器	8EH	-	-	-	-	-	-	EXTRAM	ALEOFF	xxxx xx00B
P1	Port 1	90H	P1.7	P1.6	P1.5	P1.4	P1.3	P1.2	P1.1	P1.0	1111 1111B
SCON	串口控制寄存器	98H	SM0/FE	SM1	SM2	REN	TB8	RB8	TI	RI	0000,0000
SBUF	串口数据缓冲器	99H									xxxx,xxxx
P2	Port 2	A0H	P2.7	P2.6	P2.5	P2.4	P2.3	P2.2	P2.1	P2.0	1111 1111B
AUXR1	辅助寄存器1	A2H	-	-	-	-	GF2	-	-	DPS	xxxx 0xx0B
IE	中断允许寄存器	A8H	EA	-	ET2	ES	ET1	EX1	ET0	EX0	0x00 0000B
SADDR	从机地址控制寄存器	A9H									0000 0000B
P3	Port 3	B0H	P3.7	P3.6	P3.5	P3.4	P3.3	P3.2	P3.1	P3.0	1111 1111B
IPH	中断优先级寄存器高	B7H	-	-	PT2H	PSH	PT1H	PX1H	PT0H	PX0H	xx00 0000B
IP	中断优先级寄存器低	B8H	-	-	PT2	PS	PT1	PX1	PT0	PX0	xx00 0000B
SADEN	从机地址掩模寄存器	B9H									0000 0000B
XICON	Auxiliary Interrupt Control	C0H	PX3	EX3	IE3	IT3	PX2	EX2	IE2	IT2	0000,0000B
T2CON	Timer/Counter 2 Control	C8H	TF2	EXF2	RCLK	TCLK	EXEN2	TR2	C/T2	CP/RL2	0000 0000B
T2MOD	Timer/Counter 2 Mode	C9H	-	-	-	-	-	-	T2OE	DCEN	xxxx xx00B
RCAP2L	Timer/Counter 2 Reload/Capture Low Byte	CAH									0000 0000B
RCAP2H	Timer/Counter 2 Reload/Capture High Byte	CBH									0000 0000B

符号	描述	地址	位地址及符号										复位值
			MSB					LSB					
TL2	Timer/Counter Low Byte	CCH											0000 0000B
TH2	Timer/Counter High Byte	CDH											0000 0000B
PSW	程序状态字寄存器	D0H	CY	AC	F0	RS1	RS0	OV	F1	P		0000 0000B	
ACC	累加器	E0H											0000 0000B
WDT_CONTR	看门狗控制寄存器	E1H	-	-	EN_WDT	CLR_WDT	IDLE_WDT	PS2	PS1	PS0		xx00 0000B	
ISP_DATA	ISP/IAP 数据寄存器	E2H											1111 1111B
ISP_ADDRH	ISP/IAP 高8位地址寄存器	E3H											0000 0000B
ISP_ADDRL	ISP/IAP 低8位地址寄存器	E4H											0000 0000B
ISP_CMD	ISP/IAP 命令寄存器	E5H	-	-	-	-	-	MS2	MS1	MS0		xxxx x000B	
ISP_TRIG	ISP/IAP 命令触发寄存器	E6H											xxxx xxxxB
ISP_CONTR	ISP/IAP控制寄存器	E7H	ISPEN	SWBS	SWRST	-	-	WT2	WT1	WT0		000x x000B	
P4	Port 4	E8H	-	-	-	-	P4.3	P4.2	P4.1	P4.0		xxxx 1111B	
B	B寄存器	F0H											0000 0000B

下面简单的介绍一下普通8051单片机常用的一些寄存器：

1. 程序计数器(PC)

程序计数器PC在物理上是独立的，不属于SFR之列。PC字长16位，是专门用来控制指令执行顺序的寄存器。单片机上电或复位后，PC=0000H，强制单片机从程序的零单元开始执行程序。

2. 累加器(ACC)

累加器ACC是8051单片机内部最常用的寄存器，也可写作A。常用于存放参加算术或逻辑运算的操作数及运算结果。

3. B寄存器

B寄存器在乘法和除法运算中须与累加器A配合使用。MUL AB指令把累加器A和寄存器B中的8位无符号数相乘，所得的16位乘积的低字节存放在A中，高字节存放在B中。DIV AB指令用B除以A，整数商存放在A中，余数存放在B中。寄存器B还可以用作通用暂存寄存器。

4. 程序状态字(PSW)寄存器

SFR name	Address	bit	B7	B6	B5	B4	B3	B2	B1	B0
PSW	D0H	name	CY	AC	F0	RS1	RS0	OV	F1	P

CY：标志位。进行加法运算时，当最高位即B7位有进位，或执行减法运算最高位有借位时，CY为1；反之为0

AC：进位辅助位。进行加法运算时，当B3位有进位，或执行减法运算B3有借位时，AC为1；反之为0。设置辅助进位标志AC的目的是为了便于BCD码加法、减法运算的调整。

F0：用户标志位0。

RS1、RS0：工作寄存器组的选择位。RS1、RS0：工作寄存器组的选择位。如下表

RS1	RS0	当前使用的工作寄存器组(R0~R7)
0	0	0组(00H~07H)
0	1	1组(08H~0FH)
1	0	2组(10H~17H)
1	1	3组(18H~1FH)

OV：溢出标志位。

F0：用户标志位1。

B1：保留位

P：奇偶标志位。该标志位始终体现累加器ACC中1的个数的奇偶性。如果累加器ACC中1的个数为奇数，则P置1；当累加器ACC中的个数为偶数(包括0个)时，P位为0

5. 堆栈指针(SP)

堆栈指针是一个8位专用寄存器。它指示出堆栈顶部在内部RAM块中的位置。系统复位后，SP初始化位07H，使得堆栈事实上由08H单元开始，考虑08H~1FH单元分别属于工作寄存器组1~3，若在程序设计中用到这些区，则最好把SP值改变为80H或更大的值为宜。STC89C51RC/RD+系列单片机的堆栈是向上生长的，即将数据压入堆栈后，SP内容增大。

6. 数据指针(DPTR)

数据指针 (DPTR) 是一个16位专用寄存器，由DPL (低8位) 和DPH (高8位) 组成, 地址是82H (DPL, 低字节) 和83H (DPH, 高字节)。DPTR是传统8051机中唯一可以直接进行16位操作的寄存器也可分别对DPL和DPH按字节进行操作。STC89C51RC/RD+系列单片机有两个16位的数据指针DPTR0和DPTR1. 这两个数据指针共用同一个地址空间，可通过设置DPS/AUXR1. 0来选择具体被使用的数据指针。

STC89C51RC/RD+系列8051 单片机 双数据指针 特殊功能寄存器

Mnemonic	Add	Name	7	6	5	4	3	2	1	0	Reset Value
AUXR1	A2H	Auxiliary Register 1	-	-	-	-	GF2	-	-	DPS	xxxx,0xx0

DPS DPTR registers select bit. DPTR 寄存器选择位

0: DPTR0 is selected DPTR0被选择

1: DPTR1 is selected DPTR1被选择

此系列单片机有两个16-bit数据指针, DPTR0, DPTR1. 当DPS选择位为0时, 选择DPTR0, 当DPS选择位为1时, 选择DPTR1.

AUXR1特殊功能寄存器, 位于A2H单元, 其中的位不可用布尔指令快速访问. 但由于DPS位位于bit0, 故对AUXR1寄存器用INC指令, DPS位便会反转, 由0变成1或由1变成0, 即可实现双数据指针的快速切换.

应用示例供参考:

;新增特殊功能寄存器定义

```
AUXR1    DATA    0A2H
MOV      AUXR1, #0          ;此时DPS为0, DPTR0有效

MOV      DPTR,  #1FFH      ;置DPTR0为1FFH
MOV      A,      #55H
MOVX     @DPTR,  A         ;将1FFH单元置为55H

MOV      DPTR,  #2FFH      ;置DPTR0为2FFH
MOV      A,      #0AAH
MOVX     @DPTR,  A         ;将2FFH单元置为0AAH
```

INC	AUXR1		；此时DPS为1, DPTR1有效
MOV	DPTR,	#1FFH	；置DPTR1为1FFH
MOVX	A,	@DPTR	；读DPTR1数据指针指向的1FFH单元的内容, 累加器A变为55H.
INC	AUXR1		；此时DPS为0, DPTR0有效
MOVX	A,	@DPTR	；读DPTR0数据指针指向的2FFH单元的内容, 累加器A变为0AAH.
INC	AUXR1		；此时DPS为1, DPTR1有效
MOVX	A,	@DPTR	；读DPTR1数据指针指向的1FFH单元的内容, 累加器A变为55H.
INC	AUXR1		；此时DPS为0, DPTR0有效
MOVX	A,	@DPTR	；读DPTR0数据指针指向的2FFH单元的内容, 累加器A变为0AAH.

第4章 STC89C51RC/RD+系列单片机的I/O口结构

4.1 I/O口各种不同的工作模式及配置介绍

I/O口配置

STC89C51RC/RD+系列单片机所有I/O口均(新增P4口)有3种工作类型: 准双向口/弱上拉(标准8051输出模式)、仅为输入(高阻)或开漏输出功能。STC89C51RC/RD+系列单片机的P1/P2/P3/P4上电复位后为准双向口/弱上拉(传统8051的I/O口)模式, P0口上电复位后是开漏输出。P0口作为总线扩展用时, 不用加上拉电阻, 作为I/O口用时, 需加10K-4.7K上拉电阻。

STC89C51RC/RD+ 的5V单片机的P0口的灌电流最大为12mA, 其他I/O口的灌电流最大为6mA。

STC89LE51RC/RD+的3V单片机的P0口的灌电流最大为8mA, 其他I/O口的灌电流最大为4mA。

4.1.1 准双向口输出配置

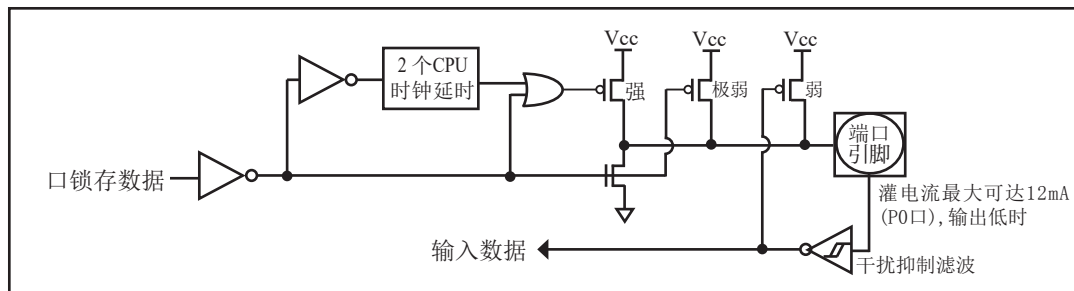
准双向口输出类型可用作输出和输入功能而不需重新配置口线输出状态。这是因为当口线输出为1时驱动能力很弱, 允许外部装置将其拉低。当引脚输出为低时, 它的驱动能力很强, 可吸收相当大的电流。准双向口有3个上拉晶体管适应不同的需要。

在3个上拉晶体管中, 有1个上拉晶体管称为“弱上拉”, 当口线寄存器为1且引脚本身也为1时打开。此上拉提供基本驱动电流使准双向口输出为1。如果一个引脚输出为1而由外部装置下拉到低时, 弱上拉关闭而“极弱上拉”维持开状态, 为了把这个引脚强拉为低, 外部装置必须有足够的灌电流能力使引脚上的电压降到门槛电压以下。

第2个上拉晶体管, 称为“极弱上拉”, 当口线锁存为1时打开。当引脚悬空时, 这个极弱的上拉源产生很弱的上拉电流将引脚上拉为高电平。

第3个上拉晶体管称为“强上拉”。当口线锁存器由0到1跳变时, 这个上拉用来加快准双向口由逻辑0到逻辑1转换。当发生这种情况时, 强上拉打开约2个时钟以使引脚能够迅速地上拉到高电平。

准双向口输出如下图所示。



准双向口输出

STC89LE51RC/RD+系列单片机为3V器件，如果用户在引脚加上5V电压，将会有电流从引脚流向Vcc，这样导致额外的功率消耗。因此，建议不要在准双向口模式中向3V单片机引脚施加5V电压，如使用的话，要加限流电阻，或用二极管做输入隔离，或用三极管做输出隔离。

准双向口带有一个干扰抑制电路。

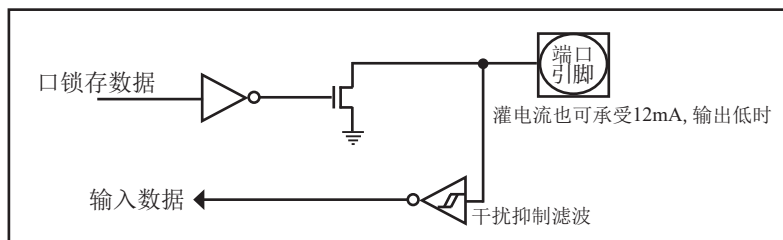
准双向口读外部状态前，要先锁存为‘1’，才可读到外部正确的状态。

4.1.2 开漏输出配置(P0口上电复位后处于开漏模式)

P0口上电复位后处于开漏模式，当P0管脚作I/O口时，需外加10K~4.7K的上拉电阻，当P0管脚作为地址/数据复用总线使用时，不用外加上拉电阻。

当口线锁存器为0时，开漏输出关闭所有上拉晶体管。当作为一个逻辑输出时，这种配置方式必须有外部上拉，一般通过电阻外接到Vcc。如果外部有上拉电阻，开漏的I/O口还可读外部状态，即此时被配置为开漏模式的I/O口还可作为输入I/O口。这种方式的下拉与准双向口相同。输出口线配置如下图所示。

开漏端口带有一个干扰抑制电路。



开漏输出(P0口上电复位后为开漏模式)

关于I/O口应用注意事项：

少数用户反映I/O口有损坏现象，后发现有

有些是I/O口由低变高读外部状态时，读不对，实际没有损坏，软件处理一下即可。

因为1T的8051单片机速度太快了，软件执行由低变高指令后立即读外部状态，此时由于实际输出还没有变高，就有可能读不对，正确的方法是在软件设置由低变高后加1到2个空操作指令延时，再读就对了。

有些实际没有损坏，加上拉电阻就OK了

有些是外围接的是NPN三极管，没有加上拉电阻，其实基极串多大电阻，I/O口就应该上拉多大的电阻。

有些确实是损坏了，原因：

发现有些是驱动LED发光二极管没有加限流电阻，建议加1K以上的限流电阻，至少也要加470欧姆以上

4.2 头文件/新增特殊功能寄存器的声明, P4口的使用

对STC89C51RC/RD+系列单片机的P4口的访问，如同访问常规的P1/P2/P3口，并且均可位寻址，P4的地址E8H。

P4端口的地址在E8h，P4口中的每一位均可位寻址，位地址如下：								
位	-	P4.6	P4.5	P4.4	P4.3	P4.2	P4.1	P4.0
位地址	EFh	EEh	EDh	ECh	EBh	EAh	E9h	E8h

C语言：

```
#include<reg51.h>
/*STC所有程序都可只包含以上头文件*/
/*新增特殊功能寄存器按如下方式声明地址即可*/
sfr    P4    = 0xe8;          /*C语言中声明P4口特殊功能寄存器地址*/
sbit   P40   = 0xe8;          /*C语言中声明P4.0口位地址*/
sbit   P41   = 0xe9;          /*C语言中声明P4.1口位地址*/
sbit   P42   = 0xea;
sbit   P43   = 0xeb;
sbit   P44   = 0xec;
sbit   P45   = 0xed;
sbit   P46   = 0xee;
/*以上为P4口的C语言地址声明*/
```

```
void main()
{
    unsigned char idata temp = 0;
    P4 = 0xff;

    temp = P4;
    P1 = temp;
    P40 = 1;
    P41 = 0;
    P42 = 1;
    P43 = 0;
    P44 = 1;
    P45 = 0;
    P46 = 1;
    while(1);
}
```

汇编语言：

```

P4      EQU    0E8H           ; or P4  DATA  0E8H
P40     EQU    0E8H           ; or P40 BIT   0E8H
P41     EQU    0E9H           ; or P41 BIT   0E9H
P42     EQU    0EAH
P43     EQU    0EBH
P44     EQU    0ECH
P45     EQU    0EDH
P46     EQU    0EEH
;以上为P4的地址声明
P26     EQU    0A6H
ORG     0000H
LJMP    MAIN

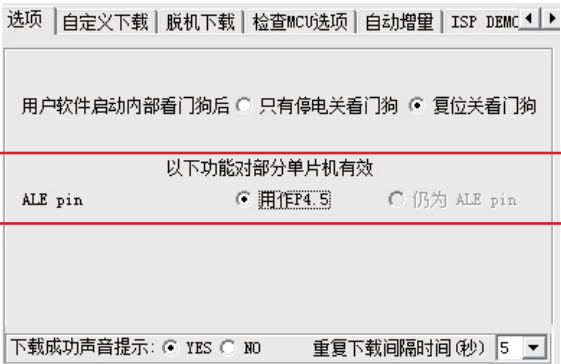
ORG     0100H
MAIN:
MOV     SP,     #0C0H
MAIN_LOOP:
MOV     A,      P4           ; Read P4 status to Accumulator.
MOV     P1,     A
MOV     P4,     #0AH         ; Output data "A" through P4.0 - P4.3
SETB    P40                     ; P4.0 = 1
CLR     P41                     ; P4.1 = 0
SETB    P42                     ; P4.2 = 1
CLR     P43                     ; P4.3 = 0
SETB    P44                     ; P4.4 = 1
CLR     P45                     ; P4.5 = 0
SETB    P46                     ; P4.6 = 1
NOP
MOV     C,      P46
MOV     P26,    C
SJMP    MAIN_LOOP
END

```

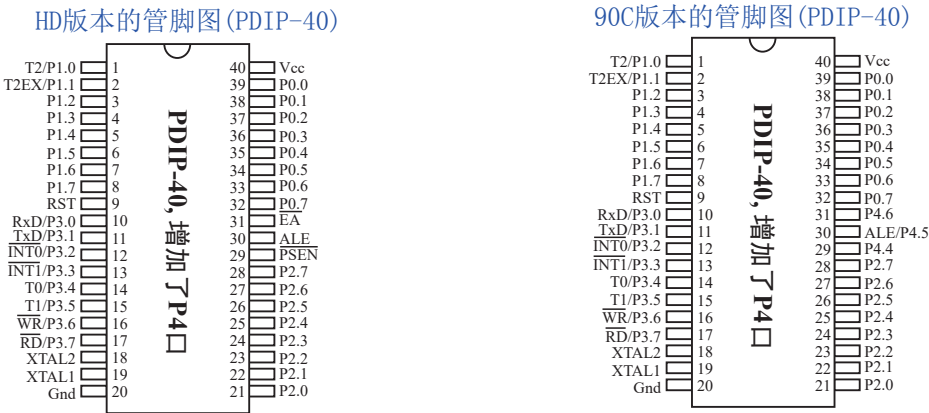
注：STC90C58AD/STC90LE58AD系列的P4口地址在C0h。

4.3 STC89C51RC系列单片机ALE/P4.5管脚作I/O口使用的设置

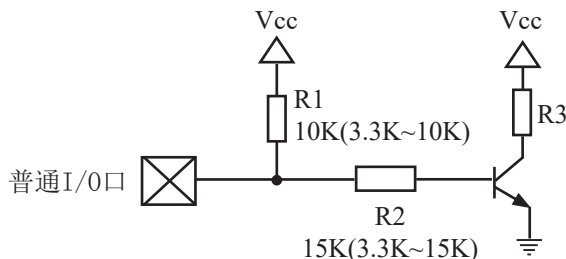
STC89C51RC/RD+系列单片机HD版无P4.5口，有ALE管脚。而90C版本的ALE/P4.5管脚既可作I/O口P4.5，也可被复用作ALE管脚，默认是用作ALE管脚。如用户需用到P4.5口，只能选择90C版本的单片机，且需在烧录用户程序时在STC-ISP编程器中将ALE pin选择为用作P4.5，在烧录用户程序时在STC-ISP编程器中该管脚默认的是作为ALE pin。具体设置如下图所示：



下面是STC89系列单片机HD版和90C版本的管脚图，主要区别在P4.6/P4.5/P4.4三个管脚处。



4.4 一种典型三极管控制电路



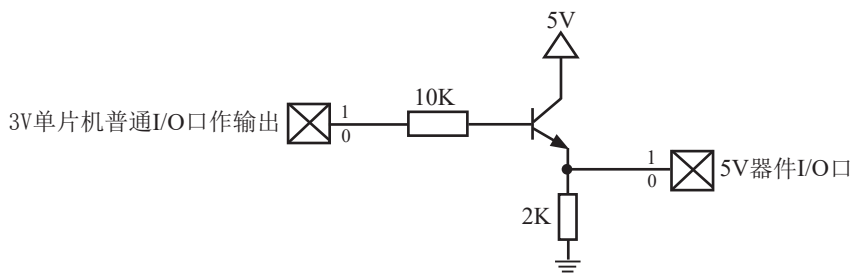
如果用弱上拉控制，建议加上拉电阻R1(3.3K~10K)，如果不加上拉电阻R1(3.3K~10K)，建议R2的值在15K以上。

4.5 混合电压供电系统3V/5V器件I/O口互连

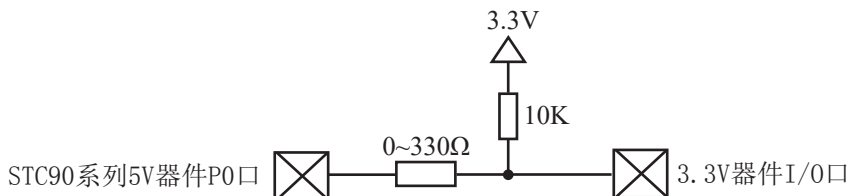
3V器件连接5V器件时作为输入时，为防止3V器件承受不了5V，可在该I/O口上串接一个隔离二极管，隔离高压部分。外部信号电压高于单片机工作电压时截止，I/O口因内部上拉到高电平，所以读I/O口状态是高电平；外部信号电压为低时导通，I/O口被钳位在0.7V，小于0.8V时单片机读I/O口状态是低电平。

3V单片机普通I/O口作输入  外部输入信号

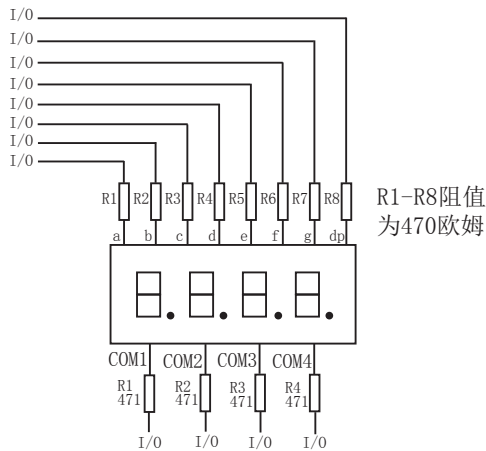
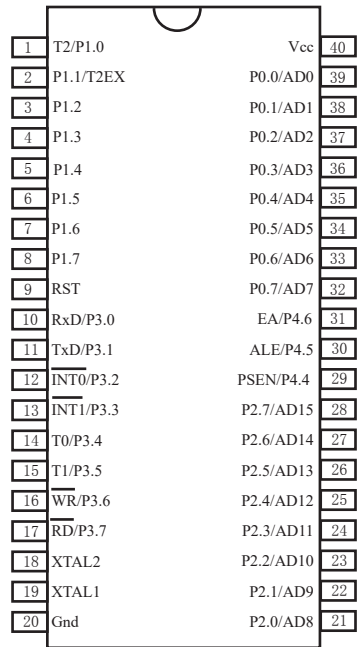
3V器件连接5V器件时作输出时，为防止3V器件承受不了5V，可用一个NPN三极管隔离，电路如下：



STC90C51RC/RD+系列5V单片机连接3.3V器件时，为防止3.3V器件承受不了5V，可将相应的5V单片机P0口先串一个0~330Ω的限流电阻到3.3V器件I/O口，相应的3.3V器件I/O口外部加10K上拉电阻到3.3V器件的Vcc，这样高电平是3.3V，低电平是0V，输入输出一切正常。



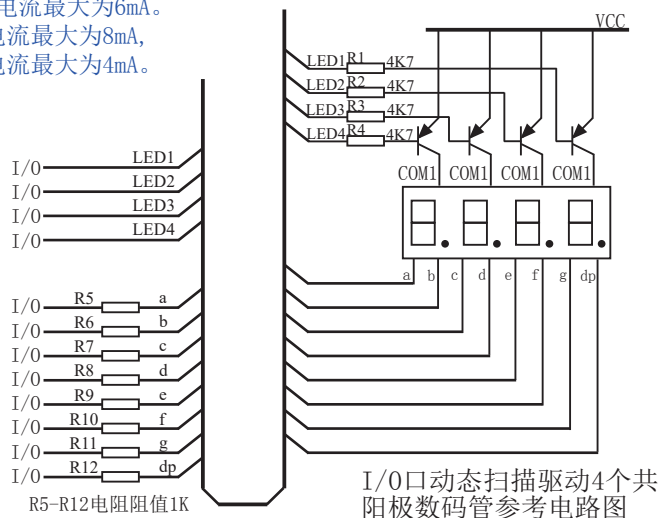
4.6 I/O口直接驱动LED数码管应用线路图



I/O口动态扫描驱动4个共阴极数码管参考电路图

I/O口动态扫描驱动数码管时，可以一次点亮一个数码管中的8段，但为降低功耗，建议可以一次只点亮其中的4段或者2段

STC89C51RC/RD+ 的5V单片机的P0口的灌电流最大为12mA，
其他I/O口的灌电流最大为6mA。
STC89LE51RC/RD+的3V单片机的P0口的灌电流最大为8mA，
其他I/O口的灌电流最大为4mA。



I/O口动态扫描驱动4个共阳极数码管参考电路图

第5章 指令系统

5.1 寻址方式

寻址方式是每一种计算机的指令集中不可缺少的部分。寻址方式规定了数据的来源和目的地。对不同的程序指令，来源和目的地的规定也会不同。在STC单片机中的寻址方式可概括为：

- 立即寻址
- 直接寻址
- 间接寻址
- 寄存器寻址
- 相对寻址
- 变址寻址
- 位寻址

5.1.1 立即寻址

立即寻址也称立即数，它是在指令操作数中直接给出参加运算的操作数，其指令格式如下：

如：MOV A, #70H

这条指令的功能是将立即数70H传送到累加器A中

5.1.2 直接寻址

在直接寻址方式中，指令操作数域给出的是参加运算操作数地址。直接寻址方式只能用来表示特殊功能寄存器、内部数据寄存器和位地址空间。其中特殊功能寄存器和位地址空间只能用直接寻址方式访问。

如：ANL 70H, #48H

表示70H单元中的数与立即数48H相“与”，结果存放在70H单元中。其中70H为直接地址，表示内部数据存储器RAM中的一个单元。

5.1.3 间接寻址

间接寻址采用R0或R1前添加“@”符号来表示。例如，假设R1中的数据是40H，内部数据存储器40H单元所包含的数据为55H，那么如下指令：

MOV A, @R1

把数据55H传送到累加器。

5.1.4 寄存器寻址

寄存器寻址是对选定的工作寄存器R7~R0、累加器A、通用寄存器B、地址寄存器和进位C中的数进行操作。其中寄存器R7~R0由指令码的低3位表示，ACC、B、DPTR及进位位C隐含在指令码中。因此，寄存器寻址也包含一种隐含寻址方式。

寄存器工作区的选择由程序状态字寄存器PSW中的RS1、RS0来决定。指令操作数指定的寄存器均指当前工作区中的寄存器。

如：INC R0 ;(R0)+1 → R0

5.1.5 相对寻址

相对寻址是将程序计数器PC中的当前值与指令第二字节给出的数相加，其结果作为转移指令的转移地址。转移地址也称为转移目的地址，PC中的当前值称为基地址，指令第二字节给出的数称为偏移量。由于目的地址是相对于PC中的基地址而言，所以这种寻址方式称为相对寻址。偏移量为带符号的数，所能表示的范围为+127~-128。这种寻址方式主要用于转移指令。

如：JC 80H ;C=1 跳转

表示若进位位C为0，则程序计数器PC中的内容不改变，即不转移。若进位位C为1，则以PC中的当前值为基地址，加上偏移量80H后所得到的结果作为该转移指令的目的地址。

5.1.6 变址寻址

在变址寻址方式中，指令操作数指定一个存放变址基值的变址寄存器。变址寻址时，偏移量与变址基值相加，其结果作为操作数的地址。变址寄存器有程序计数器PC和地址寄存器DPTR。

如：MOVC A, @A+DPTR

表示累加器A为偏移量寄存器，其内容与地址寄存器DPTR中的内容相加，其结果作为操作数的地址，取出该单元中的数送入累加器A。

5.1.7 位寻址

位寻址是指对一些内部数据存储器RAM和特殊功能寄存器进行位操作时的寻址。在进行位操作时，借助于进位位C作为位操作累加器，指令操作数直接给出该位的地址，然后根据操作码的性质对该位进行位操作。位地址与字节直接寻址中的字节地址形式完全一样，主要由操作码加以区分，使用时应注意。

如：MOV C, 20H ; 片内位单元位操作型指令

5.2 指令系统分类总结

----与普通8051指令代码完全兼容

如果按功能分类，STC89C51RC/RD+系列单片机指令系统可分为：

- 1. 数据传送类指令；
- 2. 算术操作类指令；
- 3. 逻辑操作类指令；
- 4. 控制转移类指令；
- 5. 布尔变量操作类指令。

按功能分类的指令系统表如下表所示。



数据传送类指令

助记符	功能说明	字节 数	12时钟/机器 周期所需时钟	6时钟/机器周 期所需时钟	效率 提升
MOV A, Rn	寄存器内容送入累加器	1	12	6	2倍
MOV A, direct	直接地址单元中的数据送入累加器	2	12	6	2倍
MOV A, @Ri	间接RAM中的数据送入累加器	1	12	6	2倍
MOV A, #data	立即送入累加器	2	12	6	2倍
MOV Rn, A	累加器内容送入寄存器	1	12	6	2倍
MOV Rn, direct	直接地址单元中的数据送入寄存器	2	24	12	2倍
MOV Rn, #data	立即数送入寄存器	2	12	6	2倍
MOV direct, A	累加器内容送入直接地址单元	2	12	6	2倍
MOV direct, Rn	寄存器内容送入直接地址单元	2	24	12	2倍
MOV direct, direct	直接地址单元中的数据送入另一个直接地址单元	3	24	12	2倍
MOV direct, @Ri	间接RAM中的数据送入直接地址单元	2	24	12	2倍
MOV direct, #data	立即数送入直接地址单元	3	24	12	2倍
MOV @Ri, A	累加器内容送间接RAM单元	1	12	6	2倍
MOV @Ri, direct	直接地址单元数据送入间接RAM单元	2	24	12	2倍
MOV @Ri, #data	立即数送入间接RAM单元	2	12	6	2倍
MOV DPTR, #data16	16位立即数送入地址寄存器	3	24	12	2倍
MOVC A, @A+DPTR	以DPTR为基地址变址寻址单元中的数据送入累加器	1	24	12	2倍
MOVC A, @A+PC	以PC为基地址变址寻址单元中的数据送入累加器	1	24	12	2倍
MOVX A, @Ri	逻辑上在外部的片内扩展RAM, (8位地址) 送入累加器	1	24	12	2倍
MOVX A, @DPTR	逻辑上在外部的片内扩展RAM, (16位地址) 送入累加器	1	24	12	2倍
MOVX @Ri, A	累加器送逻辑上在外部的片内扩展RAM (8位地址)	1	24	12	2倍
MOVX @DPTR, A	累加器送逻辑上在外部的片内扩展RAM (16位地址)	1	24	12	2倍
PUSH direct	直接地址单元中的数据压入堆栈	2	24	12	2倍
POP direct	出栈送直接地址单元	2	24	12	2倍
XCH A, Rn	寄存器与累加器交换	1	12	6	2倍
XCH A, direct	直接地址单元与累加器交换	2	12	6	2倍
XCH A, @Ri	间接RAM与累加器交换	1	12	6	2倍
XCHD A, @Ri	间接RAM的低半字节与累加器交换	1	12	6	2倍

算术操作类指令

助记符	功能说明	字节数	12时钟/机器周期所需时钟	6时钟/机器周期所需时钟	效率提升
ADD A, Rn	寄存器内容送入累加器	1	12	6	2倍
ADD A, direct	直接地址单元中的数据加到累加器	2	12	6	2倍
ADD A, @Ri	间接RAM中的数据加到累加器	1	12	6	2倍
ADD A, #data	立即加到累加器	2	12	6	2倍
ADDC A, Rn	寄存器内容带进位加到累加器	1	12	6	2倍
ADDC A, direct	直接地址单元的内容带进位加到累加器	2	12	6	2倍
ADDC A, @Ri	间接RAM内容带进位加到累加器	1	12	6	2倍
ADDC A, #data	立即数带进位加到累加器	2	12	6	2倍
SUBB A, Rn	累加器带借位减寄存器内容	1	12	6	2倍
SUBB A, direct	累加器带借位减直接地址单元的内容	2	12	6	2倍
SUBB A, @Ri	累加器带借位减间接RAM中的内容	1	12	6	2倍
SUBB A, #data	累加器带借位减立即数	2	12	6	2倍
INC A	累加器加1	1	12	6	2倍
INC Rn	寄存器加1	1	12	6	2倍
INC direct	直接地址单元加1	2	12	6	2倍
INC @Ri	间接RAM单元加1	1	12	6	2倍
DEC A	累加器减1	1	12	6	2倍
DEC Rn	寄存器减1	1	12	6	2倍
DEC direct	直接地址单元减1	2	12	6	2倍
DEC @Ri	间接RAM单元减1	1	12	6	2倍
INC DPTR	地址寄存器DPTR加1	1	24	12	2倍
MUL AB	A乘以B	1	48	24	2倍
DIV AB	A除以B	1	48	24	2倍
DA A	累加器十进制调整	1	12	6	2倍

逻辑操作类指令

助记符	功能说明	字节数	12时钟/机器周期所需时钟	6时钟/机器周期所需时钟	效率提升
ANL A, Rn	累加器与寄存器相“与”	1	12	6	2倍
ANL A, direct	累加器与直接地址单元相“与”	2	12	6	2倍
ANL A, @Ri	累加器与间接RAM单元相“与”	1	12	6	2倍
ANL A, #data	累加器与立即数相“与”	2	12	6	2倍
ANL direct, A	直接地址单元与累加器相“与”	2	12	6	2倍
ANL direct, #data	直接地址单元与立即数相“与”	3	24	12	2倍
ORL A, Rn	累加器与寄存器相“或”	1	12	6	2倍
ORL A, direct	累加器与直接地址单元相“或”	2	12	6	2倍
ORL A, @Ri	累加器与间接RAM单元相“或”	1	12	6	2倍
ORL A, #data	累加器与立即数相“或”	2	12	6	2倍
ORL direct, A	直接地址单元与累加器相“或”	2	12	6	2倍
ORL direct, #data	直接地址单元与立即数相“或”	3	24	12	2倍
XRL A, Rn	累加器与寄存器相“异或”	1	12	6	2倍
XRL A, direct	累加器与直接地址单元相“异或”	2	12	6	2倍
XRL A, @Ri	累加器与间接RAM单元相“异或”	1	12	6	2倍
XRL A, #data	累加器与立即数相“异或”	2	12	6	2倍
XRL direct, A	直接地址单元与累加器相“异或”	2	12	6	2倍
XRL direct, #data	直接地址单元与立即数相“异或”	3	24	12	2倍
CLR A	累加器清“0”	1	12	6	2倍
CPL A	累加器求反	1	12	6	2倍
RL A	累加器循环左移	1	12	6	2倍
RLC A	累加器带进位位循环左移	1	12	6	2倍
RR A	累加器循环右移	1	12	6	2倍
RRC A	累加器带进位位循环右	1	12	6	2倍
SWAP A	累加器半字节交换	1	12	6	2倍

控制转移类指令

助记符	功能说明	字节数	12时钟/机器周期所需时钟	6时钟/机器周期所需时钟	效率提升
ACALL addr11	绝对（短）调用子程序	2	24	12	2倍
LCALL addr16	长调用子程序	3	24	12	2倍
RET	子程序返回	1	24	12	2倍
RETI	中断返回	1	24	12	2倍
AJMP addr11	绝对（短）转移	2	24	12	2倍
LJMP addr16	长转移	3	24	12	2倍
SJMP rel	相对转移	2	24	12	2倍
JMP @A+DPTR	相对于DPTR的间接转移	1	24	12	2倍
JZ rel	累加器为零转移	2	24	12	2倍
JNZ rel	累加器非零转移	2	24	12	2倍
CJNE A, direct, rel	累加器与直接地址单元比较，不相等则转移	3	24	12	2倍
CJNE A, #data, rel	累加器与立即数比较，不相等则转移	3	24	12	2倍
CJNE Rn, #data, rel	寄存器与立即数比较，不相等则转移	3	24	12	2倍
CJNE @Ri, #data, rel	间接RAM单元与立即数比较，不相等则转移	3	24	12	2倍
DJNZ Rn, rel	寄存器减1，非零转移	3	24	12	2倍
DJNZ direct, rel	直接地址单元减1，非零转移	3	24	12	2倍
NOP	空操作	1	12	6	2倍

布尔变量操作类指令

助记符	功能说明	字节数	12时钟/机器周期所需时钟	6时钟/机器周期所需时钟	效率提升
CLR C	清零进位位	1	12	6	2倍
CLR bit	清0直接地址位	2	12	6	2倍
SETB C	置1进位位	1	12	6	2倍
SETB bit	置1直接地址位	2	12	6	2倍
CPL C	进位位求反	1	12	6	2倍
CPL bit	直接地址位求反	2	12	6	2倍
ANL C, bit	进位位和直接地址位相“与”	2	24	12	2倍
ANL C, /bit	进位位和直接地址位的反码相“与”	2	24	12	2倍
ORL C, bit	进位位和直接地址位相“或”	2	24	12	2倍
ORL C, /bit	进位位和直接地址位的反码相“或”	2	24	12	2倍
MOV C, bit	直接地址位送入进位位	2	12	6	2倍
MOV bit, C	进位位送入直接地址位	2	24	12	2倍
JC rel	进位位为1则转移	2	24	12	2倍
JNC rel	进位位为0则转移	2	24	12	2倍
JB bit, rel	直接地址位为1则转移	3	24	12	2倍
JNB bit, rel	直接地址位为0则转移	3	24	12	2倍
JBC bit, rel	直接地址位为1则转移，该位清0	3	24	12	2倍

5.3 传统8051单片机的指令定义

ACALL addr 11

Function: Absolute Call

Description: ACALL unconditionally calls a subroutine located at the indicated address. The instruction increments the PC twice to obtain the address of the following instruction, then pushes the 16-bit result onto the stack (low-order byte first) and increments the Stack Pointer twice. The destination address is obtained by successively concatenating the five high-order bits of the incremented PC opcode bits 7-5, and the second byte of the instruction. The subroutine called must therefore start within the same 2K block of the program memory as the first byte of the instruction following ACALL. No flags are affected.

Example: Initially SP equals 07H. The label “SUBRTN” is at program memory location 0345H. After executing the instruction,

ACALL SUBRTN

at location 0123H, SP will contain 09H, internal RAM locations 08H and 09H will contain 25H and 01H, respectively, and the PC will contain 0345H.

Bytes: 2

Cycles: 2

Encoding:

a10	a9	a8	1	0	0	1	0
-----	----	----	---	---	---	---	---

a7	a6	a5	a4	a3	a2	a1	a0
----	----	----	----	----	----	----	----

Operation: ACALL
 $(PC) \leftarrow (PC) + 2$
 $(SP) \leftarrow (SP) + 1$
 $((SP)) \leftarrow (PC_{7-0})$
 $(SP) \leftarrow (SP) + 1$
 $((SP)) \leftarrow (PC_{15-8})$
 $(PC_{10-0}) \leftarrow \text{page address}$

ADD A,<src-byte>

Function: Add

Description: ADD adds the byte variable indicated to the Accumulator, leaving the result in the Accumulator. The carry and auxiliary-carry flags are set, respectively, if there is a carry-out from bit 7 or bit 3, and cleared otherwise. When adding unsigned integers, the carry flag indicates an overflow occurred.

OV is set if there is a carry-out of bit 6 but not out of bit 7, or a carry-out of bit 7 but not bit 6; otherwise OV is cleared. When adding signed integers, OV indicates a negative number produced as the sum of two positive operands, or a positive sum from two negative operands.

Four source operand addressing modes are allowed: register, direct register-indirect, or immediate.

Example: The Accumulator holds 0C3H(11000011B) and register 0 holds 0AAH (10101010B). The instruction,

ADD A,R0

will leave 6DH (01101101B) in the Accumulator with the AC flag cleared and both the carry flag and OV set to 1.

ADD A,Rn

Bytes: 1
Cycles: 1
Encoding:

0	0	1	0
1	r	r	r

Operation: ADD
 $(A) \leftarrow (A) + (Rn)$

ADD A,direct

Bytes: 2
Cycles: 1
Encoding:

0	0	1	0
0	1	0	1

direct address

Operation: ADD
 $(A) \leftarrow (A) + (\text{direct})$

ADD A,@Ri

Bytes: 1
Cycles: 1
Encoding:

0	0	1	0
0	1	1	i

Operation: ADD
 $(A) \leftarrow (A) + ((Ri))$

ADD A,#data

Bytes: 2
Cycles: 1
Encoding:

0	0	1	0
0	1	0	0

immediate data

Operation: ADD
 $(A) \leftarrow (A) + \#data$

ADDC A,<src-byte>

Function: Add with Carry

Description: ADDC simultaneously adds the byte variable indicated, the Carry flag and the Accumulator, leaving the result in the Accumulator. The carry and auxiliary-carry flags are set, respectively, if there is a carry-out from bit 7 or bit 3, and cleared otherwise. When adding unsigned integers, the carry flag indicates an overflow occurred. OV is set if there is a carry-out of bit 6 but not out of bit 7, or a carry-out of bit 7 but not out of bit 6; otherwise OV is cleared. When adding signed integers, OV indicates a negative number produced as the sum of two positive operands or a positive sum from two negative operands. Four source operand addressing modes are allowed: register, direct, register-indirect, or immediate.

Example: The Accumulator holds 0C3H(11000011B) and register 0 holds 0AAH (10101010B) with the Carry. The instruction, ADDC A,R0 will leave 6EH (01101101B) in the Accumulator with the AC flag cleared and both the carry flag and OV set to 1.

ADDC A,Rn**Bytes:** 1**Cycles:** 1**Encoding:**

0	0	1	1
---	---	---	---

1	r	r	r
---	---	---	---

Operation: ADDC
 $(A) \leftarrow (A) + (C) + (Rn)$ **ADDC A,direct****Bytes:** 2**Cycles:** 1**Encoding:**

0	0	1	1
---	---	---	---

0	1	0	1
---	---	---	---

direct address

Operation: ADDC
 $(A) \leftarrow (A) + (C) + (\text{direct})$ **ADDC A,@Ri****Bytes:** 1**Cycles:** 1**Encoding:**

0	0	1	1
---	---	---	---

0	1	1	i
---	---	---	---

Operation: ADDC
 $(A) \leftarrow (A) + (C) + ((Ri))$ **ADDC A,#data****Bytes:** 2**Cycles:** 1**Encoding:**

0	0	1	1
---	---	---	---

0	1	0	0
---	---	---	---

immediate data

Operation: ADDC
 $(A) \leftarrow (A) + (C) + \#data$ **AJMP addr 11****Function:** Absolute Jump**Description:** AJMP transfers program execution to the indicated address, which is formed at run-time by concatenating the high-order five bits of the PC (after incrementing the PC twice), opcode bits 7-5, and the second byte of the instruction. The destination must therefore be within the same 2K block of program memory as the first byte of the instruction following AJMP.**Example:** The label "JMPADR" is at program memory location 0123H. The instruction, AJMP JMPADR is at location 0345H and will load the PC with 0123H.**Bytes:** 2**Cycles:** 2**Encoding:**

a10	a9	a8	0
-----	----	----	---

0	0	0	1
---	---	---	---

a7	a6	a5	a4
----	----	----	----

a3	a2	a1	a0
----	----	----	----

Operation: AJMP
 $(PC) \leftarrow (PC) + 2$
 $(PC_{10-0}) \leftarrow \text{page address}$

ANL <dest-byte> , <src-byte>**Function:** Logical-AND for byte variables**Description:** ANL performs the bitwise logical-AND operation between the variables indicated and stores the results in the destination variable. No flags are affected.

The two operands allow six addressing mode combinations. When the destination is the Accumulator, the source can use register, direct, register-indirect, or immediate addressing; when the destination is a direct address, the source can be the Accumulator or immediate data.

Note: When this instruction is used to modify an output port, the value used as the original port data will be read from the output data latch not the input pins.

Example: If the Accumulator holds 0C3H(11000011B) and register 0 holds 55H (01010101B) then the instruction,

ANL A,R0

will leave 41H (01000001B) in the Accumulator.

When the destination is a directly addressed byte, this instruction will clear combinations of bits in any RAM location or hardware register. The mask byte determining the pattern of bits to be cleared would either be a constant contained in the instruction or a value computed in the Accumulator at run-time. The instruction,

ANL Pl, #01110011B

will clear bits 7, 3, and 2 of output port 1.

ANL A,Rn**Bytes:** 1**Cycles:** 1**Encoding:**

0	1	0	1
---	---	---	---

1	r	r	r
---	---	---	---

Operation: ANL
 $(A) \leftarrow (A) \wedge (Rn)$ **ANL A,direct****Bytes:** 2**Cycles:** 1**Encoding:**

0	1	0	1
---	---	---	---

0	1	0	1
---	---	---	---

direct address

Operation: ANL
 $(A) \leftarrow (A) \wedge (\text{direct})$ **ANL A,@Ri****Bytes:** 1**Cycles:** 1**Encoding:**

0	1	0	1
---	---	---	---

0	1	1	i
---	---	---	---

Operation: ANL
 $(A) \leftarrow (A) \wedge ((Ri))$

ANL A,#data**Bytes:** 2**Cycles:** 1**Encoding:**

0	1	0	1
---	---	---	---

0	1	0	0
---	---	---	---

immediate data			
----------------	--	--	--

Operation: ANL
 $(A) \leftarrow (A) \wedge \#data$ **ANL direct,A****Bytes:** 2**Cycles:** 1**Encoding:**

0	1	0	1
---	---	---	---

0	0	1	0
---	---	---	---

direct address			
----------------	--	--	--

Operation: ANL
 $(direct) \leftarrow (direct) \wedge (A)$ **ANL direct,#data****Bytes:** 3**Cycles:** 2**Encoding:**

0	1	0	1
---	---	---	---

0	0	1	1
---	---	---	---

direct address			
----------------	--	--	--

immediate data			
----------------	--	--	--

Operation: ANL
 $(direct) \leftarrow (direct) \wedge \#data$ **ANL C,<src-bit>****Function:** Logical-AND for bit variables**Description:** If the Boolean value of the source bit is a logical 0 then clear the carry flag; otherwise leave the carry flag in its current state. A slash (“/”) preceding the operand in the assembly language indicates that the logical complement of the addressed bit is used as the source value, *but the source bit itself is not affected*. No other flgs are affected.

Only direct addressing is allowed for the source operand.

Example: Set the carry flag if, and only if, P1.0 = 1, ACC. 7 = 1, and OV = 0:

MOV C, P1.0	;LOAD CARRY WITH INPUT PIN STATE
ANL C, ACC.7	;AND CARRY WITH ACCUM. BIT.7
ANL C, /OV	;AND WITH INVERSE OF OVERFLOW FLAG

ANL C,bit**Bytes:** 2**Cycles:** 2**Encoding:**

1	0	0	0
---	---	---	---

0	0	1	0
---	---	---	---

bit address			
-------------	--	--	--

Operation: ANL
 $(C) \leftarrow (C) \wedge (bit)$

ANL C, /bit**Bytes:** 2**Cycles:** 2**Encoding:**

1	0	1	1
---	---	---	---

0	0	0	0
---	---	---	---

bit address

Operation: ADD
 $(C) \leftarrow (C) \wedge (\overline{\text{bit}})$ **CJNE <dest-byte>, <src-byte>, rel****Function:** Compare and Jump if Not Equal**Description:** CJNE compares the magnitudes of the first two operands, and branches if their values are not equal. The branch destination is computed by adding the signed relative-displacement in the last instruction byte to the PC, after incrementing the PC to the start of the next instruction. The carry flag is set if the unsigned integer value of <dest-byte> is less than the unsigned integer value of <src-byte>; otherwise, the carry is cleared. Neither operand is affected.

The first two operands allow four addressing mode combinations: the Accumulator may be compared with any directly addressed byte or immediate data, and any indirect RAM location or working register can be compared with an immediate constant.

Example: The Accumulator contains 34H. Register 7 contains 56H. The first instruction in the sequence

	CJNE	R7, #60H, NOT-EQ	
	;	...	; R7 = 60H.
NOT_EQ:	JC	REQ_LOW	; IF R7 < 60H.
	;	...	; R7 > 60H.

sets the carry flag and branches to the instruction at label NOT-EQ. By testing the carry flag, this instruction determines whether R7 is greater or less than 60H.

If the data being presented to Port 1 is also 34H, then the instruction,

WAIT: CJNE A, P1, WAIT

clears the carry flag and continues with the next instruction in sequence, since the Accumulator does equal the data read from P1. (If some other value was being input on P1, the program will loop at this point until the P1 data changes to 34H.)

CJNE A, direct, rel**Bytes:** 3**Cycles:** 2**Encoding:**

1	0	1	1
---	---	---	---

0	1	0	1
---	---	---	---

direct address

rel. address

Operation: $(PC) \leftarrow (PC) + 3$
IF $(A) < > (direct)$
THEN
 $(PC) \leftarrow (PC) + \text{relative offset}$
IF $(A) < (direct)$
THEN
 $(C) \leftarrow 1$
ELSE
 $(C) \leftarrow 0$

CJNE A,#data,rel**Bytes:** 3**Cycles:** 2

Encoding:

1	0	1	1
---	---	---	---

0	1	0	1
---	---	---	---

immediata	data
-----------	------

rel. address

Operation: $(PC) \leftarrow (PC) + 3$
 IF $(A) < > (data)$
 THEN
 $(PC) \leftarrow (PC) + \text{relative offset}$
 IF $(A) < (data)$
 THEN
 $(C) \leftarrow 1$
 ELSE
 $(C) \leftarrow 0$

CJNE Rn,#data,rel**Bytes:** 3**Cycles:** 2

Encoding:

1	0	1	1
---	---	---	---

1	r	r	r
---	---	---	---

immediata	data
-----------	------

rel. address

Operation: $(PC) \leftarrow (PC) + 3$
 IF $(Rn) < > (data)$
 THEN
 $(PC) \leftarrow (PC) + \text{relative offset}$
 IF $(Rn) < (data)$
 THEN
 $(C) \leftarrow 1$
 ELSE
 $(C) \leftarrow 0$

CJNE @Ri,#data,rel**Bytes:** 3**Cycles:** 2

Encoding:

1	0	1	1
---	---	---	---

0	1	1	i
---	---	---	---

immediate data

rel. address

Operation: $(PC) \leftarrow (PC) + 3$
 IF $((Ri)) < > (data)$
 THEN
 $(PC) \leftarrow (PC) + \text{relative offset}$
 IF $((Ri)) < (data)$
 THEN
 $(C) \leftarrow 1$
 ELSE
 $(C) \leftarrow 0$

CLR A

- Function:** Clear Accumulator
- Description:** The Accumulator is cleared (all bits set on zero). No flags are affected.
- Example:** The Accumulator contains 5CH (01011100B). The instruction,
CLR A
will leave the Accumulator set to 00H (00000000B).
- Bytes:** 1
- Cycles:** 1
- Encoding:**

1	1	1	0	0	1	0	0
---	---	---	---	---	---	---	---
- Operation:** CLR
(A) ← 0

CLR bit

- Function:** Clear bit
- Description:** The indicated bit is cleared (reset to zero). No other flags are affected. CLR can operate on the carry flag or any directly addressable bit.
- Example:** Port 1 has previously been written with 5DH (01011101B). The instruction,
CLR P1.2
will leave the port set to 59H (01011001B).

CLR C

- Bytes:** 1
- Cycles:** 1
- Encoding:**

1	1	0	0	0	0	1	1
---	---	---	---	---	---	---	---
- Operation:** CLR
(C) ← 0

CLR bit

- Bytes:** 2
- Cycles:** 1
- Encoding:**

1	1	0	0	0	0	1	0
---	---	---	---	---	---	---	---

bit address

- Operation:** CLR
(bit) ← 0

CPL A

Function: Complement Accumulator**Description:** Each bit of the Accumulator is logically complemented (one's complement). Bits which previously contained a one are changed to a zero and vice-versa. No flags are affected.**Example:** The Accumulator contains 5CH(01011100B). The instruction,

CPL A

will leave the Accumulator set to 0A3H (101000011B).

Bytes: 1**Cycles:** 1**Encoding:**

1	1	1	1	0	1	0	0
---	---	---	---	---	---	---	---

Operation: CPL
(A) ← $\overline{(A)}$

CPL bit

Function: Complement bit**Description:** The bit variable specified is complemented. A bit which had been a one is changed to zero and vice-versa. No other flags are affected. CLR can operate on the carry or any directly addressable bit.

Note:When this instruction is used to modify an output pin, the value used as the original data will be read from the output data latch, not the input pin.

Example: Port 1 has previously been written with 5DH (01011101B). The instruction,

CLR P1.1

CLR P1.2

will leave the port set to 59H (01011001B).

CPL C

Bytes: 1**Cycles:** 1**Encoding:**

1	0	1	1	0	0	1	1
---	---	---	---	---	---	---	---

Operation: CPL
(C) ← $\overline{(C)}$

CPL bit

Bytes: 2**Cycles:** 1**Encoding:**

1	0	1	1	0	0	1	0
---	---	---	---	---	---	---	---

bit address

Operation: CPL
(bit) ← $\overline{(\text{bit})}$

DA A

Function: Decimal-adjust Accumulator for Addition

Description: DA A adjusts the eight-bit value in the Accumulator resulting from the earlier addition of two variables (each in packed-BCD format), producing two four-bit digits. Any ADD or ADDC instruction may have been used to perform the addition.

If Accumulator bits 3-0 are greater than nine (xxxx1010-xxxx1111), or if the AC flag is one, six is added to the Accumulator producing the proper BCD digit in the low-order nibble. This internal addition would set the carry flag if a carry-out of the low-order four-bit field propagated through all high-order bits, but it would not clear the carry flag otherwise.

If the carry flag is now set or if the four high-order bits now exceed nine(1010xxxx-111xxxx), these high-order bits are incremented by six, producing the proper BCD digit in the high-order nibble. Again, this would set the carry flag if there was a carry-out of the high-order bits, but wouldn't clear the carry. The carry flag thus indicates if the sum of the original two BCD variables is greater than 100, allowing multiple precision decimal addition. OV is not affected.

All of this occurs during the one instruction cycle. Essentially, this instruction performs the decimal conversion by adding 00H, 06H, 60H, or 66H to the Accumulator, depending on initial Accumulator and PSW conditions.

Note: DA A cannot simply convert a hexadecimal number in the Accumulator to BCD notation, nor does DA A apply to decimal subtraction.

Example: The Accumulator holds the value 56H(01010110B) representing the packed BCD digits of the decimal number 56. Register 3 contains the value 67H (01100111B) representing the packed BCD digits of the decimal number 67. The carry flag is set. The instruction sequence.

```
ADDC A,R3
DA A
```

will first perform a standard twos-complement binary addition, resulting in the value 0BEH (10111110) in the Accumulator. The carry and auxiliary carry flags will be cleared.

The Decimal Adjust instruction will then alter the Accumulator to the value 24H (00100100B), indicating the packed BCD digits of the decimal number 24, the low-order two digits of the decimal sum of 56,67, and the carry-in. The carry flag will be set by the Decimal Adjust instruction, indicating that a decimal overflow occurred. The true sum 56, 67, and 1 is 124.

BCD variables can be incremented or decremented by adding 01H or 99H. If the Accumulator initially holds 30H (representing the digits of 30 decimal), then the instruction sequence,

```
ADD A,#99H
DA A
```

will leave the carry set and 29H in the Accumulator, since 30+99=129. The low-order byte of the sum can be interpreted to mean 30 – 1 = 29.

Bytes: 1
Cycles: 1
Encoding:

1	1	0	1	0	1	0	0
---	---	---	---	---	---	---	---

Operation: DA
 -contents of Accumulator are BCD
 IF $[(A_{3-0}) > 9] \vee [(AC) = 1]$
 THEN $(A_{3-0}) \leftarrow (A_{3-0}) + 6$
 AND
 IF $[(A_{7-4}) > 9] \vee [(C) = 1]$
 THEN $(A_{7-4}) \leftarrow (A_{7-4}) + 6$

DEC byte

Function: Decrement
Description: The variable indicated is decremented by 1. An original value of 00H will underflow to 0FFH.
 No flags are affected. Four operand addressing modes are allowed: accumulator, register, direct, or register-indirect.
Note: When this instruction is used to modify an output port, the value used as the original port data will be read from the output data latch, not the input pins.

Example: Register 0 contains 7FH (01111111B). Internal RAM locations 7EH and 7FH contain 00H and 40H, respectively. The instruction sequence,

DEC @R0

DEC R0

DEC @R0

will leave register 0 set to 7EH and internal RAM locations 7EH and 7FH set to 0FFH and 3FH.

DEC A

Bytes: 1
Cycles: 1
Encoding:

0	0	0	1	0	1	0	0
---	---	---	---	---	---	---	---

Operation: DEC
 $(A) \leftarrow (A) - 1$

DEC Rn

Bytes: 1
Cycles: 1
Encoding:

0	0	0	1	1	r	r	r
---	---	---	---	---	---	---	---

Operation: DEC
 $(Rn) \leftarrow (Rn) - 1$

DEC direct**Bytes:** 2**Cycles:** 1**Encoding:**

0 0 0 1	0 1 0 1
---------	---------

direct address

Operation: DEC
 $(\text{direct}) \leftarrow (\text{direct}) - 1$ **DEC @Ri****Bytes:** 1**Cycles:** 1**Encoding:**

0 0 0 1	0 1 1 i
---------	---------

Operation: DEC
 $((Ri)) \leftarrow ((Ri)) - 1$

DIV AB**Function:** Divide**Description:** DIV AB divides the unsigned eight-bit integer in the Accumulator by the unsigned eight-bit integer in register B. The Accumulator receives the integer part of the quotient; register B receives the integer remainder. The carry and OV flags will be cleared.

Exception: if B had originally contained 00H, the values returned in the Accumulator and B-register will be undefined and the overflow flag will be set. The carry flag is cleared in any case.

Example: The Accumulator contains 251(0FBH or 11111011B) and B contains 18(12H or 00010010B). The instruction,

DIV AB

will leave 13 in the Accumulator (0DH or 00001101B) and the value 17 (11H or 00010010B) in B, since $251 = (13 \times 18) + 17$. Carry and OV will both be cleared.

Bytes: 1**Cycles:** 4**Encoding:**

1 0 0 0	0 1 0 0
---------	---------

Operation: DIV
$$\begin{matrix} (A)_{15-8} \\ (B)_{7-0} \end{matrix} \leftarrow (A)/(B)$$

DJNZ <byte>, <rel-addr>

Function: Decrement and Jump if Not Zero

Description: DJNZ decrements the location indicated by 1, and branches to the address indicated by the second operand if the resulting value is not zero. An original value of 00H will underflow to 0FFH. No flags are affected. The branch destination would be computed by adding the signed relative-displacement value in the last instruction byte to the PC, after incrementing the PC to the first byte of the following instruction.

The location decremented may be a register or directly addressed byte.

Note: When this instruction is used to modify an output port, the value used as the original port data will be read from the output data latch, not the input pins.

Example: Internal RAM locations 40H, 50H, and 60H contain the values 01H, 70H, and 15H, respectively. The instruction sequence,

```
DJNZ 40H, LABEL_1
DJNZ 50H, LABEL_2
DJNZ 60H, LABEL_3
```

will cause a jump to the instruction at label LABEL_2 with the values 00H, 6FH, and 15H in the three RAM locations. The first jump was not taken because the result was zero.

This instruction provides a simple way of executing a program loop a given number of times, or for adding a moderate time delay (from 2 to 512 machine cycles) with a single instruction. The instruction sequence,

```
MOV R2, #8
TOGGLE: CPL P1.7
        DJNZ R2, TOGGLE
```

will toggle P1.7 eight times, causing four output pulses to appear at bit 7 of output Port 1. Each pulse will last three machine cycles; two for DJNZ and one to alter the pin.

DJNZ Rn,rel

Bytes: 2

Cycles: 2

Encoding:

1	1	0	1
---	---	---	---

1	r	r	r
---	---	---	---

rel. address

Operation: DJNZ
 $(PC) \leftarrow (PC) + 2$
 $(Rn) \leftarrow (Rn) - 1$
 IF $(Rn) > 0$ or $(Rn) < 0$
 THEN
 $(PC) \leftarrow (PC) + rel$

DJNZ direct, rel

Bytes: 3

Cycles: 2

Encoding:

1	1	0	1
---	---	---	---

0	1	0	1
---	---	---	---

direct address

rel. address

Operation: DJNZ
 $(PC) \leftarrow (PC) + 2$
 $(direct) \leftarrow (direct) - 1$
IF $(direct) > 0$ or $(direct) < 0$
THEN
 $(PC) \leftarrow (PC) + rel$

INC <byte>

Function: Increment

Description: INC increments the indicated variable by 1. An original value of 0FFH will overflow to 00H. No flags are affected. Three addressing modes are allowed: register, direct, or register-indirect.

Note: When this instruction is used to modify an output port, the value used as the original port data will be read from the output data latch, not the input pins.

Example: Register 0 contains 7EH (01111110B). Internal RAM locations 7EH and 7FH contain 0FFH and 40H, respectively. The instruction sequence,

```
INC @R0
INC R0
INC @R0
```

will leave register 0 set to 7FH and internal RAM locations 7EH and 7FH holding (respectively) 00H and 41H.

INC A

Bytes: 1

Cycles: 1

Encoding:

0	0	0	0
---	---	---	---

0	1	0	0
---	---	---	---

Operation: INC
 $(A) \leftarrow (A) + 1$

INC Rn

Bytes: 1

Cycles: 1

Encoding:

0	0	0	0
---	---	---	---

1	r	r	r
---	---	---	---

Operation: INC
 $(Rn) \leftarrow (Rn) + 1$

INC direct

Bytes: 2

Cycles: 1

Encoding:

0	0	0	0
---	---	---	---

0	1	0	1
---	---	---	---

direct address

Operation: INC
 $(direct) \leftarrow (direct) + 1$

INC @Ri**Bytes:** 1**Cycles:** 1**Encoding:**

0	0	0	0	0	0	1	1	i
---	---	---	---	---	---	---	---	---

Operation: INC
 $((Ri)) \leftarrow ((Ri)) + 1$ **INC DPTR****Function:** Increment Data Pointer**Description:** Increment the 16-bit data pointer by 1. A 16-bit increment (modulo 2^{16}) is performed; an overflow of the low-order byte of the data pointer (DPL) from 0FFH to 00H will increment the high-order-byte (DPH). No flags are affected.
This is the only 16-bit register which can be incremented.**Example:** Register DPH and DPL contains 12H and 0FEH, respectively. The instruction sequence,
INC DPTR
INC DPTR
INC DPTR
will change DPH and DPL to 13H and 01H.**Bytes:** 1**Cycles:** 2**Encoding:**

1	0	1	0	0	0	1	1
---	---	---	---	---	---	---	---

Operation: INC
 $(DPTR) \leftarrow (DPTR) + 1$ **JB bit, rel****Function:** Jump if Bit set**Description:** If the indicated bit is a one, jump to the address indicated; otherwise proceed with the next instruction. The branch destination is computed by adding the signed relative-displacement in the third instruction byte to the PC, after incrementing the PC to the first byte of the next instruction. *The bit tested is not modified. No flags are affected.***Example:** The data present at input port 1 is 11001010B. The Accumulator holds 56 (01010110B). The instruction sequence,
JB P1.2, LABEL1
JB ACC.2, LABEL2
will cause program execution to branch to the instruction at label LABEL2.**Bytes:** 3**Cycles:** 2**Encoding:**

0	0	1	0	0	0	0
---	---	---	---	---	---	---

bit address

rel. address

Operation: JB
 $(PC) \leftarrow (PC) + 3$
IF (bit) = 1
THEN
 $(PC) \leftarrow (PC) + rel$

JBC bit, rel**Function:** Jump if Bit is set and Clear bit**Description:** If the indicated bit is one, branch to the address indicated; otherwise proceed with the next instruction. *The bit will not be cleared if it is already a zero.* The branch destination is computed by adding the signed relative-displacement in the third instruction byte to the PC, after incrementing the PC to the first byte of the next instruction. No flags are affected.

Note: When this instruction is used to test an output pin, the value used as the original data will be read from the output data latch, not the input pin.

Example: The Accumulator holds 56H (01010110B). The instruction sequence,

JBC ACC.3, LABEL1

JBC ACC.2, LABEL2

will cause program execution to continue at the instruction identified by the label LABEL2, with the Accumulator modified to 52H (01010010B).

Bytes: 3**Cycles:** 2**Encoding:**

0	0	0	1	0	0	0	0
---	---	---	---	---	---	---	---

bit address

rel. address

Operation: JBC
 $(PC) \leftarrow (PC) + 3$
 IF (bit) = 1
 THEN
 (bit) $\leftarrow$ 0
 $(PC) \leftarrow (PC) + \text{rel}$

JC rel**Function:** Jump if Carry is set**Description:** If the carry flag is set, branch to the address indicated; otherwise proceed with the next instruction. The branch destination is computed by adding the signed relative-displacement in the second instruction byte to the PC, after incrementing the PC twice. No flags are affected.**Example:** The carry flag is cleared. The instruction sequence,

JC LABEL1

CPL C

JC LABEL2s

will set the carry and cause program execution to continue at the instruction identified by the label LABEL2.

Bytes: 2**Cycles:** 2**Encoding:**

0	1	0	0	0	0	0	0
---	---	---	---	---	---	---	---

rel. address

Operation: JC
 $(PC) \leftarrow (PC) + 2$
 IF (C) = 1
 THEN
 $(PC) \leftarrow (PC) + \text{rel}$

JMP @A+DPTR**Function:** Jump indirect**Description:** Add the eight-bit unsigned contents of the Accumulator with the sixteen-bit data pointer, and load the resulting sum to the program counter. This will be the address for subsequent instruction fetches. Sixteen-bit addition is performed (modulo 2^{16}): a carry-out from the low-order eight bits propagates through the higher-order bits. Neither the Accumulator nor the Data Pointer is altered. No flags are affected.**Example:** An even number from 0 to 6 is in the Accumulator. The following sequence of instructions will branch to one of four AJMP instructions in a jump table starting at JMP_TBL:

```

                MOV     DPTR, #JMP_TBL
                JMP     @A+DPTR
JMP-TBL:      AJMP    LABEL0
                AJMP    LABEL1
                AJMP    LABEL2
                AJMP    LABEL3

```

If the Accumulator equals 04H when starting this sequence, execution will jump to label LABEL2. Remember that AJMP is a two-byte instruction, so the jump instructions start at every other address.

Bytes: 1**Cycles:** 2**Encoding:**

0	1	1	1
---	---	---	---

0	0	1	1
---	---	---	---

Operation: JMP
(PC) $\leftarrow$ (A) + (DPTR)**JNB bit, rel****Function:** Jump if Bit is not set**Description:** If the indicated bit is a zero, branch to the indicated address; otherwise proceed with the next instruction. The branch destination is computed by adding the signed relative-displacement in the third instruction byte to the PC, after incrementing the PC to the first byte of the next instruction. *The bit tested is not modified.* No flags are affected.**Example:** The data present at input port 1 is 11001010B. The Accumulator holds 56H (01010110B). The instruction sequence,

```

JNB    P1.3, LABEL1
JNB    ACC.3, LABEL2

```

will cause program execution to continue at the instruction at label LABEL2

Bytes: 3**Cycles:** 2**Encoding:**

0	0	1	1
---	---	---	---

0	0	0	0
---	---	---	---

bit address

rel. address

Operation: JNB
(PC) $\leftarrow$ (PC) + 3
IF (bit) = 0
THEN (PC) $\leftarrow$ (PC) + rel

JNC rel

Function: Jump if Carry not set

Description: If the carry flag is a zero, branch to the address indicated; otherwise proceed with the next instruction. The branch destination is computed by adding the signed relative-displacement in the second instruction byte to the PC, after incrementing the PC twice to point to the next instruction. The carry flag is not modified

Example: The carry flag is set. The instruction sequence,

```
JNC LABEL1
CPL C
JNC LABEL2
```

will clear the carry and cause program execution to continue at the instruction identified by the label LABEL2.

Bytes: 2

Cycles: 2

Encoding:

0	1	0	1
---	---	---	---

0	0	0	0
---	---	---	---

rel. address

Operation: JNC
 $(PC) \leftarrow (PC) + 2$
IF $(C) = 0$
THEN $(PC) \leftarrow (PC) + rel$

JNZ rel

Function: Jump if Accumulator Not Zero

Description: If any bit of the Accumulator is a one, branch to the indicated address; otherwise proceed with the next instruction. The branch destination is computed by adding the signed relative-displacement in the second instruction byte to the PC, after incrementing the PC twice. The Accumulator is not modified. No flags are affected.

Example: The Accumulator originally holds 00H. The instruction sequence,

```
JNZ LABEL1
INC A
JNZ LAEEL2
```

will set the Accumulator to 01H and continue at label LABEL2.

Bytes: 2

Cycles: 2

Encoding:

0	1	1	1
---	---	---	---

0	0	0	0
---	---	---	---

rel. address

Operation: JNZ
 $(PC) \leftarrow (PC) + 2$
IF $(A) \neq 0$
THEN $(PC) \leftarrow (PC) + rel$

JZ rel**Function:** Jump if Accumulator Zero**Description:** If all bits of the Accumulator are zero, branch to the address indicated; otherwise proceed with the next instruction. The branch destination is computed by adding the signed relative-displacement in the second instruction byte to the PC, after incrementing the PC twice. The Accumulator is not modified. No flags are affected.**Example:** The Accumulator originally contains 01H. The instruction sequence,

JZ LABEL1

DEC A

JZ LAEEL2

will change the Accumulator to 00H and cause program execution to continue at the instruction identified by the label LABEL2.

Bytes: 2**Cycles:** 2**Encoding:**

0	1	1	0
---	---	---	---

0	0	0	0
---	---	---	---

rel. address

Operation: JZ
 $(PC) \leftarrow (PC) + 2$
IF $(A) = 0$
THEN $(PC) \leftarrow (PC) + rel$ **LCALL addr16****Function:** Long call**Description:** LCALL calls a subroutine located at the indicated address. The instruction adds three to the program counter to generate the address of the next instruction and then pushes the 16-bit result onto the stack (low byte first), incrementing the Stack Pointer by two. The high-order and low-order bytes of the PC are then loaded, respectively, with the second and third bytes of the LCALL instruction. Program execution continues with the instruction at this address. The subroutine may therefore begin anywhere in the full 64K-byte program memory address space. No flags are affected.**Example:** Initially the Stack Pointer equals 07H. The label “SUBRTN” is assigned to program memory location 1234H. After executing the instruction,

LCALL SUBRTN

at location 0123H, the Stack Pointer will contain 09H, internal RAM locations 08H and 09H will contain 26H and 01H, and the PC will contain 1234H.

Bytes: 3**Cycles:** 2**Encoding:**

0	0	0	1
---	---	---	---

0	0	1	0
---	---	---	---

addr15-addr8

addr7-addr0

Operation: LCALL
 $(PC) \leftarrow (PC) + 3$
 $(SP) \leftarrow (SP) + 1$
 $((SP)) \leftarrow (PC_{7-0})$
 $(SP) \leftarrow (SP) + 1$
 $((SP)) \leftarrow (PC_{15-8})$
 $(PC) \leftarrow addr_{15-0}$

LJMP addr16**Function:** Long Jump**Description:** LJMP causes an unconditional branch to the indicated address, by loading the high-order and low-order bytes of the PC (respectively) with the second and third instruction bytes. The destination may therefore be anywhere in the full 64K program memory address space. No flags are affected.**Example:** The label “JMPADR” is assigned to the instruction at program memory location 1234H. The instruction,

LJMP JMPADR

at location 0123H will load the program counter with 1234H.

Bytes: 3**Cycles:** 2**Encoding:**

0	0	0	0	0	0	1	0
---	---	---	---	---	---	---	---

addr15-addr8

addr7-addr0

Operation: LJMP(PC) $\leftarrow$ addr₁₅₋₀**MOV <dest-byte> , <src-byte>****Function:** Move byte variable**Description:** The byte variable indicated by the second operand is copied into the location specified by the first operand. The source byte is not affected. No other register or flag is affected.

This is by far the most flexible operation. Fifteen combinations of source and destination addressing modes are allowed.

Example: Internal RAM location 30H holds 40H. The value of RAM location 40H is 10H. The data present at input port 1 is 11001010B (0CAH).

```

MOV    R0, #30H    ;R0<= 30H
MOV    A, @R0      ;A<= 40H
MOV    R1, A        ;R1<= 40H
MOV    B, @R1      ;B<= 10H
MOV    @R1, P1      ;RAM (40H) <= 0CAH
MOV    P2, P1       ;P2 #0CAH

```

leaves the value 30H in register 0, 40H in both the Accumulator and register 1, 10H in register B, and 0CAH(11001010B) both in RAM location 40H and output on port 2.

MOV A,Rn**Bytes:** 1**Cycles:** 1**Encoding:**

1	1	1	0	1	r	r	r
---	---	---	---	---	---	---	---

Operation: MOV(A) $\leftarrow$ (Rn)

MOV A,direct*Bytes:** 2**Cycles:** 1**Encoding:**

1	1	1	0
---	---	---	---

0	1	0	1
---	---	---	---

direct address

Operation: MOV
(A) ← (direct)***MOV A,ACC is not a valid instruction****MOV A,@Ri****Bytes:** 1**Cycles:** 1**Encoding:**

1	1	1	0
---	---	---	---

0	1	1	i
---	---	---	---

Operation: MOV
(A) ← ((Ri))**MOV A,#data****Bytes:** 2**Cycles:** 1**Encoding:**

0	1	1	1
---	---	---	---

0	1	0	0
---	---	---	---

immediate data

Operation: MOV
(A) ← #data**MOV Rn,A****Bytes:** 1**Cycles:** 1**Encoding:**

1	1	1	1
---	---	---	---

1	r	r	r
---	---	---	---

Operation: MOV
(Rn) ← (A)**MOV Rn,direct****Bytes:** 2**Cycles:** 2**Encoding:**

1	0	1	0
---	---	---	---

1	r	r	r
---	---	---	---

direct addr.

Operation: MOV
(Rn) ← (direct)**MOV Rn,#data****Bytes:** 2**Cycles:** 1**Encoding:**

0	1	1	1
---	---	---	---

1	r	r	r
---	---	---	---

immediate data

Operation: MOV
(Rn) ← #data

MOV direct, A**Bytes:** 2**Cycles:** 1**Encoding:**

1	1	1	1
---	---	---	---

0	1	0	1
---	---	---	---

direct address			
----------------	--	--	--

Operation: MOV
(direct) ← (A)**MOV direct, Rn****Bytes:** 2**Cycles:** 2**Encoding:**

1	0	0	0
---	---	---	---

1	r	r	r
---	---	---	---

direct address			
----------------	--	--	--

Operation: MOV
(direct) ← (Rn)**MOV direct, direct****Bytes:** 3**Cycles:** 2**Encoding:**

1	0	0	0
---	---	---	---

0	1	0	1
---	---	---	---

dir.addr. (src)			
-----------------	--	--	--

Operation: MOV
(direct) ← (direct)**MOV direct, @Ri****Bytes:** 2**Cycles:** 2**Encoding:**

1	0	0	0
---	---	---	---

0	1	1	i
---	---	---	---

direct addr.			
--------------	--	--	--

Operation: MOV
(direct) ← ((Ri))**MOV direct, #data****Bytes:** 3**Cycles:** 2**Encoding:**

0	1	1	1
---	---	---	---

0	1	0	1
---	---	---	---

direct address			
----------------	--	--	--

Operation: MOV
(direct) ← #data**MOV @Ri, A****Bytes:** 1**Cycles:** 1**Encoding:**

1	1	1	1
---	---	---	---

0	1	1	i
---	---	---	---

Operation: MOV
((Ri)) ← (A)

MOV @Ri, direct**Bytes:** 2**Cycles:** 2**Encoding:**

1	0	1	0
---	---	---	---

0	1	1	i
---	---	---	---

direct addr.

Operation: MOV
((Ri)) ← (direct)**MOV @Ri, #data****Bytes:** 2**Cycles:** 1**Encoding:**

0	1	1	1
---	---	---	---

0	1	1	i
---	---	---	---

immediate data

Operation: MOV
((Ri)) ← #data**MOV <dest-bit>, <src-bit>****Function:** Move bit data**Description:** The Boolean variable indicated by the second operand is copied into the location specified by the first operand. One of the operands must be the carry flag; the other may be any directly addressable bit. No other register or flag is affected.**Example:** The carry flag is originally set. The data present at input Port 3 is 11000101B. The data previously written to output Port 1 is 35H (00110101B).

```

MOV    P1.3, C
MOV    C, P3.3
MOV    P1.2, C

```

will leave the carry cleared and change Port 1 to 39H (00111001B).

MOV C, bit**Bytes:** 2**Cycles:** 1**Encoding:**

1	0	1	0
---	---	---	---

0	0	1	1
---	---	---	---

bit address

Operation: MOV
(C) ← (bit)**MOV bit, C****Bytes:** 2**Cycles:** 2**Encoding:**

1	0	0	1
---	---	---	---

0	0	1	0
---	---	---	---

bit address

Operation: MOV
(bit) ← (C)

MOV DPTR, #data 16

Function: Load Data Pointer with a 16-bit constant

Description: The Data Pointer is loaded with the 16-bit constant indicated. The 16-bit constant is loaded into the second and third bytes of the instruction. The second byte (DPH) is the high-order byte, while the third byte (DPL) holds the low-order byte. No flags are affected.
This is the only instruction which moves 16 bits of data at once.

Example: The instruction,
MOV DPTR, #1234H
will load the value 1234H into the Data Pointer: DPH will hold 12H and DPL will hold 34H.

Bytes: 3

Cycles: 2

Encoding:

1	0	0	1
---	---	---	---

0	0	0	0
---	---	---	---

immediate data 15-8

Operation: MOV
(DPTR) $\leftarrow$ #data₁₅₋₀
DPH DPL $\leftarrow$ #data₁₅₋₈ #data₇₋₀

MOVC A, @A+ <base-reg>

Function: Move Code byte

Description: The MOVC instructions load the Accumulator with a code byte, or constant from program memory. The address of the byte fetched is the sum of the original unsigned eight-bit Accumulator contents and the contents of a sixteen-bit base register, which may be either the Data Pointer or the PC. In the latter case, the PC is incremented to the address of the following instruction before being added with the Accumulator; otherwise the base register is not altered. Sixteen-bit addition is performed so a carry-out from the low-order eight bits may propagate through higher-order bits. No flags are affected.

Example: A value between 0 and 3 is in the Accumulator. The following instructions will translate the value in the Accumulator to one of four values defined by the DB (define byte) directive.

```
REL-PC: INC    A
          MOVC  A, @A+PC
          RET
          DB    66H
          DB    77H
          DB    88H
          DB    99H
```

If the subroutine is called with the Accumulator equal to 01H, it will return with 77H in the Accumulator. The INC A before the MOVC instruction is needed to “get around” the RET instruction above the table. If several bytes of code separated the MOVC from the table, the corresponding number would be added to the Accumulator instead.

MOVC A, @A+DPTR

Bytes: 1

Cycles: 2

Encoding:

1	0	0	1
---	---	---	---

0	0	1	1
---	---	---	---

Operation: MOVC
(A) $\leftarrow$ ((A)+(DPTR))

MOVC A,@A+PC**Bytes:** 1**Cycles:** 2**Encoding:**

1	0	0	0	0	0	1	1
---	---	---	---	---	---	---	---

Operation: MOVC
(PC) $\leftarrow$ (PC)+1
(A) $\leftarrow$ ((A)+(PC))**MOVX <dest-byte> , <src-byte>****Function:** Move External**Description:** The MOVX instructions transfer data between the Accumulator and a byte of external data memory, hence the “X” appended to MOV. There are two types of instructions, differing in whether they provide an eight-bit or sixteen-bit indirect address to the external data RAM.

In the first type, the contents of R0 or R1 in the current register bank provide an eight-bit address multiplexed with data on P0. Eight bits are sufficient for external I/O expansion decoding or for a relatively small RAM array. For somewhat larger arrays, any output port pins can be used to output higher-order address bits. These pins would be controlled by an output instruction preceding the MOVX.

In the second type of MOVX instruction, the Data Pointer generates a sixteen-bit address. P2 outputs the high-order eight address bits (the contents of DPH) while P0 multiplexes the low-order eight bits (DPL) with data. The P2 Special Function Register retains its previous contents while the P2 output buffers are emitting the contents of DPH. This form is faster and more efficient when accessing very large data arrays (up to 64K bytes), since no additional instructions are needed to set up the output ports.

It is possible in some situations to mix the two MOVX types. A large RAM array with its high-order address lines driven by P2 can be addressed via the Data Pointer, or with code to output high-order address bits to P2 followed by a MOVX instruction using R0 or R1.

Example: An external 256 byte RAM using multiplexed address/data lines (e.g., an Intel 8155 RAM/I/O/Timer) is connected to the 8051 Port 0. Port 3 provides control lines for the external RAM. Ports 1 and 2 are used for normal I/O. Registers 0 and 1 contain 12H and 34H. Location 34H of the external RAM holds the value 56H. The instruction sequence,

```
MOVX    A, @R1
MOVX    @R0, A
```

copies the value 56H into both the Accumulator and external RAM location 12H.

MOVX A,@Ri**Bytes:** 1**Cycles:** 2**Encoding:**

1	1	1	0	0	0	1	i
---	---	---	---	---	---	---	---

Operation: MOVX
(A) $\leftarrow$ ((Ri))

MOVX A,@DPTR

Bytes: 1

Cycles: 2

Encoding:

1 1 1 0	0 0 0 0
---------	---------

Operation: MOVX
 $(A) \leftarrow ((DPTR))$

MOVX @Ri,A

Bytes: 1

Cycles: 2

Encoding:

1 1 1 1	0 0 1 i
---------	---------

Operation: MOVX
 $((Ri)) \leftarrow (A)$

MOVX @DPTR,A

Bytes: 1

Cycles: 2

Encoding:

1 1 1 1	0 0 0 0
---------	---------

Operation: MOVX
 $(DPTR) \leftarrow (A)$

MUL AB

Function: Multiply

Description: MUL AB multiplies the unsigned eight-bit integers in the Accumulator and register B. The low-order byte of the sixteen-bit product is left in the Accumulator, and the high-order byte in B. If the product is greater than 255 (0FFH) the overflow flag is set; otherwise it is cleared. The carry flag is always cleared

Example: Originally the Accumulator holds the value 80 (50H). Register B holds the value 160 (0A0H). The instruction,

MUL AB

will give the product 12,800 (3200H), so B is changed to 32H (00110010B) and the Accumulator is cleared. The overflow flag is set, carry is cleared.

Bytes: 1

Cycles: 4

Encoding:

1 0 1 0	0 1 0 0
---------	---------

Operation: MUL
 $(A)_{7-0} \leftarrow (A) \times (B)$
 $(B)_{15-8}$

NOP

Function: No Operation**Description:** Execution continues at the following instruction. Other than the PC, no registers or flags are affected.**Example:** It is desired to produce a low-going output pulse on bit 7 of Port 2 lasting exactly 5 cycles. A simple SETB/CLR sequence would generate a one-cycle pulse, so four additional cycles must be inserted. This may be done (assuming no interrupts are enabled) with the instruction sequence.

```

CLR    P2.7
NOP
NOP
NOP
NOP
SETB   P2.7

```

Bytes: 1**Cycles:** 1**Encoding:**

0	0	0	0	0	0	0	0
---	---	---	---	---	---	---	---

Operation: NOP
(PC) ← (PC)+1

ORL <dest-byte> , <src-byte>

Function: Logical-OR for byte variables**Description:** ORL performs the bitwise logical-OR operation between the indicated variables, storing the results in the destination byte. No flags are affected.

The two operands allow six addressing mode combinations. When the destination is the Accumulator, the source can use register, direct, register-indirect, or immediate addressing; when the destination is a direct address, the source can be the Accumulator or immediate data.

Note: When this instruction is used to modify an output port, the value used as the original port data will be read from the output data latch, not the input pins.

Example: If the Accumulator holds 0C3H (11000011B) and R0 holds 55H (01010101B) then the instruction,

```
ORL    A, R0
```

will leave the Accumulator holding the value 0D7H (11010111B).

When the destination is a directly addressed byte, the instruction can set combinations of bits in any RAM location or hardware register. The pattern of bits to be set is determined by a mask byte, which may be either a constant data value in the instruction or a variable computed in the Accumulator at run-time. The instruction,

```
ORL    P1, #00110010B
```

will set bits 5,4, and 1 of output Port 1.

ORL A,Rn**Bytes:** 1**Cycles:** 1**Encoding:**

0	1	0	0
---	---	---	---

1	r	r	r
---	---	---	---

Operation: ORL
 $(A) \leftarrow (A) \vee (Rn)$ **ORL A,direct****Bytes:** 2**Cycles:** 1**Encoding:**

0	1	0	0
---	---	---	---

0	1	0	1
---	---	---	---

direct address

Operation: ORL
 $(A) \leftarrow (A) \vee (\text{direct})$ **ORL A,@Ri****Bytes:** 1**Cycles:** 1**Encoding:**

0	1	0	0
---	---	---	---

0	1	1	i
---	---	---	---

Operation: ORL
 $(A) \leftarrow (A) \vee ((Ri))$ **ORL A,#data****Bytes:** 2**Cycles:** 1**Encoding:**

0	1	0	0
---	---	---	---

0	1	0	0
---	---	---	---

immediate data

Operation: ORL
 $(A) \leftarrow (A) \vee \#data$ **ORL direct, A****Bytes:** 2**Cycles:** 1**Encoding:**

0	1	0	0
---	---	---	---

0	0	1	0
---	---	---	---

direct address

Operation: ORL
 $(\text{direct}) \leftarrow (\text{direct}) \vee (A)$ **ORL direct, #data****Bytes:** 3**Cycles:** 2**Encoding:**

0	1	0	0
---	---	---	---

0	0	1	1
---	---	---	---

direct address

immediate data

Operation: ORL
 $(\text{direct}) \leftarrow (\text{direct}) \vee \#data$

ORL C, <src-bit>**Function:** Logical-OR for bit variables**Description:** Set the carry flag if the Boolean value is a logical 1; leave the carry in its current state otherwise. A slash (“/”) preceding the operand in the assembly language indicates that the logical complement of the addressed bit is used as the source value, but the source bit itself is not affected. No other flags are affected.**Example:** Set the carry flag if and only if P1.0 = 1, ACC. 7 = 1, or OV = 0:

```

MOV    C, P1.0           ;LOAD CARRY WITH INPUT PIN P10
ORL    C, ACC.7          ;OR CARRY WITH THE ACC.BIT 7
ORL    C, /OV            ;OR CARRY WITH THE INVERSE OF OV

```

ORL C, bit**Bytes:** 2**Cycles:** 2**Encoding:**

0	1	1	1
---	---	---	---

0	0	1	0
---	---	---	---

bit address

Operation: ORL
(C) ← (C) ∨ (bit)**ORL C, /bit****Bytes:** 2**Cycles:** 2**Encoding:**

1	0	1	0
---	---	---	---

0	0	0	0
---	---	---	---

bit address

Operation: ORL
(C) ← (C) ∨ $\overline{(\text{bit})}$ **POP direct****Function:** Pop from stack**Description:** The contents of the internal RAM location addressed by the Stack Pointer is read, and the Stack Pointer is decremented by one. The value read is then transferred to the directly addressed byte indicated. No flags are affected.

Example: The Stack Pointer originally contains the value 32H, and internal RAM locations 30H through 32H contain the values 20H, 23H, and 01H, respectively. The instruction sequence,

```

POP    DPH
POP    DPL

```

will leave the Stack Pointer equal to the value 30H and the Data Pointer set to 0123H. At this point the instruction,

```

POP    SP

```

will leave the Stack Pointer set to 20H. Note that in this special case the Stack Pointer was decremented to 2FH before being loaded with the value popped (20H).

Bytes: 2**Cycles:** 2**Encoding:**

1	1	0	1
---	---	---	---

0	0	0	0
---	---	---	---

direct address

Operation: POP
(direct) ← ((SP))
(SP) ← (SP) - 1

PUSH direct

Function: Push onto stack

Description: The Stack Pointer is incremented by one. The contents of the indicated variable is then copied into the internal RAM location addressed by the Stack Pointer. Otherwise no flags are affected.

Example: On entering interrupt routine the Stack Pointer contains 09H. The Data Pointer holds the value 0123H. The instruction sequence,

PUSH DPL
PUSH DPH

will leave the Stack Pointer set to 0BH and store 23H and 01H in internal RAM locations 0AH and 0BH, respectively.

Bytes: 2

Cycles: 2

Encoding:

1	1	0	0
---	---	---	---

0	0	0	0
---	---	---	---

direct address

Operation: PUSH
 $(SP) \leftarrow (SP) + 1$
 $((SP)) \leftarrow (direct)$

RET

Function: Return from subroutine

Description: RET pops the high-and low-order bytes of the PC successively from the stack, decrementing the Stack Pointer by two. Program execution continues at the resulting address, generally the instruction immediately following an ACALL or LCALL. No flags are affected.

Example: The Stack Pointer originally contains the value 0BH. Internal RAM locations 0AH and 0BH contain the values 23H and 01H, respectively. The instruction,

RET

will leave the Stack Pointer equal to the value 09H. Program execution will continue at location 0123H.

Bytes: 1

Cycles: 2

Encoding:

0	0	1	0
---	---	---	---

0	0	1	0
---	---	---	---

Operation: RET
 $(PC_{15-8}) \leftarrow ((SP))$
 $(SP) \leftarrow (SP) - 1$
 $(PC_{7-0}) \leftarrow ((SP))$
 $(SP) \leftarrow (SP) - 1$

RETI**Function:** Return from interrupt**Description:** RETI pops the high- and low-order bytes of the PC successively from the stack, and restores the interrupt logic to accept additional interrupts at the same priority level as the one just processed. The Stack Pointer is left decremented by two. No other registers are affected; the PSW is not automatically restored to its pre-interrupt status. Program execution continues at the resulting address, which is generally the instruction immediately after the point at which the interrupt request was detected. If a lower- or same-level interrupt had been pending when the RETI instruction is executed, that one instruction will be executed before the pending interrupt is processed.**Example:** The Stack Pointer originally contains the value 0BH. An interrupt was detected during the instruction ending at location 0122H. Internal RAM locations 0AH and 0BH contain the values 23H and 01H, respectively. The instruction,

RETI

will leave the Stack Pointer equal to 09H and return program execution to location 0123H.

Bytes: 1**Cycles:** 2**Encoding:**

0	0	1	1	0	0	1	0
---	---	---	---	---	---	---	---

Operation: RETI
 $(PC_{15-8}) \leftarrow ((SP))$
 $(SP) \leftarrow (SP) - 1$
 $(PC_{7-0}) \leftarrow ((SP))$
 $(SP) \leftarrow (SP) - 1$

RL A**Function:** Rotate Accumulator Left**Description:** The eight bits in the Accumulator are rotated one bit to the left. Bit 7 is rotated into the bit 0 position. No flags are affected.**Example:** The Accumulator holds the value 0C5H (11000101B). The instruction,

RL A

leaves the Accumulator holding the value 8BH (10001011B) with the carry unaffected.

Bytes: 1**Cycles:** 1**Encoding:**

0	0	1	0	0	0	1	1
---	---	---	---	---	---	---	---

Operation: RL
 $(A_{n+1}) \leftarrow (A_n) \quad n = 0-6$
 $(A_0) \leftarrow (A_7)$

RLC A

Function: Rotate Accumulator Left through the Carry flag**Description:** The eight bits in the Accumulator and the carry flag are together rotated one bit to the left. Bit 7 moves into the carry flag; the original state of the carry flag moves into the bit 0 position. No other flags are affected.**Example:** The Accumulator holds the value 0C5H (11000101B), and the carry is zero. The instruction, RLC A leaves the Accumulator holding the value 8BH (10001011B) with the carry set.**Bytes:** 1**Cycles:** 1**Encoding:**

0	0	1	1
---	---	---	---

0	0	1	1
---	---	---	---

Operation: RLC
 $(A_{n+1}) \leftarrow (A_n) \quad n = 0-6$
 $(A_0) \leftarrow (C)$
 $(C) \leftarrow (A_7)$

RR A

Function: Rotate Accumulator Right**Description:** The eight bits in the Accumulator are rotated one bit to the right. Bit 0 is rotated into the bit 7 position. No flags are affected.**Example:** The Accumulator holds the value 0C5H (11000101B). The instruction, RR A leaves the Accumulator holding the value 0E2H (11100010B) with the carry unaffected.**Bytes:** 1**Cycles:** 1**Encoding:**

0	0	0	0
---	---	---	---

0	0	1	1
---	---	---	---

Operation: RR
 $(A_n) \leftarrow (A_{n+1}) \quad n = 0 - 6$
 $(A_7) \leftarrow (A_0)$

RRC A

Function: Rotate Accumulator Right through the Carry flag**Description:** The eight bits in the Accumulator and the carry flag are together rotated one bit to the right. Bit 0 moves into the carry flag; the original value of the carry flag moves into the bit 7 position. No other flags are affected.**Example:** The Accumulator holds the value 0C5H (11000101B), and the carry is zero. The instruction, RRC A leaves the Accumulator holding the value 62H (01100010B) with the carry set.**Bytes:** 1**Cycles:** 1**Encoding:**

0	0	0	1
---	---	---	---

0	0	1	1
---	---	---	---

Operation: RRC
 $(A_{n+1}) \leftarrow (A_n) \quad n = 0-6$
 $(A_7) \leftarrow (C)$
 $(C) \leftarrow (A_0)$

SETB <bit>

Function: Set bit**Description:** SETB sets the indicated bit to one. SETB can operate on the carry flag or any directly addressable bit. No other flags are affected

Example: The carry flag is cleared. Output Port 1 has been written with the value 34H (00110100B). The instructions,

```
SETB    C
SETB    P1.0
```

will leave the carry flag set to 1 and change the data output on Port 1 to 35H (00110101B).

SETB C**Bytes:** 1**Cycles:** 1**Encoding:**

1	1	0	1
---	---	---	---

0	0	1	1
---	---	---	---

Operation: SETB
(C) ← 1**SETB bit****Bytes:** 2**Cycles:** 1**Encoding:**

1	1	0	1
---	---	---	---

0	0	1	0
---	---	---	---

bit address

Operation: SETB
(bit) ← 1

SJMP rel

Function: Short Jump**Description:** Program control branches unconditionally to the address indicated. The branch destination is computed by adding the signed displacement in the second instruction byte to the PC, after incrementing the PC twice. Therefore, the range of destinations allowed is from 128bytes preceding this instruction to 127 bytes following it.

Example: The label “RELADR” is assigned to an instruction at program memory location 0123H. The instruction,

```
SJMP    RELADR
```

will assemble into location 0100H. After the instruction is executed, the PC will contain the value 0123H.

(Note: Under the above conditions the instruction following SJMP will be at 102H. Therefore, the displacement byte of the instruction will be the relative offset (0123H - 0102H) = 21H. Put another way, an SJMP with a displacement of 0FEH would be an one-instruction infinite loop).

Bytes: 2**Cycles:** 2**Encoding:**

1	0	0	0
---	---	---	---

0	0	0	0
---	---	---	---

rel. address

Operation: SJMP
(PC) ← (PC)+2
(PC) ← (PC)+rel

SUBB A, <src-byte>**Function:** Subtract with borrow

Description: SUBB subtracts the indicated variable and the carry flag together from the Accumulator, leaving the result in the Accumulator. SUBB sets the carry (borrow) flag if a borrow is needed for bit 7, and clears C otherwise. (If C was set before executing a SUBB instruction, this indicates that a borrow was needed for the previous step in a multiple precision subtraction, so the carry is subtracted from the Accumulator along with the source operand). AC is set if a borrow is needed for bit 3, and cleared otherwise. OV is set if a borrow is needed into bit 6, but not into bit 7, or into bit 7, but not bit 6.

When subtracting signed integers OV indicates a negative number produced when a negative value is subtracted from a positive value, or a positive result when a positive number is subtracted from a negative number.

The source operand allows four addressing modes: register, direct, register-indirect, or immediate.

Example: The Accumulator holds 0C9H (11001001B), register 2 holds 54H (01010100B), and the carry flag is set. The instruction,

SUBB A, R2

will leave the value 74H (01110100B) in the accumulator, with the carry flag and AC cleared but OV set.

Notice that 0C9H minus 54H is 75H. The difference between this and the above result is due to the carry (borrow) flag being set before the operation. If the state of the carry is not known before starting a single or multiple-precision subtraction, it should be explicitly cleared by a CLR C instruction.

SUBB A, Rn**Bytes:** 1**Cycles:** 1**Encoding:**

1	0	0	1
---	---	---	---

1	r	r	r
---	---	---	---

Operation: SUBB
 $(A) \leftarrow (A) - (C) - (Rn)$

SUBB A, direct**Bytes:** 2**Cycles:** 1**Encoding:**

1	0	0	1
---	---	---	---

0	1	0	1
---	---	---	---

direct address

Operation: SUBB
 $(A) \leftarrow (A) - (C) - (\text{direct})$

SUBB A, @Ri**Bytes:** 1**Cycles:** 1**Encoding:**

1	0	0	1
---	---	---	---

0	1	1	i
---	---	---	---

Operation: SUBB
 $(A) \leftarrow (A) - (C) - ((Ri))$

SUBB A, #data**Bytes:** 2**Cycles:** 1**Encoding:**

1	0	0	1	0	1	0	0
---	---	---	---	---	---	---	---

immediate data

Operation: SUBB
 $(A) \leftarrow (A) - (C) - \#data$ **SWAP A****Function:** Swap nibbles within the Accumulator**Description:** SWAP A interchanges the low- and high-order nibbles (four-bit fields) of the Accumulator (bits 3-0 and bits 7-4). The operation can also be thought of as a four-bit rotate instruction. No flags are affected.**Example:** The Accumulator holds the value 0C5H (11000101B). The instruction,
SWAP A
leaves the Accumulator holding the value 5CH (01011100B).**Bytes:** 1**Cycles:** 1**Encoding:**

1	1	0	0	0	1	0	0
---	---	---	---	---	---	---	---

Operation: SWAP
 $(A_{3-0}) \longleftrightarrow (A_{7-4})$ **XCH A, <byte>****Function:** Exchange Accumulator with byte variable**Description:** XCH loads the Accumulator with the contents of the indicated variable, at the same time writing the original Accumulator contents to the indicated variable. The source/destination operand can use register, direct, or register-indirect addressing.**Example:** R0 contains the address 20H. The Accumulator holds the value 3FH (00111111B). Internal RAM location 20H holds the value 75H (01110101B). The instruction,
XCH A, @R0
will leave RAM location 20H holding the values 3FH (00111111B) and 75H (01110101B) in the accumulator.**XCH A, Rn****Bytes:** 1**Cycles:** 1**Encoding:**

1	1	0	0	1	r	r	r
---	---	---	---	---	---	---	---

Operation: XCH
 $(A) \longleftrightarrow (Rn)$ **XCH A, direct****Bytes:** 2**Cycles:** 1**Encoding:**

1	1	0	0	0	1	0	1
---	---	---	---	---	---	---	---

direct address

Operation: XCH
 $(A) \longleftrightarrow (\text{direct})$

XCH A, @Ri**Bytes:** 1**Cycles:** 1**Encoding:**

1	1	0	0
---	---	---	---

0	1	1	i
---	---	---	---

Operation: XCH
(A) $\longleftrightarrow$ ((Ri))**XCHD A, @Ri****Function:** Exchange Digit**Description:** XCHD exchanges the low-order nibble of the Accumulator (bits 3-0), generally representing a hexadecimal or BCD digit, with that of the internal RAM location indirectly addressed by the specified register. The high-order nibbles (bits 7-4) of each register are not affected. No flags are affected.**Example:** R0 contains the address 20H. The Accumulator holds the value 36H (00110110B). Internal RAM location 20H holds the value 75H (01110101B). The instruction,

XCHD A, @R0

will leave RAM location 20H holding the value 76H (01110110B) and 35H (00110101B) in the accumulator.

Bytes: 1**Cycles:** 1**Encoding:**

1	1	0	1
---	---	---	---

0	1	1	i
---	---	---	---

Operation: XCHD
(A₃₋₀) $\longleftrightarrow$ (Ri₃₋₀)**XRL <dest-byte>, <src-byte>****Function:** Logical Exclusive-OR for byte variables**Description:** XRL performs the bitwise logical Exclusive-OR operation between the indicated variables, storing the results in the destination. No flags are affected.

The two operands allow six addressing mode combinations. When the destination is the Accumulator, the source can use register, direct, register-indirect, or immediate addressing; when the destination is a direct address, the source can be the Accumulator or immediate data.

(Note: When this instruction is used to modify an output port, the value used as the original port data will be read from the output data latch, not the input pins.)

Example: If the Accumulator holds 0C3H (11000011B) and register 0 holds 0AAH (10101010B) then the instruction,

XRL A, R0

will leave the Accumulator holding the value 69H (01101001B).

When the destination is a directly addressed byte, this instruction can complement combination of bits in any RAM location or hardware register. The pattern of bits to be complemented is then determined by a mask byte, either a constant contained in the instruction or a variable computed in the Accumulator at run-time. The instruction,

XRL P1, #00110001B

will complement bits 5, 4 and 0 of output Port 1.

XRL A, Rn**Bytes:** 1**Cycles:** 1**Encoding:**

0	1	1	0
---	---	---	---

1	r	r	r
---	---	---	---

Operation: XRL
 $(A) \leftarrow (A) \hat{\wedge} (Rn)$ **XRL A, direct****Bytes:** 2**Cycles:** 1**Encoding:**

0	1	1	0
---	---	---	---

0	1	0	1
---	---	---	---

direct address

Operation: XRL
 $(A) \leftarrow (A) \hat{\wedge} (\text{direct})$ **XRL A, @Ri****Bytes:** 1**Cycles:** 1**Encoding:**

0	1	1	0
---	---	---	---

0	1	1	i
---	---	---	---

Operation: XRL
 $(A) \leftarrow (A) \hat{\wedge} ((Ri))$ **XRL A, #data****Bytes:** 2**Cycles:** 1**Encoding:**

0	1	1	0
---	---	---	---

0	1	0	0
---	---	---	---

immediate data

Operation: XRL
 $(A) \leftarrow (A) \hat{\wedge} \#data$ **XRL direct, A****Bytes:** 2**Cycles:** 1**Encoding:**

0	1	1	0
---	---	---	---

0	0	1	0
---	---	---	---

direct address

Operation: XRL
 $(\text{direct}) \leftarrow (\text{direct}) \hat{\wedge} (A)$ **XRL direct, #dataw****Bytes:** 3**Cycles:** 2**Encoding:**

0	1	1	0
---	---	---	---

0	0	1	1
---	---	---	---

direct address

immediate data

Operation: XRL
 $(\text{direct}) \leftarrow (\text{direct}) \hat{\wedge} \#data$

第6章 中断系统

中断系统是为使CPU具有对外界紧急事件的实时处理能力而设置的。

当中央处理机CPU正在处理某件事的时候外界发生了紧急事件请求，要求CPU暂停当前的工作，转而去处理这个紧急事件，处理完以后，再回到原来被中断的地方，继续原来的工作，这样的过程称为中断。实现这种功能的部件称为中断系统，请示CPU中断的请求源称为中断源。微型机的中断系统一般允许多个中断源，当几个中断源同时向CPU请求中断，要求为它服务的时候，这就存在CPU优先响应哪一个中断源请求的问题。通常根据中断源的轻重缓急排队，优先处理最紧急事件的中断请求源，即规定每一个中断源有一个优先级别。CPU总是先响应优先级别最高的中断请求。

当CPU正在处理一个中断源请求的时候（执行相应的中断服务程序），发生了另外一个优先级比它还高的中断源请求。如果CPU能够暂停对原来中断源的服务程序，转而去处理优先级更高的中断请求源，处理完以后，再回到原低级中断服务程序，这样的过程称为中断嵌套。这样的中断系统称为多级中断系统，没有中断嵌套功能的中断系统称为单级中断系统。

STC89C51RC/RD+系列单片机提供了8个中断请求源，它们分别是：外部中断0($\overline{\text{INT0}}$)、定时器0中断、外部中断1($\overline{\text{INT1}}$)、定时器1中断、定时器2中断、串口(UART)中断、外部中断2($\overline{\text{INT2}}$)、外部中断3($\overline{\text{INT3}}$)。所有的中断都具有4个中断优先级。用户可以用关总中断允许位(EA/IE.7)或相应中断的允许位来屏蔽所有的中断请求，也可以用打开相应的中断允许位来使CPU响应相应的中断申请；每一个中断源可以用软件独立地控制为开中断或关中断状态；每一个中断的优先级别均可用软件设置。高优先级的中断请求可以打断低优先级的中断，反之，低优先级的中断请求不可以打断高优先级及同优先级的中断。当两个相同优先级的中断同时产生时，将由查询次序来决定系统先响应哪个中断。STC89C51RC/RD+系列单片机的各个中断查询次序如下表6-1所示：

表6-1 中断查询次序

中断源	中断 向量 地址	相同优先级内 的查询次序	中断优先级 设置 (IPH,IP)	优先级0 (最低)	优先 级1	优先 级2	优先级3 (最高)	中断请求标志位	中断允许控制位
$\overline{\text{INT0}}$ (外部中断0)	0003H	0(highest)	PX0H, PX0	0, 0	0, 1	1, 0	1, 1	IE0	EX0/EA
Timer 0	000BH	1	PT0H, PT0	0, 0	0, 1	1, 0	1, 1	TF0	ET0/EA
$\overline{\text{INT1}}$ (外部中断1)	0013H	2	PX1H, PX1	0, 0	0, 1	1, 0	1, 1	IE1	EX1/EA
Timer1	001BH	3	PT1H, PT1	0, 0	0, 1	1, 0	1, 1	TF1	ET1/EA
UART	0023H	4	PSH, PS	0, 0	0, 1	1, 0	1, 1	RI+TI	
Timer2	002BH	5	PT2H, PT2	0, 0	0, 1	1, 0	1, 1	TF2 + EXF2	(ET2)/EA
$\overline{\text{INT2}}$ (外部中断2)	0033H	6	PX2H, PX2	0, 0	0, 1	1, 0	1, 1	IE2	EX2/EA
$\overline{\text{INT3}}$ (外部中断3)	003BH	7(lowest)	PX3H, PX3	0, 0	0, 1	1, 0	1, 1	IE3	EX3/EA

通过设置新增加的特殊功能寄存器IPH中的相应位，可将中断优先级设为四级，如果只设置IP或XICON，那么中断优先级就只有两级，与传统8051单片机两级中断优先级完全兼容。

如果使用C语言编程，中断查询次序号就是中断号，例如：

```

void    Int0_Routine(void)           interrupt 0;
void    Timer0_Routine(void)         interrupt 1;
void    Int1_Routine(void)           interrupt 2;
void    Timer1_Routine(void)         interrupt 3;
void    UART_Routine(void)           interrupt 4;
void    Timer2_Routine(void)         interrupt 5;
void    Int2_Routine(void)           interrupt 6;
void    Int3_Routine(void)           interrupt 7;
```

6.1 中断结构

STC89C51RC/RD+系列单片机的中断系统结构示意图如图6-1所示

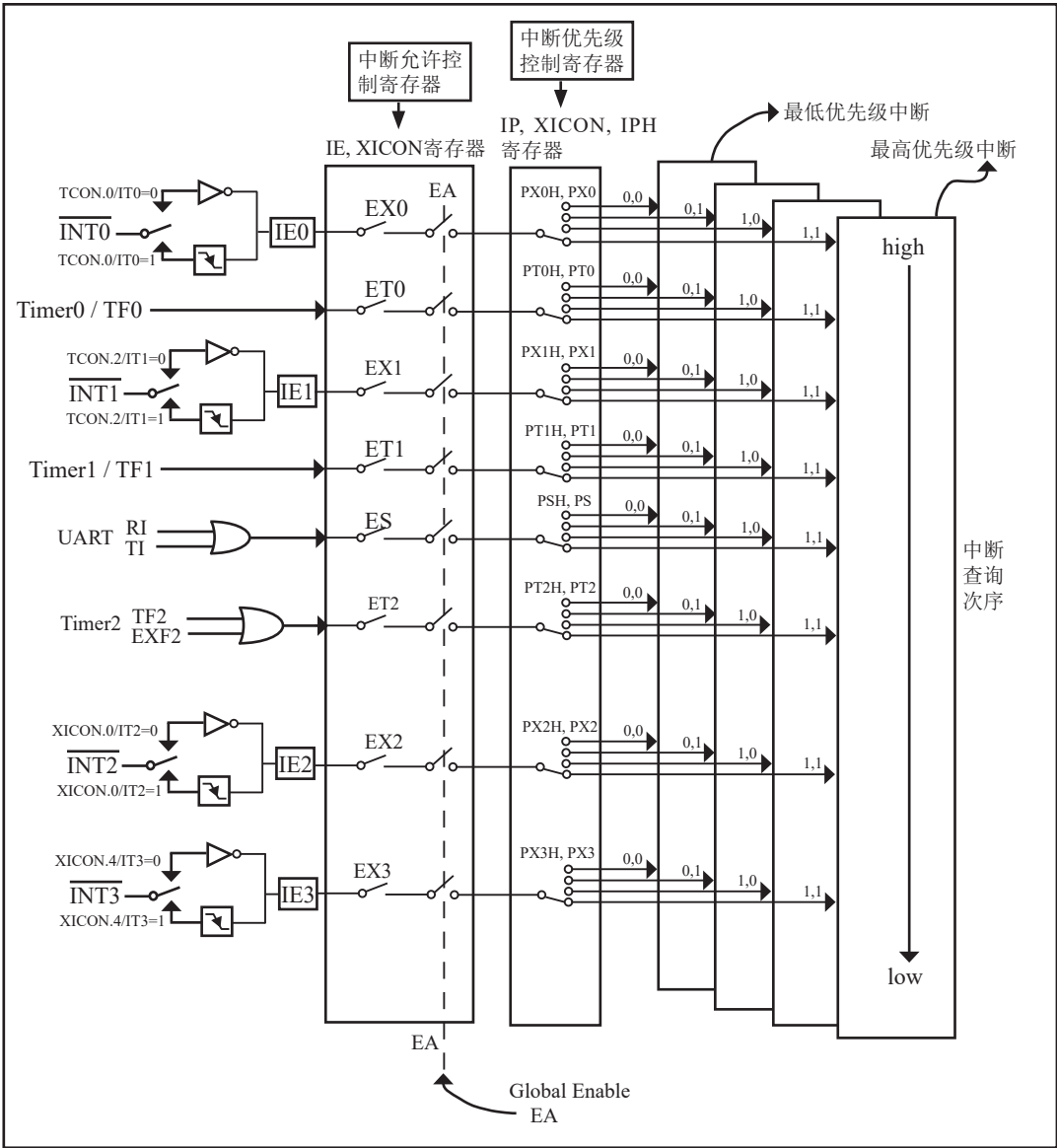


图6-1 STC89C51RC/RD+系列中断系统结构图

外部中断0($\overline{\text{INT0}}$)、外部中断1($\overline{\text{INT1}}$)、外部中断2($\overline{\text{INT2}}$)和外部中断3($\overline{\text{INT3}}$)既可低电平触发，也下降沿触发。请求四个外部中断的标志位是位于寄存器TCON中的IE0/TCON.1、IE1/TCON.3、IE2/XICON.2和IE3/XICON.5。当外部中断服务程序被响应后，中断请求标志位IE0、IE1、IE2和IE3会自动被清0。TCON寄存器中的IT0/TCON.0、IT1/TCON.2、IT2/XICON.0和IT3/XICON.4决定了外部中断0、1、2和3是低电平触发方式还是下降沿触发方式。如果IT_x = 0(x = 0,1,2,3)，那么系统在INT_x(x = 0,1,2,3)脚探测到低电平后可产生外部中断。如果IT_x = 1(x = 0,1,2,3)，那么系统在INT_x(x = 0,1,2,3)脚探测下降沿后可产生外部中断。外部中断0($\overline{\text{INT0}}$)、外部中断1($\overline{\text{INT1}}$)、外部中断2($\overline{\text{INT2}}$)和外部中断3($\overline{\text{INT3}}$)还可以用于将单片机从掉电模式唤醒。

定时器0和1的中断请求标志位是TF0和TF1。当定时器寄存器TH_x/TL_x(x = 0,1)溢出时，溢出标志位TF_x(x = 0,1)会被置位，定时器中断发生。当单片机转去执行该定时器中断时，定时器的溢出标志位TF_x(x = 0,1)会被硬件清除。

当串行口接收中断请求标志位RI和串行口1发送中断请求标志位TI中的任何一个被置为1后，串行口中断都会产生。。

定时器2的中断请求标志位是TF2和EXF2。当定时器寄存器TH2/TL2溢出时，溢出标志位TF2会被置位，定时器中断发生。当单片机转去执行该定时器中断时，定时器的溢出标志位TF2会被硬件清除。当EXEN2=1且T2EX的负跳变产生捕获或重装时，EXF2置位。定时器2中断使能时，EXF2=也将使CPU从中断向量处执行定时器2中断子程序。

各个中断触发行为总结如下表6-2所示：

表6-2 中断触发

中断源	触发行为
$\overline{\text{INT0}}$ (外部中断0)	(IT0/TCON.0 = 1): 下降沿 (IT0/TCON.0 = 0): 低电平
Timer 0	定时器0溢出
$\overline{\text{INT1}}$ (外部中断1)	(IT1/TCON.2 = 1): 下降沿 (IT1/TCON.2 = 0): 低电平
Timer1	定时器1溢出
UART	发送或接受完成
Timer2	定时器2溢出
$\overline{\text{INT2}}$ (外部中断2)	(IT2/XICON.0 = 1): 下降沿 (IT2/XICON.0 = 0): 低电平
$\overline{\text{INT3}}$ (外部中断3)	(IT3/XICON.4 = 1): 下降沿 (IT3/XICON.4 = 0): 低电平

6.2 中断寄存器

符号	描述	地址	位地址及符号								复位值
			MSB				LSB				
IE	Interrupt Enable	A8H	EA	-	ET2	ES	ET1	EX1	ET0	EX0	0x00 0000B
IP	Interrupt Priority Low	B8H	-	-	PT2	PS	PT1	PX1	PT0	PX0	xx00 0000B
IPH	Interrupt Priority High	B7H	PX3H	PX2H	PT2H	PSH	PT1H	PX1H	PT0H	PX0H	0000,0000B
TCON	Timer/Counter 0 and 1 Control	88H	TF1	TR1	TF0	TR0	IE1	IT1	IE0	IT0	0000 0000B
SCON	Serial Control	98H	SM0/FE	SM1	SM2	REN	TB8	RB8	TI	RI	0000 0000B
T2CON	Timer/Counter 2 Control	C8H	TF2	EXF2	RCLK	TCLK	EXEN2	TR2	C/T2	CP/RL2	0000 0000B
XICON	Auxiliary Interrupt Control	C0H	PX3	EX3	IE3	IT3	PX2	EX2	IE2	IT2	0000 0000B

上表中列出了与STC89C51RC/RD+系列单片机中断相关的所有寄存器，下面逐一地对上述寄存器进行介绍。

1. 中断允许寄存器IE和XICON

STC89C51RC/RD+系列单片机CPU对中断源的开放或屏蔽，每一个中断源是否被允许中断，是由内部的中断允许寄存器IE（地址为A8H）和XICON（地址为C0H）控制的。寄存器IE的格式如下：

IE：中断允许寄存器（可位寻址）

SFR name	Address	bit	B7	B6	B5	B4	B3	B2	B1	B0
IE	A8H	name	EA	-	ET2	ES	ET1	EX1	ET0	EX0

EA：CPU的总中断允许控制位，EA=1，CPU开放中断，EA=0，CPU屏蔽所有的中断申请。
EA的作用是使中断允许形成两级控制。即各中断源首先受EA控制；其次还受各中断源自己的中断允许控制位控制。

ET2：定时/计数器T2的溢出中断允许位。ET2=1，允许T2中断；ET2=0，禁止T2中断。

ES：串行口1中断允许位。ES=1，允许串行口1中断；ES=0，禁止串行口1中断。

ET1：定时/计数器T1的溢出中断允许位。ET1=1，允许T1中断；ET1=0，禁止T1中断。

EX1：外部中断1中断允许位。EX1=1，允许外部中断1中断；EX1=0，禁止外部中断1中断。

ET0：T0的溢出中断允许位。ET0=1，允许T0中断；ET0=0禁止T0中断。

EX0：外部中断0中断允许位。EX0=1，允许中断；EX0=0禁止中断。

寄存器XICON的格式如下：

XICON：辅助中断控制寄存器（可位寻址）

SFR name	Address	bit	B7	B6	B5	B4	B3	B2	B1	B0
XICON	C0H	name	PX3	EX3	IE3	IT3	PX2	EX2	IE2	IT2

PX3：置位表明外部中断3的优先级为高，优先级最终由[PXH3, PX3]=[0, 0]；[0, 1]；[1, 0]；[1, 1]来决定。

EX3：如被设置成1，允许外部中断3中断；如被清成0，禁止外部中断3中断。

IE3：外部中断3中断请求标志位，中断条件成立后，IE3=1,可由硬件自动清零。

IT3：当此位由软件置位时，外部中断3为下降沿触发中断；当此位由软件清零时，为低电平触发中断。

PX2：置位表明外部中断2的优先级为高，优先级最终由[PXH2, PX2]=[0, 0]；[0, 1]；[1, 0]；[1, 1]来决定。

EX2：如被设置成1，允许外部中断2中断；如被清成0，禁止外部中断2中断。

IE2：外部中断2中断请求标志位，中断条件成立后，IE2=1,可由硬件自动清零。

IT2：当此位由软件置位时，外部中断2为下降沿触发中断；当此位由软件清零时，为低电平触发中断。

STC89C51RC/RD+系列单片机复位以后，IE和XICON被清0，由用户程序置“1”或清“0”IE和XICON相应的位，实现允许或禁止各中断源的中断申请，若使某一个中断源允许中断必须同时使CPU开放中断。更新IE和XICON的内容可由位操作指令来实现（SETB BIT；CLR BIT），也可用字节操作指令实现（即MOV IE, #DATA, ANL IE, #DATA；ORL IE, #DATA；MOV IE, A等）。

2. 中断优先级控制寄存器IP/XICON和IPH

传统8051单片机具有两个中断优先级，即高优先级和低优先级，可以实现两级中断嵌套。STC89C51RC/RD+系列单片机通过设置新增加的特殊功能寄存器(IPH)中的相应位，可将中断优先级设置为4个中断优先级；如果只设置IP，那么中断优先级只有两级，与传统8051单片机两级中断优先级完全兼容。

一个正在执行的低优先级中断能被高优先级中断所中断，但不能被另一个低优先级中断所中断，一直执行到结束，遇到返回指令**RETI**，返回主程序后再执行一条指令才能响应新的中断申请。以上所述可归纳为下面两条基本规则：

1. 低优先级中断可被高优先级中断所中断，反之不能。
2. 任何一种中断(不管是高级还是低级)，一旦得到响应，不会再被它的同级中断所中断

STC12C5410AD系列单片机的片内各优先级控制寄存器的格式如下：

IPH: 中断优先级控制寄存器高(不可位寻址)

SFR name	Address	bit	B7	B6	B5	B4	B3	B2	B1	B0
IPH	B7H	name	-	-	PT2	PSH	PT1H	PX1H	PT0H	PX0H

XICON: 辅助中断控制寄存器(可位寻址)

SFR name	Address	bit	B7	B6	B5	B4	B3	B2	B1	B0
XICON	C0H	name	PX3	EX3	IE3	IT3	PX2	EX2	IE2	IT2

IP: 中断优先级控制寄存器低(可位寻址)

SFR name	Address	bit	B7	B6	B5	B4	B3	B2	B1	B0
IP	B8H	name	PX3	PX2	PT2	PS	PT1	PX1	PT0	PX0

PX3H, PX3: 外部中断3优先级控制位。

当PX3H=0且PX3=0时，外部中断3为最低优先级中断(优先级0)

当PX3H=0且PX3=1时，外部中断3为较低优先级中断(优先级1)

当PX3H=1且PX3=0时，外部中断3为较高优先级中断(优先级2)

当PX3H=1且PX3=1时，外部中断3为最高优先级中断(优先级3)

PX2H, PX2: 外部中断2优先级控制位。

当PX2H=0且PX2=0时，外部中断2为最低优先级中断(优先级0)

当PX2H=0且PX2=1时，外部中断2为较低优先级中断(优先级1)

当PX2H=1且PX2=0时，外部中断2为较高优先级中断(优先级2)

当PX2H=1且PX2=1时，外部中断2为最高优先级中断(优先级3)

PT2H, PT2: 定时器2中断优先级控制位。

当PT2H=0且PT2=0时, 定时器2中断为最低优先级中断(优先级0)

当PT2H=0且PT2=1时, 定时器2中断为较低优先级中断(优先级1)

当PT2H=1且PT2=0时, 定时器2中断为较高优先级中断(优先级2)

当PT2H=1且PT2=1时, 定时器2中断为最高优先级中断(优先级3)

PSH, PS: 串口1中断优先级控制位。

当PSH=0且PS=0时, 串口1中断为最低优先级中断(优先级0)

当PSH=0且PS=1时, 串口1中断为较低优先级中断(优先级1)

当PSH=1且PS=0时, 串口1中断为较高优先级中断(优先级2)

当PSH=1且PS=1时, 串口1中断为最高优先级中断(优先级3)

PT1H, PT1: 定时器1中断优先级控制位。

当PT1H=0且PT1=0时, 定时器1中断为最低优先级中断(优先级0)

当PT1H=0且PT1=1时, 定时器1中断为较低优先级中断(优先级1)

当PT1H=1且PT1=0时, 定时器1中断为较高优先级中断(优先级2)

当PT1H=1且PT1=1时, 定时器1中断为最高优先级中断(优先级3)

PX1H, PX1: 外部中断1优先级控制位。

当PX1H=0且PX1=0时, 外部中断1为最低优先级中断(优先级0)

当PX1H=0且PX1=1时, 外部中断1为较低优先级中断(优先级1)

当PX1H=1且PX1=0时, 外部中断1为较高优先级中断(优先级2)

当PX1H=1且PX1=1时, 外部中断1为最高优先级中断(优先级3)

PT0H, PT0: 定时器0中断优先级控制位。

当PT0H=0且PT0=0时, 定时器0中断为最低优先级中断(优先级0)

当PT0H=0且PT0=1时, 定时器0中断为较低优先级中断(优先级1)

当PT0H=1且PT0=0时, 定时器0中断为较高优先级中断(优先级2)

当PT0H=1且PT0=1时, 定时器0中断为最高优先级中断(优先级3)

PX0H, PX0: 外部中断0优先级控制位。

当PX0H=0且PX0=0时, 外部中断0为最低优先级中断(优先级0)

当PX0H=0且PX0=1时, 外部中断0为较低优先级中断(优先级1)

当PX0H=1且PX0=0时, 外部中断0为较高优先级中断(优先级2)

当PX0H=1且PX0=1时, 外部中断0为最高优先级中断(优先级3)

中断优先级控制寄存器IP和IPH的各位都由可用户程序置“1”和清“0”。但IP寄存器可位操作, 所以可用位操作指令或字节操作指令更新IP的内容。而IPH寄存器的内容只能用字节操作指令来更新。STC89C51RC/RD+系列单片机复位后IP和IPH均为00H, 各个中断源均为低优先级中断。

3. 定时器/计数器控制寄存器TCON

TCON为定时器/计数器T0、T1的控制寄存器，同时也锁存T0、T1溢出中断源和外部请求中断源等，TCON格式如下：

TCON：定时器/计数器中断控制寄存器（可位寻址）

SFR name	Address	bit	B7	B6	B5	B4	B3	B2	B1	B0
TCON	88H	name	TF1	TR1	TF0	TR0	IE1	IT1	IE0	IT0

TF1：T1溢出中断标志。T1被允许计数以后，从初值开始加1计数。当产生溢出时由硬件置“1”TF1，向CPU请求中断，一直保持到CPU响应中断时，才由硬件清“0”（也可由查询软件清“0”）。

TR1：定时器1的运行控制位。

TF0：T0溢出中断标志。T0被允许计数以后，从初值开始加1计数，当产生溢出时，由硬件置“1”TF0，向CPU请求中断，一直保持CPU响应该中断时，才由硬件清0（也可由查询软件清0）。

TR0：定时器0的运行控制位。

IE1：外部中断1请求源（ $\overline{\text{INT1}}/\text{P3.3}$ ）标志。IE1=1，外部中断向CPU请求中断，当CPU响应该中断时由硬件清“0”IE1。

IT1：外部中断1中断源类型选择位。IT1=0， $\overline{\text{INT1}}/\text{P3.3}$ 引脚上的低电平信号可触发外部中断1。IT1=1，外部中断1为下降沿触发方式。

IE0：外部中断0请求源（ $\overline{\text{INT0}}/\text{P3.2}$ ）标志。IE0=1外部中断0向CPU请求中断，当CPU响应外部中断时，由硬件清“0”IE0（边沿触发方式）。

IT0：外部中断0中断源类型选择位。IT0=0， $\overline{\text{INT0}}/\text{P3.2}$ 引脚上的低电平可触发外部中断0。IT0=1，外部中断0为下降沿触发方式。

4. 串行口控制寄存器SCON

SCON为串行口控制寄存器，SCON格式如下：

SCON：串行口控制寄存器（可位寻址）

SFR name	Address	bit	B7	B6	B5	B4	B3	B2	B1	B0
SCON	98H	name	SM0/FE	SM1	SM2	REN	TB8	RB8	TI	RI

RI：串行口1接收中断标志。若串行口1允许接收且以方式0工作，则每当接收到第8位数据时置1；若以方式1、2、3工作且SM2=0时，则每当接收到停止位的中间时置1；当串行口以方式2或方式3工作且SM2=1时，则仅当接收到的第9位数据RB8为1后，同时还要接收到停止位的中间时置1。RI为1表示串行口1正向CPU申请中断（接收中断），RI必须由用户的中断服务程序清零。

TI：串行口1发送中断标志。串行口1以方式0发送时，每当发送完8位数据，由硬件置1；若以方式1、方式2或方式3发送时，在发送停止位的开始时置1。TI=1表示串行口1正在向CPU申请中断（发送中断）。值得注意的是，CPU响应发送中断请求，转向执行中断服务程序时并不将TI清零，TI必须由用户在中断服务程序中清零。

SCON寄存器的其他位与中断无关，在此不作介绍。

3. 定时器/计数器2控制寄存器T2CON

TCON为定时器/计数器T0、T1的控制寄存器，同时也锁存T0、T1溢出中断源和外部请求中断源等，TCON格式如下：

TCON：定时器/计数器中断控制寄存器（可位寻址）

SFR name	Address	bit	B7	B6	B5	B4	B3	B2	B1	B0
T2CON	C8H	name	TF2	EXF2	RCLK	TCLK	EXEN2	TR2	$\overline{C/T2}$	$\overline{CP/RL2}$

TF2：定时器2 溢出标志。定时器2溢出时置位，必须由软件清除。当RCLK或TCLK=1 时，TF2 将不会置位

EXF2：定时器2外部标志。当EXEN2=1且T2EX的负跳变产生捕获或重装时，EXF2置位。定时器2 中断使能时，EXF2=1将使CPU从中断向量处执行定时器2 中断子程序。EXF2位必须用软件清零。在递增/递减计数器模式（DCEN=1）中，EXF2不会引起中断

RCLK：接收时钟标志。RCLK置位时，定时器2的溢出脉冲作为串行口模式1和模式3的接收时钟。RCLK=0时，将定时器1的溢出脉冲作为接收时钟

TCLK：发送时钟标志。TCLK置位时，定时器2的溢出脉冲作为串行口模式1和模式3的发送时钟。TCLK=0时，将定时器1的溢出脉冲作为发送时钟

EXEN2：定时器2外部使能标志。当其置位且定时器2未作为串行口时钟时，允许T2EX的负跳变产生捕获或重装。EXEN2=0 时，T2EX的跳变对定时器2无效

TR2：定时器2启动/停止控制位。置1时启动定时器

$\overline{C/T2}$ ：定时器/ 计数器选择。（定时器2）

0= 内部定时器（OSC/12 或OSC/6）

1 = 外部事件计数器（下降沿触发）

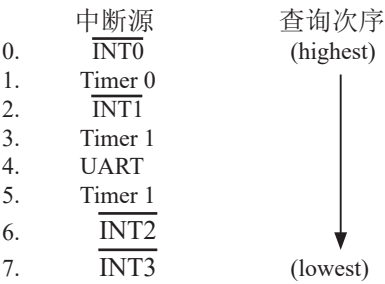
$\overline{CP/RL2}$ ：捕获/ 重装标志。置位：EXEN2=1 时，T2EX 的负跳变产生捕获。 清零：EXEN2=0 时，定时器2溢出或T2EX 的负跳变都可使定时器自动重装。当RCLK=1 或TCLK=1时，该位无效且定时器强制为溢出时自动重装

6.3 中断优先级

STC89C51RC/RD+系列单片机的所有的中断都具有4个中断优先级，对于这些中断请求源可编程为高优先级中断或低优先级中断，可实现两级中断服务程序嵌套。一个正在执行的低优先级中断能被高优先级中断所中断，但不能被另一个低优先级中断所中断，一直执行到结束，遇到返回指令RETI，返回主程序后再执行一条指令才能响应新的中断申请。以上所述可归纳为下面两条基本规则：

- 1. 低优先级中断可被高优先级中断所中断，反之不能。
- 2. 任何一种中断(不管是高级还是低级)，一旦得到响应，不会再被它的同级中断所中断

当同时收到几个同一优先级的中断要求时，哪一个要求得到服务，取决于内部的查询次序。这相当于在每个优先级内，还同时存在另一个辅助优先级结构，STC89C51RC/RD+系列单片机各中断优先查询次序如下：



如果使用C语言编程，中断查询次序号就是中断号，例如：

```
void    Int0_Routine(void)           interrupt 0;
void    Timer0_Routine(void)         interrupt 1;
void    Int1_Routine(void)           interrupt 2;
void    Timer1_Routine(void)         interrupt 3;
void    UART_Routine(void)           interrupt 4;
void    Timer2_Routine(void)         interrupt 5;
void    Int2_Routine(void)           interrupt 6;
void    Int3_Routine(void)           interrupt 7;
```

6.4 中断处理

当某中断产生而且被CPU响应，主程序被中断，接下来将执行如下操作：

1. 当前正被执行的指令全部执行完毕；
2. PC值被压入栈；
3. 现场保护；
4. 阻止同级别其他中断；
5. 将中断向量地址装载到程序计数器PC；
6. 执行相应的中断服务程序。

中断服务程序ISR完成和该中断相应的一些操作。ISR以RETI (中断返回)指令结束，将PC值从栈中取回，并恢复原来的中断设置，之后从主程序的断点处继续执行。

当某中断被响应时，被装载到程序计数器PC中的数值称为中断向量，是同该中断源相对应的中断服务程序的起始地址。各中断源服务程序的入口地址（即中断向量）为：

中断源	中断向量
External Interrupt 0	0003H
Timer 0	000BH
External Interrupt 1	0013H
Timer 1	001BH
UART	0023H
Timer 2	002BH
External Interrupt 2	0033H
External Interrupt 3	003BH

当“转去执行中断”时，引起中断的标志位将被硬件自动清零。由于中断向量入口地址位于程序存储器的开始部分，所以主程序的第1条指令通常为跳转指令，越过中断向量区(LJMP MAIN)。

注意: 不能用RET指令代替RETI指令

RET指令虽然也能控制PC返回到原来中断的地方，但RET指令没有清零中断优先级状态触发器的功能，中断控制系统会认为中断仍在进行，其后果是与此同级或低级的中断请求将不被响应。

若用户在中断服务程序中进行了入栈操作，则在RETI指令执行前应进行相应的出栈操作，即在中断服务程序中PUSH指令与POP指令必须成对使用，否则不能正确返回断点。

6.5 外部中断

外部中断0($\overline{\text{INT0}}$)、外部中断1($\overline{\text{INT1}}$)、外部中断2($\overline{\text{INT2}}$)和外部中断3($\overline{\text{INT3}}$)有两种触发方式，下降沿触发方式和低电平触发方式。

请求四个外部中断的标志位是位于寄存器TCON中的IE0/TCON.1、IE1/TCON.3、IE2/XICON.2和IE3/XICON.5。当外部中断服务程序被响应后，中断请求标志位IE0、IE1、IE2和IE3会自动被清0。TCON寄存器中的IT0/TCON.0、IT1/TCON.2、IT2/XICON.0和IT3/XICON.4决定了外部中断0、1、2和3是低电平触发方式还是下降沿触发方式。如果 $\text{IT}_x = 0(x = 0,1,2,3)$ ，那么系统在 $\text{INT}_x(x = 0,1,2,3)$ 脚探测到低电平后可产生外部中断。如果 $\text{IT}_x = 1(x = 0,1,2,3)$ ，那么系统在 $\text{INT}_x(x = 0,1,2,3)$ 脚探测下降沿后可产生外部中断。外部中断0($\overline{\text{INT0}}$)、外部中断1($\overline{\text{INT1}}$)、外部中断2($\overline{\text{INT2}}$)和外部中断3($\overline{\text{INT3}}$)还可以用于将单片机从掉电模式唤醒。

由于系统每个时钟对外部中断引脚采样1次，所以为了确保被检测到，输入信号应该至少维持2个系统时钟。如果外部中断是仅下降沿触发，要求必须在相应的引脚维持高电平至少1个系统时钟，而且低电平也要持续至少一个系统时钟，才能确保该下降沿被CPU检测到。同样，如果外部中断是低电平可触发，则要求必须在相应的引脚维持低电平至少2个系统时钟，这样才能确保CPU能够检测到该低电平信号。

6.6 中断测试程序

6.6.1 外部中断0($\overline{\text{INT0}}$)的测试程序(C程序及汇编程序)

1. 程序1——演示外部中断0的下降沿中断

C程序:

```
/*-----*/
/* --- STC MCU International Limited -----*/
/* --- 演示STC89xx系列单片机外部中断0(下降沿) -----*/
/* 如果要在程序中使用或在文章中引用该程序, -----*/
/* 请在程序中或文章中注明使用了宏晶科技的资料及程序 -----*/
/*-----*/

#include "reg51.h"

//External interrupt0 service routine
void exint0() interrupt 0                //INT0, interrupt 0 (location at 0003H)
{
    P0++;
}

void main()
{
    IT0 = 1;                //set INT0 interrupt type (1:Falling 0:Low level)
    EX0 = 1;                //enable INT0 interrupt
    EA = 1;                 //open global interrupt switch

    while (1);
}
```

汇编程序：

```
/*-----*/
/* --- STC MCU International Limited -----*/
/* --- 演示STC89xx系列单片机外部中断0(下降沿) -----*/
/* 如果要在程序中使用或在文章中引用该程序， -----*/
/* 请在程序中或文章中注明使用了宏晶科技的资料及程序 -----*/
/*-----*/

;-----
;interrupt vector table

        ORG     0000H
        LJMP    MAIN

        ORG     0003H                ;INT0, interrupt 0 (location at 0003H)
        LJMP    EXINT0

;-----

        ORG     0100H
MAIN:
        MOV     SP,      #7FH                ;initial SP
        SETB    IT0                ;set INT0 interrupt type (1:Falling 0:Low level)
        SETB    EX0                ;enable INT0 interrupt
        SETB    EA                ;open global interrupt switch
        SJMP    $

;-----
;External interrupt0 service routine

EXINT0:
        CPL     P0.0
        RETI

;-----

        END
```

2. 程序2——演示外部中断0的下降沿中断唤醒掉电模式

C程序：

```

/*-----*/
/* --- STC MCU International Limited -----*/
/* --- 演示STC89xx系列单片机外部中断0(下降沿)唤醒掉电模式 ----*/
/* 如果要在程序中使用或在文章中引用该程序， -----*/
/* 请在程序中或文章中注明使用了宏晶科技的资料及程序 -----*/
/*-----*/

#include "reg51.h"
#include "intrins.h"

//External interrupt0 service routine
void exint0( )      interrupt 0           //INT0, interrupt 0 (location at 0003H)
{
}

void main()
{
    IT0 = 1;           //set INT0 interrupt type (1:Falling 0:Low level)
    EX0 = 1;           //enable INT0 interrupt
    EA = 1;            //open global interrupt switch

    while (1)
    {
        INT0 = 1;      //ready read INT0 port
        while (!INT0); //check INT0
        _nop_();
        _nop_();
        PCON = 0x02;    //MCU power down
        _nop_();
        _nop_();
        P1++;
    }
}

```

汇编程序：

```
/*-----*/
/* --- STC MCU International Limited -----*/
/* --- 演示STC89xx系列单片机外部中断0(下降沿)唤醒掉电模式 ----*/
/* 如果要在程序中使用或在文章中引用该程序， -----*/
/* 请在程序中或文章中注明使用了宏晶科技的资料及程序 -----*/
/*-----*/

;-----
;interrupt vector table

        ORG     0000H
        LJMP    MAIN

        ORG     0003H                ;INT0, interrupt 0 (location at 0003H)
        LJMP    EXINT0

;-----

        ORG     0100H
MAIN:
        MOV     SP,      #7FH        ;initial SP
        SETB    IT0              ;set INT0 interrupt type (1:Falling 0:Low level)
        SETB    EX0              ;enable INT0 interrupt
        SETB    EA                ;open global interrupt switch
LOOP:
        SETB    INT0              ;ready read INT0 port
        JNB     INT0,    $          ;check INT0
        NOP
        NOP
        MOV     PCON,    #02H        ;MCU power down
        NOP
        NOP
        CPL     P1.0
        SJMP    LOOP

;-----
;External interrupt0 service routine
EXINT0:
        RETI

;-----

        END
```

6.6.2 外部中断1($\overline{\text{INT1}}$)的测试程序(C程序及汇编程序)

1. 程序1——演示外部中断1的下降沿中断

C程序:

```
/*-----*/
/* --- STC MCU International Limited -----*/
/* --- 演示STC89xx系列单片机外部中断1(下降沿) -----*/
/* 如果要在程序中使用或在文章中引用该程序, -----*/
/* 请在程序或文章中注明使用了宏晶科技的资料及程序 -----*/
/*-----*/

#include "reg51.h"

//External interrupt1 service routine
void exint1() interrupt 2           //INT1, interrupt 2 (location at 0013H)
{
    P0++;
}

void main()
{
    IT1 = 1;           //set INT1 interrupt type (1:Falling only 0:Low level)
    EX1 = 1;           //enable INT1 interrupt
    EA = 1;            //open global interrupt switch

    while (1);
}
```

汇编程序:

```
/*-----*/
/* --- STC MCU International Limited -----*/
/* --- 演示STC89xx系列单片机外部中断1(下降沿) -----*/
/* 如果要在程序中使用或在文章中引用该程序, -----*/
/* 请在程序中或文章中注明使用了宏晶科技的资料及程序 -----*/
/*-----*/

;-----
;interrupt vector table

        ORG     0000H
        LJMP    MAIN

        ORG     0013H                ;INT1, interrupt 2 (location at 0013H)
        LJMP    EXINT1

;-----

        ORG     0100H
MAIN:
        MOV     SP,      #7FH                ;initial SP
        SETB    IT1                ;set INT1 interrupt type (1:Falling 0:Low level)
        SETB    EX1                ;enable INT1 interrupt
        SETB    EA                ;open global interrupt switch
        SJMP    $

;-----
;External interrupt1 service routine

EXINT1:
        CPL     P0.0
        RETI

;-----

        END
```

2. 程序2——演示外部中断1的下降沿中断唤醒掉电模式

C程序：

```

/*-----*/
/* --- STC MCU International Limited -----*/
/* --- 演示STC89xx系列单片机外部中断1(下降沿)唤醒掉电模式 -----*/
/* 如果要在程序中使用或在文章中引用该程序， -----*/
/* 请在程序中或文章中注明使用了宏晶科技的资料及程序 -----*/
/*-----*/

#include "reg51.h"
#include "intrins.h"

//External interrupt0 service routine
void exint1( ) interrupt 2                //INT1, interrupt 2 (location at 0013H)
{
}

void main()
{
    IT1 = 1;                            //set INT1 interrupt type (1:Falling 0:Low level)
    EX1 = 1;                            //enable INT1 interrupt
    EA = 1;                             //open global interrupt switch

    while (1)
    {
        INT1 = 1;                       //ready read INT1 port
        while (!INT1);                  //check INT1
        _nop_();
        _nop_();
        PCON = 0x02;                    //MCU power down
        _nop_();
        _nop_();
        P1++;
    }
}

```

汇编程序:

```
/*-----*/
/* --- STC MCU International Limited -----*/
/* --- 演示STC89xx系列单片机外部中断1(下降沿)唤醒掉电模式 ---*/
/* 如果要在程序中使用或在文章中引用该程序, -----*/
/* 请在程序中或文章中注明使用了宏晶科技的资料及程序 -----*/
/*-----*/

;-----
;interrupt vector table

        ORG     0000H
        LJMP    MAIN

        ORG     0013H                ;INT1, interrupt 2 (location at 0013H)
        LJMP    EXINT1

;-----

        ORG     0100H
MAIN:
        MOV     SP,      #7FH                ;initial SP
        SETB    IT1                ;set INT1 interrupt type (1:Falling 0:Low level)
        SETB    EX1                ;enable INT1 interrupt
        SETB    EA                ;open global interrupt switch
LOOP:
        SETB    INT1                ;ready read INT1 port
        JNB     INT1    ,$            ;check INT1
        NOP
        NOP
        MOV     PCON,    #02H                ;MCU power down
        NOP
        NOP
        CPL     P1.0
        SJMP    LOOP

;-----
;External interrupt1 service routine
EXINT1:
        RETI

;-----
        END
```

6.6.3 外部中断2($\overline{\text{INT2}}$)的测试程序(C程序及汇编程序)

1. 程序1——演示外部中断2的下降沿中断

C程序:

```

/*-----*/
/* --- STC MCU International Limited -----*/
/* --- 演示STC89xx系列单片机外部中断2(下降沿) -----*/
/* 如果要在程序中使用或在文章中引用该程序, -----*/
/* 请在程序或文章中注明使用了宏晶科技的资料及程序 -----*/
/*-----*/

#include "reg51.h"

sfr P4 = 0xe8;           //for 90C58AD series, location at 0C0H
sbit INT2 = P4^3;
sbit INT3 = P4^2;

sfr XICON = 0xc0;        //for 90C58AD series, location at 0E8H
sbit PX3 = XICON^7;
sbit EX3 = XICON^6;
sbit IE3 = XICON^5;
sbit IT3 = XICON^4;
sbit PX2 = XICON^3;
sbit EX2 = XICON^2;
sbit IE2 = XICON^1;
sbit IT2 = XICON^0;

//External interrupt2 service routine
void exint2() interrupt 6 //INT2, interrupt 6 (location at 0033H)
{
    P0++;
}

void main()
{
    IT2 = 1;           //set INT2 interrupt type (1:Falling only 0:Low level)
    EX2 = 1;           //enable INT2 interrupt
    EA = 1;            //open global interrupt switch

    while (1);
}

```

汇编程序：

```
/*-----*/
/* --- STC MCU International Limited -----*/
/* --- 演示STC89xx系列单片机外部中断2(下降沿) -----*/
/* 如果要在程序中使用或在文章中引用该程序， -----*/
/* 请在程序中或文章中注明使用了宏晶科技的资料及程序 -----*/
/*-----*/
P4      EQU      0E8H                      ;for 90C58AD series, location at 0C0H
INT2     BIT      P4.3
INT3     BIT      P4.2

XICON    EQU      0C0H                      ;for 90C58AD series, location at 0E8H
PX3      BIT      XICON.7
EX3      BIT      XICON.6
IE3      BIT      XICON.5
IT3      BIT      XICON.4
PX2      BIT      XICON.3
EX2      BIT      XICON.2
IE2      BIT      XICON.1
IT2      BIT      XICON.0
;-----
;interrupt vector table

      ORG      0000H
      LJMP     MAIN

      ORG      0033H                      ;INT2, interrupt 6 (location at 0033H)
      LJMP     EXINT2
;-----
      ORG      0100H
MAIN:
      MOV      SP,      #7FH              ;initial SP
      SETB     IT2              ;set INT2 interrupt type (1:Falling 0:Low level)
      SETB     EX2              ;enable INT2 interrupt
      SETB     EA              ;open global interrupt switch
      SJMP     $
;-----
;External interrupt2 service routine
EXINT2:
      CPL      P0.0
      RETI
;-----
      END
```


2. 程序2——演示外部中断2的下降沿中断唤醒掉电模式

C程序：

```

/*-----*/
/* --- STC MCU International Limited -----*/
/* --- 演示STC89xx系列单片机外部中断2(下降沿)唤醒掉电模式 -----*/
/* 如果要在程序中使用或在文章中引用该程序, -----*/
/* 请在程序中或文章中注明使用了宏晶科技的资料及程序 -----*/
/*-----*/

#include "reg51.h"
#include "intrins.h"

sfr P4 = 0xe8;          //for 90C58AD series, location at 0C0H
sbit INT2 = P4^3;
sbit INT3 = P4^2;

sfr XICON = 0xc0;       //for 90C58AD series, location at 0E8H
sbit PX3 = XICON^7;
sbit EX3 = XICON^6;
sbit IE3 = XICON^5;
sbit IT3 = XICON^4;
sbit PX2 = XICON^3;
sbit EX2 = XICON^2;
sbit IE2 = XICON^1;
sbit IT2 = XICON^0;

//External interrupt2 service routine
void exint2() interrupt 6    //INT2, interrupt 6 (location at 0033H)
{
}

void main()
{
    IT2 = 1;                //set INT2 interrupt type (1:Falling 0:Low level)
    EX2 = 1;                //enable INT2 interrupt
    EA = 1;                 //open global interrupt switch
}

```

```
while (1)
{
    INT2 = 1;           //ready read INT2 port
    while (!INT2);      //check INT2
    _nop_();
    _nop_();
    PCON = 0x02;        //MCU power down
    _nop_();
    _nop_();
    P1++;
}
}
```

汇编程序：

```
/*-----*/
/* --- STC MCU International Limited -----*/
/* --- 演示STC89xx系列单片机外部中断2(下降沿)唤醒掉电模式 ----*/
/* 如果要在程序中使用或在文章中引用该程序， -----*/
/* 请在程序中或文章中注明使用了宏晶科技的资料及程序 -----*/
/*-----*/

P4      EQU      0E8H           ;for 90C58AD series, location at 0C0H
INT2     BIT      P4.3
INT3     BIT      P4.2

XICON    EQU      0C0H          ;for 90C58AD series, location at 0E8H
PX3      BIT      XICON.7
EX3      BIT      XICON.6
IE3      BIT      XICON.5
IT3      BIT      XICON.4
PX2      BIT      XICON.3
EX2      BIT      XICON.2
IE2      BIT      XICON.1
IT2      BIT      XICON.0

;-----
;interrupt vector table

        ORG      0000H
        LJMP     MAIN
```

```
        ORG    0033H                ;INT2, interrupt 6 (location at 0033H)
        LJMP   EXINT2

;-----

        ORG    0100H
MAIN:
        MOV    SP,    #7FH          ;initial SP
        SETB   IT2                ;set INT2 interrupt type (1:Falling 0:Low level)
        SETB   EX2                ;enable INT2 interrupt
        SETB   EA                ;open global interrupt switch
LOOP:
        SETB   INT2                ;ready read INT2 port
        JNB    INT2,    $           ;check INT2
        NOP
        NOP
        MOV    PCON,    #02H        ;MCU power down
        NOP
        NOP
        CPL    P1.0
        SJMP   LOOP

;-----
;External interrupt2 service routine
EXINT2:
        RETI

;-----

        END
```

6.6.3 外部中断3($\overline{\text{INT3}}$)的测试程序(C程序及汇编程序)

1. 程序1——演示外部中断3的下降沿中断

C程序:

```
/*-----*/
/* --- STC MCU International Limited -----*/
/* --- 演示STC89xx系列单片机外部中断3(下降沿) -----*/
/* 如果要在程序中使用或在文章中引用该程序， -----*/
/* 请在程序中或文章中注明使用了宏晶科技的资料及程序 -----*/
/*-----*/

#include "reg51.h"

sfr P4    = 0xe8;                //for 90C58AD series, location at 0C0H
sbit INT2 = P4^3;
sbit INT3 = P4^2;

sfr XICON = 0xc0;                //for 90C58AD series, location at 0E8H
sbit PX3  = XICON^7;
sbit EX3  = XICON^6;
sbit IE3  = XICON^5;
sbit IT3  = XICON^4;
sbit PX2  = XICON^3;
sbit EX2  = XICON^2;
sbit IE2  = XICON^1;
sbit IT2  = XICON^0;

//External interrupt3 service routine
void exint3() interrupt 7        //INT3, interrupt 7 (location at 003BH)
{
    P0++;
}

void main()
{
    IT3    = 1;                //set INT3 interrupt type (1:Falling only 0:Low level)
    EX3    = 1;                //enable INT3 interrupt
    EA     = 1;                //open global interrupt switch

    while (1);
}
```

汇编程序：

```

/*-----*/
/* --- STC MCU International Limited -----*/
/* --- 演示STC89xx系列单片机外部中断3(下降沿) -----*/
/* 如果要在程序中使用或在文章中引用该程序， -----*/
/* 请在程序中或文章中注明使用了宏晶科技的资料及程序 -----*/
/*-----*/

P4      EQU    0E8H          ;for 90C58AD series, location at 0C0H
INT2     BIT    P4.3
INT3     BIT    P4.2

XICON    EQU    0C0H          ;for 90C58AD series, location at 0E8H
PX3      BIT    XICON.7
EX3      BIT    XICON.6
IE3      BIT    XICON.5
IT3      BIT    XICON.4
PX2      BIT    XICON.3
EX2      BIT    XICON.2
IE2      BIT    XICON.1
IT2      BIT    XICON.0
;-----
;interrupt vector table

        ORG     0000H
        LJMP    MAIN

        ORG     003BH          ;INT3, interrupt 7 (location at 003BH)
        LJMP    EXINT3
;-----

        ORG     0100H
MAIN:
        MOV     SP,#7FH          ;initial SP
        SETB    IT3              ;set INT3 interrupt type (1:Falling 0:Low level)
        SETB    EX3              ;enable INT3 interrupt
        SETB    EA              ;open global interrupt switch
        SJMP    $
;-----
;External interrupt3 service routine
EXINT3:
        CPL     P0.0
        RETI
;-----
        END

```

2. 程序2——演示外部中断3的下降沿中断唤醒掉电模式

C程序:

```
/*-----*/
/* --- STC MCU International Limited -----*/
/* --- 演示STC89xx系列单片机外部中断3(下降沿)唤醒掉电模式 ----*/
/* 如果要在程序中使用或在文章中引用该程序, -----*/
/* 请在程序中或文章中注明使用了宏晶科技的资料及程序 -----*/
/*-----*/

#include "reg51.h"
#include "intrins.h"

sfr P4 = 0xe8;          //for 90C58AD series, location at 0C0H
sbit INT2 = P4^3;
sbit INT3 = P4^2;

sfr XICON = 0xc0;       //for 90C58AD series, location at 0E8H
sbit PX3 = XICON^7;
sbit EX3 = XICON^6;
sbit IE3 = XICON^5;
sbit IT3 = XICON^4;
sbit PX2 = XICON^3;
sbit EX2 = XICON^2;
sbit IE2 = XICON^1;
sbit IT2 = XICON^0;

//External interrupt3 service routine
void exint3() interrupt 7 //INT3, interrupt 7 (location at 003BH)
{
}

void main()
{
    IT3 = 1;          //set INT3 interrupt type (1:Falling 0:Low level)
    EX3 = 1;          //enable INT3 interrupt
    EA = 1;           //open global interrupt switch
```

```

while (1)
{
    INT3 = 1;                                //ready read INT3 port

    while (!INT3);                          //check INT3
    _nop_();
    _nop_();
    PCON = 0x02;                            //MCU power down
    _nop_();
    _nop_();
    P1++;
}
}

```

汇编程序：

```

/*-----*/
/* --- STC MCU International Limited -----*/
/* --- 演示STC89xx系列单片机外部中断3(下降沿)唤醒掉电模式 ----*/
/* 如果要在程序中使用或在文章中引用该程序， -----*/
/* 请在程序或文章中注明使用了宏晶科技的资料及程序 -----*/
/*-----*/

P4      EQU    0E8H      ;for 90C58AD series, location at 0C0H
INT2     BIT    P4.3
INT3     BIT    P4.2

XICON    EQU    0C0H      ;for 90C58AD series, location at 0E8H
PX3      BIT    XICON.7
EX3      BIT    XICON.6
IE3      BIT    XICON.5
IT3      BIT    XICON.4
PX2      BIT    XICON.3
EX2      BIT    XICON.2
IE2      BIT    XICON.1
IT2      BIT    XICON.0

;-----
;interrupt vector table

ORG      0000H
LJMP     MAIN

```

```
        ORG    003BH                ;INT3, interrupt 7 (location at 003BH)
        LJMP   EXINT3

;-----

        ORG    0100H
MAIN:
        MOV    SP,    #7FH          ;initial SP
        SETB   IT3                ;set INT3 interrupt type (1:Falling 0:Low level)
        SETB   EX3                ;enable INT3 interrupt
        SETB   EA                ;open global interrupt switch
LOOP:
        SETB   INT3                ;ready read INT3 port
        JNB    INT3,    $           ;check INT3
        NOP
        NOP
        MOV    PCON,#02H          ;MCU power down
        NOP
        NOP
        CPL    P1.0
        SJMP   LOOP

;-----
;External interrupt3 service routine

EXINT3:
        RETI

;-----

        END
```


第7章 定时器/计数器

7.1 定时器/计数器0/1

STC89C51RC/RD+系列单片机的定时器0和定时器1，与传统8051的定时器完全兼容，当在定时器1做波特率发生器时，定时器0可以当两个8位定时器用。

STC89C51RC/RD+系列单片机内部设置的两个16位定时器/计数器T0和T1都具有计数方式和定时方式两种工作方式。对每个定时器/计数器(T0和T1)，在特殊功能寄存器TMOD中都有一控制位— $C/\bar{T}$ 来选择T0或T1为定时器还是计数器。定时器/计数器的核心部件是一个加法(也有减法)的计数器，其本质是对脉冲进行计数。只是计数脉冲来源不同：如果计数脉冲来自系统时钟，则为定时方式，此时定时器/计数器每12个时钟或者每6个时钟得到一个计数脉冲，计数值加1；如果计数脉冲来自单片机外部引脚(T0为P3.4, T1为P3.5)，则为计数方式，每来一个脉冲加1。

当定时器/计数器工作在定时模式时，可在烧录用户程序时在STC-ISP编程器中设置(如下图所示)是系统时钟/12还是系统时钟/6后让T0和T1进行计数。当定时器/计数器工作在计数模式时，对外部脉冲计数不分频。

Step4/步骤4: 设置本框和右下方‘选项’中的选项
Double speed / 双倍速: ☐ 6T/双倍速 ☒ 12T/单倍速

定时器/计数器0有4种工作模式：模式0(13位定时器/计数器)，模式1(16位定时器/计数器模式)，模式2(8位自动重装模式)，模式3(两个8位定时器/计数器)。定时器/计数器1除模式3外，其他工作模式与定时器/计数器0相同，T1在模式3时无效，停止计数。

7.1.1 定时器/计数器0和1的相关寄存器

符号	描述	地址	位地址及其符号								复位值
			MSB				LSB				
TCON	定时器控制寄存器	88H	TF1	TR1	TF0	TR0	IE1	IT1	IE0	IT0	0000 0000B
TMOD	定时器模式寄存器	89H	GATE	C/ $\overline{T}$	M1	M0	GATE	C/ $\overline{T}$	M1	M0	0000 0000B
TL0	Timer Low 0	8AH									0000 0000B
TL1	Timer Low 1	8BH									0000 0000B
TH0	Timer High 0	8CH									0000 0000B
TH1	Timer High 1	8DH									0000 0000B

1. 定时器/计数器控制寄存器TCON

TCON为定时器/计数器T0、T1的控制寄存器，同时也锁存T0、T1溢出中断源和外部请求中断源等，TCON格式如下：

TCON：定时器/计数器中断控制寄存器（可位寻址）

SFR name	Address	bit	B7	B6	B5	B4	B3	B2	B1	B0
TCON	88H	name	TF1	TR1	TF0	TR0	IE1	IT1	IE0	IT0

TF1：定时器/计数器T1溢出标志。T1被允许计数以后，从初值开始加1计数。当最高位产生溢出时由硬件置“1”TF1，向CPU请求中断，一直保持到CPU响应中断时，才由硬件清“0”TF1（TF1也可由程序查询清“0”）。

TR1：定时器T1的运行控制位。该位由软件置位和清零。当GATE（TMOD.7）=0，TR1=1时就允许T1开始计数，TR1=0时禁止T1计数。当GATE（TMOD.7）=1，TR1=1且 $\overline{\text{INT1}}$ 输入高电平时，才允许T1计数。

TF0：定时器/计数器T0溢出中断标志。T0被允许计数以后，从初值开始加1计数，当最高位产生溢出时，由硬件置“1”TF0，向CPU请求中断，一直保持CPU响应该中断时，才由硬件清“0”TF0（TF0也可由程序查询清“0”）。

TR0：定时器T0的运行控制位。该位由软件置位和清零。当GATE（TMOD.3）=0，TR0=1时就允许T0开始计数，TR0=0时禁止T0计数。当GATE（TMOD.3）=1，TR1=0且 $\overline{\text{INT0}}$ 输入高电平时，才允许T0计数。

IE1：外部中断1请求源（ $\overline{\text{INT1}}$ /P3.3）标志。IE1=1，外部中断向CPU请求中断，当CPU响应该中断时由硬件清“0”IE1。

IT1：外部中断1触发方式控制位。IT1=0时，外部中断1为低电平触发方式，当 $\overline{\text{INT1}}$ （P3.3）输入低电平时，置位IE1。采用低电平触发方式时，外部中断源（输入到 $\overline{\text{INT1}}$ ）必须保持低电平有效，直到该中断被CPU响应，同时在该中断服务程序执行完之前，外部中断源必须被清除（P3.3要变高），否则将产生另一次中断。当IT1=1时，则外部中断1（ $\overline{\text{INT1}}$ ）端口由“1”→“0”下降沿跳变，激活中断请求标志位IE1，向主机请求中断处理。

IE0：外部中断0请求源（ $\overline{\text{INT0}}$ /P3.2）标志。IE0=1外部中断0向CPU请求中断，当CPU响应外部中断时，由硬件清“0”IE0（边沿触发方式）。

IT0：外部中断0触发方式控制位。IT0=0时，外部中断0为低电平触发方式，当 $\overline{\text{INT0}}$ （P3.2）输入低电平时，置位IE0。采用低电平触发方式时，外部中断源（输入到 $\overline{\text{INT0}}$ ）必须保持低电平有效，直到该中断被CPU响应，同时在该中断服务程序执行完之前，外部中断源必须被清除（P3.2要变高），否则将产生另一次中断。当IT0=1时，则外部中断0（ $\overline{\text{INT0}}$ ）端口由“1”→“0”下降沿跳变，激活中断请求标志位IE1，向主机请求中断处理。

2. 定时器/计数器工作模式寄存器TMOD

定时和计数功能由特殊功能寄存器TMOD的控制位C/T进行选择，TMOD寄存器的各位信息如下表所列。可以看出，2个定时/计数器有4种操作模式，通过TMOD的M1和M0选择。2个定时/计数器的模式0、1和2都相同，模式3不同，各模式下的功能如下所述。

寄存器TMOD各位的功能描述

TMOD	地址：89H	复位值：00H																								
不可位寻址																										
<table><tr><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td></tr><tr><td>GATE</td><td>C/$\overline{T}$</td><td>M1</td><td>M0</td><td>GATE</td><td>C/$\overline{T}$</td><td>M1</td><td>M0</td></tr><tr><td colspan="4">定时器1</td><td colspan="4">定时器0</td></tr></table>			7	6	5	4	3	2	1	0	GATE	C/ $\overline{T}$	M1	M0	GATE	C/ $\overline{T}$	M1	M0	定时器1				定时器0			
7	6	5	4	3	2	1	0																			
GATE	C/ $\overline{T}$	M1	M0	GATE	C/ $\overline{T}$	M1	M0																			
定时器1				定时器0																						
位	符号	功能																								
TMOD.7/	GATE	TMOD. 7控制定时器1, 置1时只有在在 $\overline{\text{INT1}}$ 脚为高及TR1控制位置1时才可打开定时器/计数器1。																								
TMOD.3/	GATE	TMOD. 3控制定时器0, 置1时只有在在 $\overline{\text{INT0}}$ 脚为高及TR0控制位置1时才可打开定时器/计数器0。																								
TMOD.6/	C/ $\overline{T}$	TMOD. 6控制定时器1用作定时器或计数器，清零则用作定时器（从内部系统时钟输入），置1用作计数器（从T1/P3. 5脚输入）																								
TMOD.2/	C/ $\overline{T}$	TMOD. 2控制定时器0用作定时器或计数器，清零则用作定时器（从内部系统时钟输入），置1用作计数器（从T0/P3. 4脚输入）																								
TMOD.5/TMOD.4	M1、M0	定时器定时器/计数器1模式选择																								
	0 0	13位定时器/计数器，兼容8048定时模式，TL1只用低5位参与分频，TH1整个8位全用。																								
	0 1	16位定时器/计数器，TL1、TH1全用																								
	1 0	8位自动重装载定时器, 当溢出时将TH1存放的值自动重装入TL1.																								
	1 1	定时器/计数器1此时无效（停止计数）。																								
TMOD.1/TMOD.0	M1、M0	定时器/计数器0模式选择																								
	0 0	13位定时器/计数器，兼容8048定时模式，TL0只用低5位参与分频，TH0整个8位全用。																								
	0 1	16位定时器/计数器，TL0、TH0全用																								
	1 0	8位自动重装载定时器，当溢出时将TH0存放的值自动重装入TL0																								
	1 1	定时器0此时作为双8位定时器/计数器。TL0作为一个8位定时器/计数器，通过标准定时器0的控制位控制。TH0仅作为一个8位定时器, 由定时器1的控制位控制。																								

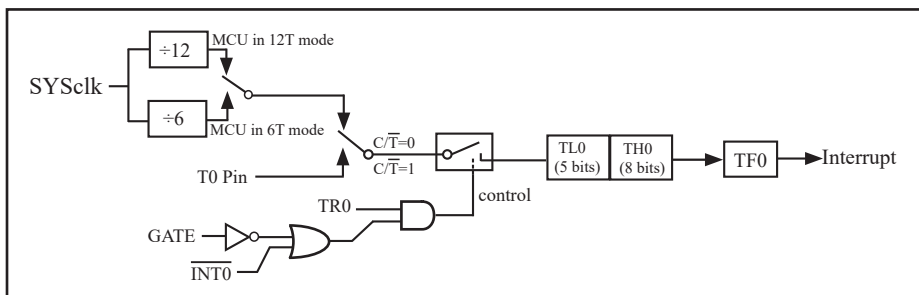
7.1.2 定时器/计数器0工作模式(与传统8051单片机兼容)

通过对寄存器TMOD中的M1(TMOD.1)、M0(TMOD.0)的设置,定时器/计数器0有4种不同的工作模式

7.1.2.1 模式0(13位定时器/计数器)

将定时器设置成模式0时类似8048定时器,即8位计数器带32分频的预分频器。下图所示为定时器/计数器的模式0工作方式。此模式下,定时器0配置为13位的计数器,由TL0的低5位和TH0的8位所构成。TL0低5位溢出向TH0进位,TH0计数溢出置位TCON中的溢出标志位TF0。GATE(TMOD.3)=0 时,如TR0=1,则定时器计数。GATE=1 时,允许由外部输入 $\overline{INT1}$ 控制定时器1, $\overline{INT0}$ 控制定时器0,这样可实现脉宽测量。TR0为TCON寄存器内的控制位,TCON寄存器各位的具体功能描述见TCON寄存器各位的具体功能描述表。

在模式0下定时器/计数器0作为13位定时器/计数器,如下图所示。



定时器/计数器0的模式0: 13位定时器/计数器

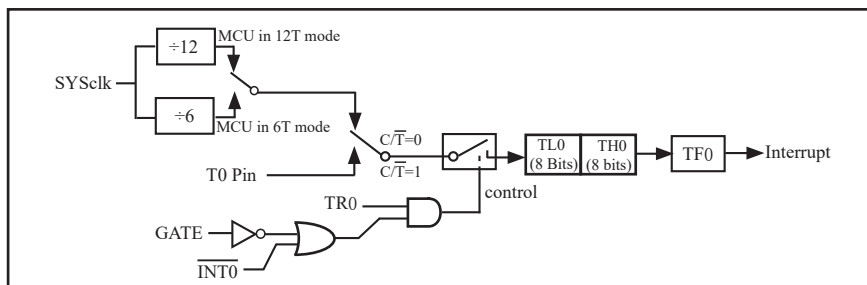
当 $C/\overline{T}=0$ 时,多路开关连接到系统时钟的分频输出,T0对时钟周期计数,T0工作在定时方式。当 $C/\overline{T}=1$ 时,多路开关连接到外部脉冲输入P3.4/T0,即T0工作在计数方式。

STC89C51RC/RD+系列单片机的定时器有两种计数速率:一种是12T模式,每12个时钟加1,与传统8051单片机相同;另外一种6T模式,每6个时钟加1,速度是传统8051单片机的2倍。T0的速率在烧录用户程序时在STC-ISP编程器中设置。

该模式下的13位寄存器包含TH0全部8个位及TL0的低5位。TL0的高3位不定,可将其忽略。置位运行标志(TR0)不能清零此寄存器。模式0的操作对于定时器0及定时器1都是相同的。2个不同的GATE位(TMOD.7和TMOD.3)分别分配给定时器1及定时器0。

7.1.2.2 模式1(16位定时器/计数器)及其测试程序(C程序及汇编程序)

模式1除了使用了TH0及TL0全部16位外，其他与模式0完全相同。即此模式下定时器/计数器0作为16位定时器/计数器，如下图所示。



定时器/计数器0的模式 1: 16位定时器/计数器

此模式下，定时器配置为16位定时器/计数器，由TL0的8位和TH0的8位所构成。TL0的8位溢出向TH0进位，TH0计数溢出置位TCON中的溢出标志位TF0。

当GATE=0 (TMOD.3)时，如TR0=1，则定时器计数。GATE=1时，允许由外部输入INT0控制定时器0，这样可实现脉宽测量。TR0为TCON寄存器内的控制位，TCON寄存器各位的具体功能描述见上节TCON寄存器的介绍。

当 $C/\overline{T}=0$ 时，多路开关连接到系统时钟的分频输出，T0对时钟周期计数，T0工作在定时方式。当 $C/\overline{T}=1$ 时，多路开关连接到外部脉冲输入P3.4/T0，即T0工作在计数方式。

STC89C51RC/RD+系列单片机的定时器有两种计数速率：一种是12T模式，每12个时钟加1，与传统8051单片机相同；另外一种为6T模式，每6个时钟加1，速度是传统8051单片机的2倍。T0的速率在烧录用户程序时在STC-ISP编程器中设置。

定时器0工作在16位定时器/计数器模式的测试程序

1. C程序:

```
/*-----*/
/* --- STC MCU International Limited -----*/
/* --- 演示STC89xx系列单片机定时器0的16位定时器/计数器模式 ---*/
/* 如果要在程序中使用或在文章中引用该程序, -----*/
/* 请在程序或文章中注明使用了宏晶科技的资料及程序 -----*/
/*-----*/
#include "reg51.h"

typedef unsigned char BYTE;
typedef unsigned int WORD;

//-----

/* define constants */
#define FOSC 18432000L

#define T1MS (65536-FOSC/12/1000) //1ms timer calculation method in 12T mode

/* define SFR */
sbit TEST_LED = P1^0; //work LED, flash once per second

/* define variables */
WORD count; //1000 times counter

//-----

/* Timer0 interrupt routine */
void tm0_isr() interrupt 1 using 1
{
    TL0 = T1MS; //reload timer0 low byte
    TH0 = T1MS >> 8; //reload timer0 high byte
    if (count-- == 0) //1ms * 1000 -> 1s
    {
        count = 1000; //reset counter
        TEST_LED = ! TEST_LED; //work LED flash
    }
}

//-----
```

```

/* main program */
void main()
{
    TMOD = 0x01;           //set timer0 as mode1 (16-bit)
    TL0 = T1MS;            //initial timer0 low byte
    TH0 = T1MS >> 8;       //initial timer0 high byte
    TR0 = 1;               //timer0 start running
    ET0 = 1;               //enable timer0 interrupt
    EA = 1;                //open global interrupt switch
    count = 0;             //initial counter

    while (1);             //loop
}

```

2. 汇编程序：

```

/*-----*/
/* --- STC MCU International Limited -----*/
/* --- 演示STC89xx系列单片机定时器0的16位定时器/计数器模式 ---*/
/* 如果要在程序中使用或在文章中引用该程序， -----*/
/* 请在程序或文章中注明使用了宏晶科技的资料及程序 -----*/
/*-----*/
; /* define constants */
T1MS    EQU    0FA00H           ;1ms timer calculation method in 12T mode is (65536-18432000/12/1000)

; /* define SFR */
TEST_LED BIT P1.0              ;work LED, flash once per second

; /* define variables */
COUNT DATA 20H               ;1000 times counter (2 bytes)

;-----

    ORG    0000H
    LJMP   MAIN
    ORG    000BH
    LJMP   TM0_ISR

;-----

```

;/* main program */

MAIN:

```
    MOV    TMOD,#01H           ;set timer0 as mode1 (16-bit)
    MOV    TL0,#LOW T1MS       ;initial timer0 low byte
    MOV    TH0,#HIGH T1MS      ;initial timer0 high byte
    SETB   TR0                 ;timer0 start running
    SETB   ET0                 ;enable timer0 interrupt
    SETB   EA                 ;open global interrupt switch
    CLR    A
    MOV    COUNT,A
    MOV    COUNT+1,A           ;initial counter
    SJMP   $
```

;-----

;/* Timer0 interrupt routine */

TM0_ISR:

```
    PUSH   ACC
    PUSH   PSW
    MOV    TL0,    #LOW  T1MS      ;reload timer0 low byte
    MOV    TH0,    #HIGH T1MS      ;reload timer0 high byte
    MOV    A,      COUNT
    ORL    A,      COUNT+1         ;check whether count(2byte) is equal to 0
    JNZ    SKIP
    MOV    COUNT,  #LOW 1000        ;1ms * 1000 -> 1s
    MOV    COUNT+1, #HIGH 1000
    CPL    TEST_LED                ;work LED flash
```

SKIP:

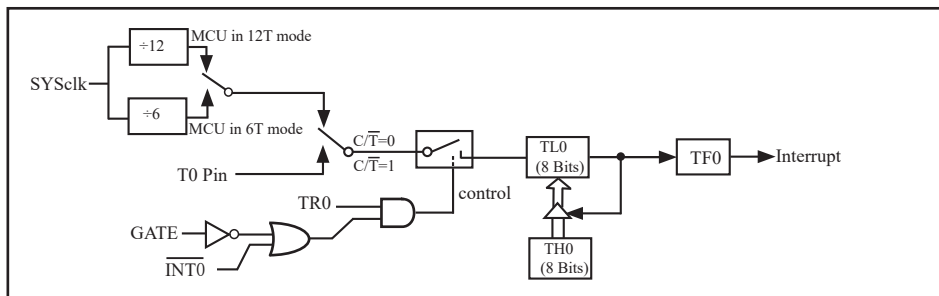
```
    CLR    C
    MOV    A,      COUNT           ;count--
    SUBB   A,      #1
    MOV    COUNT,  A
    MOV    A,      COUNT+1
    SUBB   A,      #0
    MOV    COUNT+1,A
    POP    PSW
    POP    ACC
    RETI
```

;-----

END

7.1.2.3 模式2(8位自动重装模式)及其测试程序(C程序及汇编程序)

此模式下定时器/计数器0作为可自动重载的8位计数器，如下图所示。



定时器/计数器0的模式 2: 8位自动重装

TL0的溢出不仅置位TF0，而且将TH0内容重新装入TL0，TH0内容由软件预置，重装时TH0内容不变。

;定时器0中断的测试程序，定时器0工作在8位自动重装模式

1. C程序：

```
/*-----*/
/* --- STC MCU International Limited -----*/
/* --- STC89-90xx Series MCU T0(Falling edge) Demo -----*/
/* If you want to use the program or the program referenced in the */
/* article, please specify in which data and procedures from STC */
/*-----*/
#include "reg51.h"

sfr AUXR = 0x8e;          //Auxiliary register

//T0 interrupt service routine
void t0int() interrupt 1    //T0 interrupt (location at 000BH)
{
    P0++;
}
```

```
void main()
{
    AUXR = 0x80;           //timer0 work in 1T mode
    TMOD = 0x06;           //set timer0 as counter mode2 (8-bit auto-reload)
    TL0 = TH0 = 0xff;      //fill with 0xff to count one time
    TR0 = 1;               //timer0 start run
    ET0 = 1;               //enable T0 interrupt
    EA = 1;                //open global interrupt switch

    while (1);
}
```

2. 汇编程序:

```
;/*-----*/
/* --- STC MCU International Limited -----*/
/* --- STC89-90xx Series MCU T0(Falling edge) Demo -----*/
/* If you want to use the program or the program referenced in the ---*/
/* article, please specify in which data and procedures from STC ----*/
/*-----*/
```

```
AUXR    DATA    08EH        ;Auxiliary register
```

```
;-----
;interrupt vector table
```

```
ORG    0000H
LJMP    MAIN
```

```
ORG    000BH                ;T0 interrupt (location at 000BH)
LJMP    T0INT
```

```
;-----
```

```
ORG    0100H
```

MAIN:

```
MOV    SP,    #7FH           ;initial SP
MOV    AUXR,  #80H           ;timer0 work in 1T mode
MOV    TMOD,  #06H           ;set timer0 as counter mode2 (8-bit auto-reload)
MOV    A,     #0FFH
MOV    TL0,   A               ;fill with 0xff to count one time
MOV    TH0,   A
SETB   TR0                   ;timer0 start run
SETB   ET0                   ;enable T0 interrupt
SETB   EA                   ;open global interrupt switch
SJMP   $
```

```
;-----
;T0 interrupt service routine
```

T0INT:

```
CPL    P0.0
RETI
```

```
;-----
```

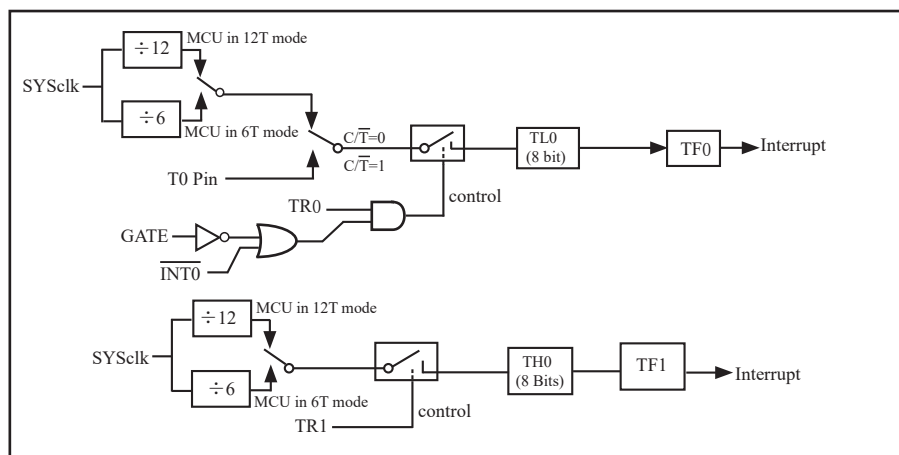
END

7.1.2.4 模式3(两个8位计数器)

对定时器1，在模式3时，定时器1停止计数，效果与将TR1设置为0相同。

对定时器0，此模式下定时器0的TL0及TH0作为2个独立的8位计数器。下图为模式3时的定时器0逻辑图。TL0占用定时器0的控制位： $C/\overline{T}$ 、GATE、TR0、INT0及TF0。TH0限定为定时器功能（计数器周期），占用定时器1的TR1及TF1。此时，TH0控制定时器1中断。

模式3是为了增加一个附加的8位定时器/计数器而提供的，使单片机具有三个定时器/计数器。模式3只适用于定时器/计数器0，定时器T1处于模式3时相当于TR1=0，停止计数，而T0可作为一个定时器用。



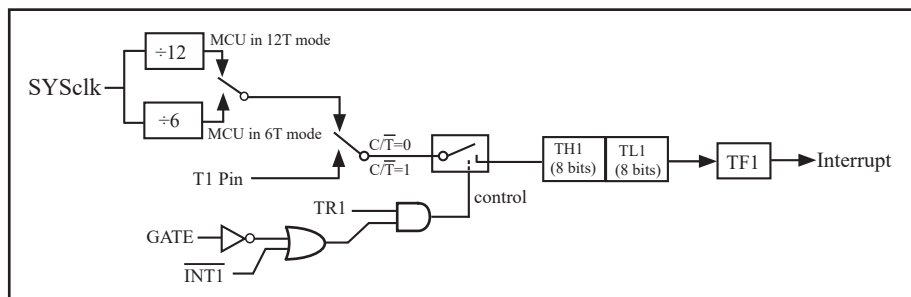
定时/计数器0 模式3: 两个8位计数器

7.1.3 定时器/计数器1工作模式(与传统8051单片机兼容)

通过对寄存器TMOD中的M1(TM0D.5)、M0(TM0D.4)的设置,定时器/计数器1有3种不同的工作模式。

7.1.3.1 模式0(13位定时器/计数器)

此模式下定时器/计数器1作为13位定时器/计数器,有TL1的低5位和TH1的8位所构成,如下图所示。模式0的操作对于定时器1和定时器0是相同的。



定时器/计数器1的模式 0: 13位定时器/计数器

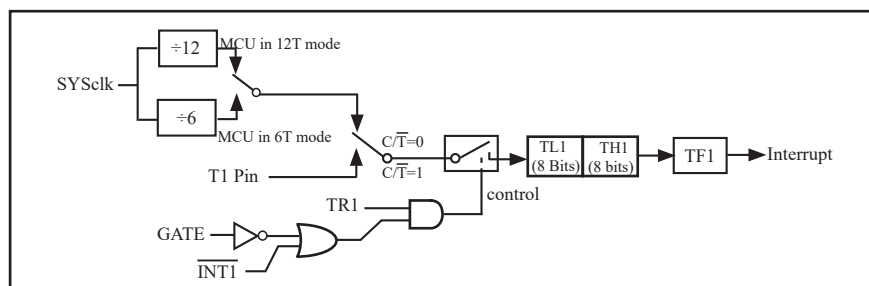
当GATE=0(TM0D.7)时,如TR1=1,则定时器计数。GATE=1时,允许由外部输入 $\overline{\text{INT1}}$ 控制定时器1,这样可实现脉宽测量。TR1为TCON寄存器内的控制位,TCON寄存器各位的具体功能描述见上节TCON寄存器的介绍。

当 $\overline{\text{C/T}}=0$ 时,多路开关连接到系统时钟的分频输出,T1对时钟周期计数,T1工作在定时方式。当 $\overline{\text{C/T}}=1$ 时,多路开关连接到外部脉冲输入P3.5/T1,即T1工作在计数方式。

STC89C51RC/RD+系列单片机的定时器有两种计数速率:一种是12T模式,每12个时钟加1,与传统8051单片机相同;另外一种6T模式,每6个时钟加1,速度是传统8051单片机的2倍。T1的速率在烧录用户程序时在STC-ISP编程器中设置。

7.1.3.2 模式1(16位定时器/计数器)及其测试程序(C程序及汇编程序)

此模式下定时器/计数器1作为16位定时器/计数器，如下图所示。



定时器/计数器1的模式 1: 16位定时器/计数器

此模式下，定时器1配置为16位定时器/计数器，由TL1的8位和TH1的8位所构成。TL1的8位溢出向TH1进位，TH1计数溢出置位TCON中的溢出标志位TF1。

当GATE=0 (TMOD.7)时，如TR1=1，则定时器计数。GATE=1时，允许由外部输入INT1控制定时器1，这样可实现脉宽测量。TR1为TCON寄存器内的控制位，TCON寄存器各位的具体功能描述见上节TCON寄存器的介绍。

当 $C/\overline{T}=0$ 时，多路开关连接到系统时钟的分频输出，T1对时钟周期计数，T1工作在定时方式。当 $C/\overline{T}=1$ 时，多路开关连接到外部脉冲输入P3.5/T1，即T1工作在计数方式。

STC89C51RC/RD+系列单片机的定时器有两种计数速率：一种是12T模式，每12个时钟加1，与传统8051单片机相同；另外一种6T模式，每6个时钟加1，速度是传统8051单片机的2倍。T1的速率在烧录用户程序时在STC-ISP编程器中设置。

定时器1工作在16位定时器/计数器模式的测试程序

1. C程序:

```

/*-----*/
/* --- STC MCU International Limited -----*/
/* --- 演示STC89xx系列单片机定时器1的16位定时器/计数器模式 --*/
/* 如果要在程序中使用或在文章中引用该程序, -----*/
/* 请在程序中或文章中注明使用了宏晶科技的资料及程序 -----*/
/*-----*/
#include "reg51.h"

typedef unsigned char    BYTE;
typedef unsigned int     WORD;

//-----

/* define constants */
#define FOSC  18432000L

#define T1MS (65536-FOSC/12/1000)                //1ms timer calculation method in 12T mode

/* define SFR */
sbit    TEST_LED = P1^0;                        //work LED, flash once per second

/* define variables */
WORD    count;                                //1000 times counter

//-----

/* Timer0 interrupt routine */
void tm1_isr() interrupt 3 using 1
{
    TL1 = T1MS;                                //reload timer1 low byte
    TH1 = T1MS >> 8;                            //reload timer1 high byte
    if (count-- == 0)                            //1ms * 1000 -> 1s
    {
        count = 1000;                            //reset counter
        TEST_LED = ! TEST_LED;                    //work LED flash
    }
}
//-----

```

```
/* main program */
void main()
{
    TMOD = 0x10;           //set timer1 as mode1 (16-bit)
    TL1 = T1MS;            //initial timer1 low byte
    TH1 = T1MS >> 8;       //initial timer1 high byte
    TR1 = 1;               //timer1 start running
    ET1 = 1;               //enable timer1 interrupt
    EA = 1;                //open global interrupt switch
    count = 0;             //initial counter

    while (1);             //loop
}
```

2. 汇编程序：

```
/*-----*/
/* --- STC MCU International Limited -----*/
/* --- 演示STC89xx系列单片机定时器1的16位定时器/计数器模式 ---*/
/* 如果要在程序中使用或在文章中引用该程序， -----*/
/* 请在程序中或文章中注明使用了宏晶科技的资料及程序 -----*/
/*-----*/
; * define constants */
T1MS    EQU    0FA00H           ;1ms timer calculation method in 12T mode is (65536-18432000/12/1000)

; * define SFR */
TEST_LED  BIT  P1.0             ;work LED, flash once per second

; * define variables */
COUNT  DATA  20H              ;1000 times counter (2 bytes)

;-----

        ORG     0000H
        LJMP    MAIN
        ORG     001BH
        LJMP    TM1_ISR

;-----
```

```
;/* main program */
```

```
MAIN:
```

```

    MOV    TMOD, #10H           ;set timer1 as model (16-bit)
    MOV    TL1,  #LOW T1MS      ;initial timer1 low byte
    MOV    TH1,  #HIGH T1MS     ;initial timer1 high byte
    SETB   TR1                  ;timer1 start running
    SETB   ET1                  ;enable timer1 interrupt
    SETB   EA                   ;open global interrupt switch
    CLR    A
    MOV    COUNT, A
    MOV    COUNT+1, A           ;initial counter
    SJMP   $

```

```
;-----
```

```
;/* Timer1 interrupt routine */
```

```
TM1_ISR:
```

```

    PUSH   ACC
    PUSH   PSW
    MOV    TL1,  #LOW T1MS      ;reload timer1 low byte
    MOV    TH1,  #HIGH T1MS     ;reload timer1 high byte
    MOV    A,     COUNT
    ORL    A,     COUNT+1       ;check whether count(2byte) is equal to 0
    JNZ    SKIP
    MOV    COUNT, #LOW 1000      ;1ms * 1000 -> 1s
    MOV    COUNT+1, #HIGH 1000
    CPL    TEST_LED             ;work LED flash

```

```
SKIP:
```

```

    CLR    C
    MOV    A,     COUNT          ;count--
    SUBB   A,     #1
    MOV    COUNT, A
    MOV    A, COUNT+1
    SUBB   A, #0
    MOV    COUNT+1, A
    POP    PSW
    POP    ACC
    RETI

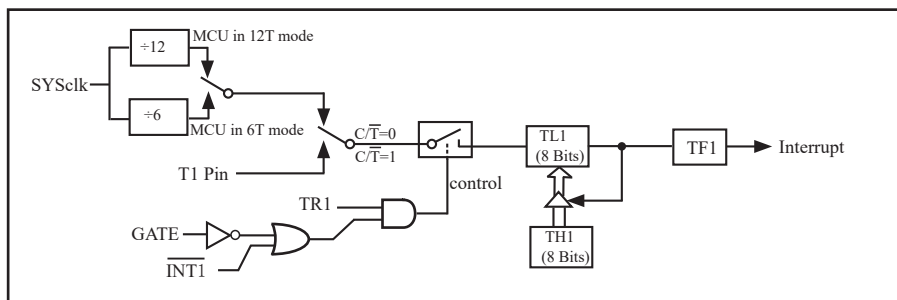
```

```
;-----
```

```
END
```

7.1.3.3 模式2(8位自动重装模式)及其测试程序(C程序及汇编程序)

此模式下定时器/计数器1作为可自动重载的8位计数器，如下图所示。



定时器/计数器1的模式 2: 8位自动重装

TL1的溢出不仅置位TF1，而且将TH1内容重新装入TL1，TH1内容由软件预置，重装时TH1内容不变。

;定时器1中断的测试程序，定时器1工作在8位自动重装模式

1. C程序：

```
/*-----*/
/* --- STC MCU International Limited -----*/
/* --- STC89-90xx Series MCU T1(Falling edge) Demo -----*/
/* If you want to use the program or the program referenced in the */
/* article, please specify in which data and procedures from STC */
/*-----*/
```

```
#include "reg51.h"
```

```
sfr AUXR = 0x8e;          //Auxiliary register
```

```
//T1 interrupt service routine
```

```
void t1int() interrupt 3    //T1 interrupt (location at 001BH)
```

```
{
    P0++;
}
```

```

void main()
{
    AUXR = 0x40;           //timer1 work in 1T mode
    TMOD = 0x60;           //set timer1 as counter mode2 (8-bit auto-reload)
    TL1 = TH1 = 0xff;      //fill with 0xff to count one time
    TR1 = 1;               //timer1 start run
    ET1 = 1;               //enable T1 interrupt
    EA = 1;                //open global interrupt switch

    while (1);
}

```

2. 汇编程序：

```

;-----*/
;--- STC MCU International Limited -----*/
;--- STC89-90xx Series MCU T1(Falling edge) Demo -----*/
; If you want to use the program or the program referenced in the */
; article, please specify in which data and procedures from STC */
;-----*/

```

```

AUXR    DATA    08EH           ;Auxiliary register

```

```

;-----
;interrupt vector table

```

```

    ORG    0000H
    LJMP   MAIN

```

```

    ORG    001BH           ;T1 interrupt (location at 001BH)
    LJMP   TIINT

```

```

;-----

```

```
        ORG    0100H
MAIN:
        MOV    SP,    #7FH        ;initial SP
        MOV    AUXR,  #40H        ;timer1 work in 1T mode
        MOV    TMOD,  #60H        ;set timer1 as counter mode2 (8-bit auto-reload)
        MOV    A,     #0FFH
        MOV    TL1,   A           ;fill with 0xff to count one time
        MOV    TH1,   A
        SETB   TR1               ;timer1 start run
        SETB   ET1              ;enable T1 interrupt
        SETB   EA               ;open global interrupt switch
        SJMP

;-----
;T1 interrupt service routine

T1INT:
        CPL    P0.0
        RETI

;-----

        END
```

7.1.4 古老Intel 8051单片机定时器0/1的应用举例

【例1】 定时/计数器编程，定时/计数器的应用编程主要需考虑：根据应用要求，通过程序初始化，正确设置控制字，正确计算和计算计数初值，编写中断服务程序，适时设置控制位等。通常情况下，设置顺序大致如下：

- 1) 工作方式控制字（TMOD、T2CON）的设置；
- 2) 计数初值的计算并装入THx、TLx、RCAP2H、RCAP2L；
- 3) 中断允许位ETx、EA的设置，使主机开放中断；
- 4) 启/停位TRx的设置等。

现以定时/计数器0或1为例作一简要介绍。

8051系列单片机的定时器/计数器0或1是以不断加1进行计数的，即属加1计数器，因此，就不能直接将实际的计数值作为计数初值送入计数寄存器THx、TLx中去，而必须将实际计数值以 2^8 、 2^{13} 、 2^{16} 为模求补，以其补码作为计数初值设置THx和TLx。

设：实际计数值为X，计数器长度为n（n=8、13、16），则应装入计数器THx、TLx中的计数初值为 $2^n - x$ ，式中 2^n 为取模值。例如，工作方式0的计数长度为13位，则n=13，以 2^{13} 为模，工作方式1的计数长度为16，则n=16，以 2^{16} 为模等等。所以，计数初值为（x）= $2^n - x$ 。

对于定时模式，是对机器周期计数，而机器周期与选定的主频密切相关。因此，需根据应用系统所选定的主频计算出机器周期值。现以主频6MHz为例，则机器周期为：

$$\text{一个机器周期} = \frac{12}{\text{主振频率}} = \frac{12}{6 \times 10^6} \mu s = 2 \mu s$$

$$\text{实际定时时间} T_c = x \cdot T_p$$

式中 T_p 为机器周期， T_c 为所需定时时间，x为所需计数次数。 T_p 和 T_c 一般为已知值，在求出 T_p 后即可求得所需计数值x，再将x求补码，即求得定时计数初值。即

$$(x) \text{ 补} = 2^n - x$$

例如，设定时间 $T_c = 5ms$ ，机器周期 $T_p = 2 \mu s$ ，可求得定时计数次数

$$x = \frac{5ms}{2 \mu s} = 2500 \text{ 次}$$

设选用工作方式1，则n=16，则应设置的定时时间计数初值为：

(x) 补 = $2^{16} - x = 65536 - 2500 = 63036$ ，还需将它分解成两个8位十六进制数，分别求得低8位为3CH装入TLx，高8位为F6H装入THx中。

工作方式0、1、2的最大计数次数分别为8192、65536和256。

对外部事件计数模式，只需根据实际计数次数求补后变换成两个十六进制码即可。

【例2】 定时/计数器应用编程，设某应用系统，选择定时/计数器1定时模式，定时时间Tc = 10ms，主频频率为12MHz，每10ms向主机请求处理。选定工作方式1。计算得计数初值：低8位初值为F0H，高8位初值为D8H。

(1) 初始化程序

所谓初始化，一般在主程序中根据应用要求对定时/计数器进行功能选择及参数设定等预置程序，本例初始化程序如下：

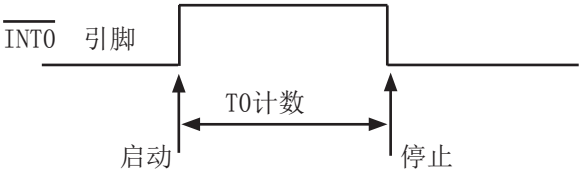
```
START:      ; 主程序段
            ;
MOV    SP, #60H      ; 设置堆栈区域
MOV    TMOD, #10H    ; 选择T1、定时模式，工作方式1
MOV    TH1, #0D8H    ; 设置高字节计数初值
MOV    TL1, #0F0H    ; 设置低字节计数初值
SETB   EA            ; } 开中断
SETB   ET1           ; }
            ;
            ; 其他初始化程序
SETB   TR1           ; 启动T1开始计时
            ;
            ; 继续主程序
```

(2) 中断服务程序

```
INTT1: PUSH  A      ; }
        PUSH  DPL    ; } 现场保护
        PUSH  DPH    ; }
        ;
        ;
MOV     TL1, #0F0H   ; }
MOV     TH1, #0D8H   ; } 重新置初值
        ;
        ;           ; 中断处理主体程序
        POP    DPH   ;
        POP    DPL   ; } 现场恢复
        POP    A     ; }
        RETI        ; 返回
```

这里展示了中断服务子程序的基本格式。STC89C51RC/RD+系列单片机的中断属于矢量中断，每一个矢量中断源只留有8个字节单元，一般是不够用的，常需用转移指令转到真正的中断服务子程序区去执行。

【例3】 对外部正脉冲测宽。选择定时/计数器2进行脉宽测试较方便，但也可选用定时/计数器0或定时/计数器1进行测宽操作。本例选用定时/计数器0（T0）以定时模式，工作方式1对INT0引脚上的正脉冲进行脉宽测试。



设置GATE为1，机器周期TP为1μs。本例程序段编制如下：

```

INTT0:      MOV    TMOD, #09H           ; 设T0为定时方式1，GATE为1
            MOV    TL0, #00H           ;
            MOV    TH0, #00H           ; } TH0, TL0清0
            CLR    EX0                 ; 关INT0中断
LOP1:       JB     P3.2, LOP1           ; 等待INT0引低电平
LOP2:       JNB    P3.2, LOP2           ; 等待INT0引脚高电平
            SETB   TR0                 ; 启动T0开始计数
LOP3:       JB     P3.2, LOP3           ; 等待INT0低电平
            CLR    TR0                 ; 停止T0计数
            MOV    A, TL0               ; 低字节计数值送A
            MOV    B, TH0               ; 高字节计数值送B
            :                           ; 计算脉宽和处理
    
```

【例4】 利用定时/计数器0或定时/计数器1的Tx端口改造成外部中断源输入端口的应用设计。

在某些应用系统中常会出现原有的两个外部中断源INT0和INT1不够用，而定时/计数器有多余，则可将Tx用于增加的外部中断源。现选择定时/计数器1为对外部事件计数模式工作方式2（自动再装入），设置计数初值为FFH，则T1端口输入一个负跳变脉冲，计数器即回0溢出，置位对应的中断请求标志位TF1为1，向主机请求中断处理，从而达到了增加一个外部中断源的目的。应用定时/计数器1（T1）的中断矢量转入中断服务程序处理。其程序示例如下：

（1）主程序段：

```
ORG    0000H
AJMP   MAIN                ; 转主程序
ORG    001BH
LJMP   INTER               ; 转T1中断服务程序
:
ORG    0100                ; 主程序入口
MAIN:  ...
:
MOV     SP, #60H           ; 设置堆栈区
MOV     TMOD, #60H        ; 设置定时/计数器1，计数方式2
MOV     TL1, #0FFH        ; 设置计数常数
MOV     TH1, #0FFH
SETB    EA                ; 开中断
SETB    ET1               ; 开定时/计数器1中断
SETB    TR1               ; 启动定时/计数器1计数
:
```


(2) 中断服务程序（具体处理程序略）

```

                                ORG      1000H
INTER:  PUSH    A                ;
                                PUSH    DPL            ; } 现场入栈保护
                                PUSH    DPH            ;
                                ⋮
                                ⋮
                                ⋮                    ; } 中断处理主体程序
                                ⋮
                                POP     DPH            ;
                                POP     DPL            ; } 现场出栈复原
                                POP     A              ;
                                RETI                  ; 返回
```

这是中断服务程序的基本格式。

【例5】 某应用系统需通过P1.0和P1.1分别输出周期为200 μs和400 μs的方波。为此，系统选用定时器/计数器0（T0），定时方式3，主频为6MHz，TP=2 μs，经计算得定时常数为9CH和38H。

本例程序段编制如下：

(1) 初始化程序段

```

                                ⋮
PLT0:  MOV     TMOD, #03H        ; 设置T0定时方式3
                                MOV     TL0, #9CH        ; 设置TL0初值
                                MOV     TH0, #38H        ; 设置TH0初值
                                SETB    EA              ;
                                SETB    ET0              ; } 开中断
                                SETB    ET1              ;
                                SETB    TR0              ; 启动
                                SETB    TR1              ; 启动
                                ⋮
```

(2) 中断服务程序段

```
1)
INT0P:  ⋮
        ⋮
        MOV    TL0, #9CH          ; 重新设置初值
        CPL    P1.0              ; 对P1.0输出信号取反
        ⋮
        RETI                    ; 返回

2)
INT1P   ⋮
        ⋮
        MOV    TH0, #38H         ; 重新设置初值
        CPL    P1.1              ; 对P1.1输出信号取反
        ⋮
        RETI                    ; 返回
```

在实际应用中应注意的问题如下。

(1) 定时/计数器的实时性

定时/计数器启动计数后，当计满回0溢出向主机请求中断处理，由内部硬件自动进行。但从回0溢出请求中断到主机响应中断并作出处理存在时间延迟，且这种延时随中断请求时的现场环境的不同而不同，一般需延时3个机器周期以上，这就给实时处理带来误差。大多数应用场合可忽略不计，但对某些要求实时性苛刻的场合，应采用补偿措施。

这种由中断响应引起的时间延时，对定时/计数器工作于方式0或1而言有两种含义：一是由于中断响应延时而引起的实时处理的误差；二是如需多次且连续不间断地定时/计数，由于中断响应延时，则在中断服务程序中再置计数初值时已延误了若干个计数值而引起误差，特别是用于定时就更明显。

例如选用定时方式1设置系统时钟，由于上述原因就会产生实时误差。这种场合应采用动态补偿办法以减少系统始终误差。所谓动态补偿，即在中断服务程序中对THx、TLx重新置计数初值时，应将THx、TLx从回0溢出又重新从0开始继续计数的值读出，并补偿到原计数初值中去进行重新设置。可考虑如下补偿方法：

```

      ⋮
CLR    EA                                ; 禁止中断
MOV     A, TLx                          ; 读TLx中已计数值
ADD     A, #LOW                          ; LOW为原低字节计数初值
MOV     TLx, A                          ; 设置低字节计数初值
MOV     A, #HIGH                        ; 原高字节计数初值送A
ADDC    A, THx                          ; 高字节计数初值补偿
MOV     THx, A                          ; 置高字节计数初值
SETB    EA                              ; 开中断
      ⋮

```

(2) 动态读取运行中的计数值

在动态读取运行中的定时/计数器的计数值时，如果不加注意，就可能出错。这是因为不可能在同一时刻同时读取THx和TLx中的计数值。比如，先读TLx后读THx，因为定时/计数器处于运行状态，在读TLx时尚未产生向THx进位，而在读THx前已产生进位，这时读得的THx就不对了；同样，先读THx后读TLx也可能出错。

一种可避免读错的方法是：先读THx，后读TLx，将两次读得的THx进行比较；若两次读得的值相等，则可确定读的值是正确的，否则重复上述过程，重复读得的值一般不会再错。此法的软件编程如下：

```

RDTM:  MOV  A, THx                      ; 读取THx存A中
        MOV  R0, TLx                   ; 读取TLx存R0中
        CJNE A, THx, RDTM               ; 比较两次THx值, 若相等, 则读得的
                                          ; 值正确, 程序往下执行, 否则重读
        MOV  R1, A                      ; 将THx存于R1中
        ⋮

```

7.2 定时器/计数器T2

定时器2是一个16位定时/计数器。通过设置特殊功能寄存器T2CON中的C/T2位，可将其作为定时器或计数器（特殊功能寄存器T2CON的描述如下所示）。

定时器/计数器2的相关寄存器表：

符号	描述	地址	位地址及其符号								复位值
			MSB				LSB				
T2CON	定时器2控制寄存器	C8H	TF2	EXF2	RCLK	TCLK	EXEN2	TR2	C/T2	CP/RL2	0000 0000B
T2MOD	定时器2模式寄存器	C9H	-	-	-	-	-	-	T2OE	DECN	xxxx xx00B
RCAP2L	Timer / Counter 2 Reload/Capture Low Byte	CAH									0000 0000B
RCAP2H	Timer / Counter 2 Reload/Capture High Byte	CBH									0000 0000B
TL2	Timer / Counter 2 Low Byte	CCH									0000 0000B
TH2	Timer/Counter 2 High Byte	CDH									0000 0000B

寄存器T2CON(定时器2的控制寄存器) 各位的功能描述

T2CON	地址：0C8H		复位值：00H													
可位寻址	7 6 5 4 3 2 1 0															
	TF2		EXF2		RCLK		TCLK		EXEN2		TR2		C/ $\overline{\text{T2}}$		CP/ $\overline{\text{RL2}}$	
位	符号		功能													
T2CON.7/	TF2		定时器2溢出标志。定时器2溢出时置位，必须由软件清除。当RCLK或TCLK=1 时，TF2将不会置位													
T2CON.6/	EXF2		定时器2外部标志。当EXEN2=1且T2EX的负跳变产生捕获或重装时，EXF2置位。定时器2中断使能时，EXF2=1将使CPU从中断向量处执行定时器2中断子程序。EXF2位必须用软件清零。在递增/递减计数器模式（DCEN=1）中，EXF2不会引起中断													
T2CON.5/	RCLK		接收时钟标志。RCLK置位时，定时器2的溢出脉冲作为串行口模式1和模式3的接收时钟。RCLK=0时，将定时器1的溢出脉冲作为串行口模式1和模式3的接收时钟													
T2CON.4/	TCLK		发送时钟标志。TCLK置位时，定时器2的溢出脉冲作为串行口模式1和模式3的发送时钟。TCLK=0时，将定时器1的溢出脉冲作为串行口模式1和模式3发送时钟													
T2CON.3/	EXEN2		定时器2外部使能标志。当其置位且定时器2未作为串行口时钟时，允许T2EX的负跳变产生捕获或重装。EXEN2=0时，T2EX的跳变对定时器2无效													

位	符号	功能
T2CON.2/	TR2	定时器2 启动/停止控制位。置1 时启动定时器
T2CON.1/	C/ $\overline{T2}$	定时器/ 计数器选择。（定时器2 ） 0 = 内部定时器（SYSclk/12 或SYSclk/6） 1 = 外部事件计数器（下降沿触发）
T2CON.0/	CP/ $\overline{RL2}$	捕获/重装标志。置位:EXEN2=1时, T2EX的负跳变产生捕获. 清零: EXEN2=0时, 定时器2溢出或T2EX的负跳变都可使定时器自动重装。当RCLK=1 或TCLK=1 时, 该位无效且定时器强制为溢出时自动重装

定时器2有3种操作模式：捕获、自动重新装载（递增或递减计数）和波特率发生器。这3种模式由T2CON中的位进行选择（如下表所列）。

定时器2的工作方式			
RCLK+TCLK	CP/ $\overline{RL2}$	TR2	模式
0	0	1	16位自动重装
0	1	1	16位捕获
1	x	1	波特率发生器
x	x	0	（关闭）

T2MOD：定时器/计数器2模式控制寄存器（不可位寻址）

SFR name	Address	bit	B7	B6	B5	B4	B3	B2	B1	B0
T2MOD	0C9H	name	-	-	-	-	-	-	T2OE	DCEN

T2OE：定时器2 输出使能位

DECN：向下计数使能位。定时器2 可配置成向上/ 向下计数器

* 用户勿将其置1。这些位在将来80C51 系列产品中用来实现新的特性。在这种情况下，以后用到保留位，复位时或非有效状态时，它的值应为0；而这些位为有效状态时，它的值为1。从保留位读到的值是不确定的。

7.2.1 定时器2的捕获模式

在捕获模式中，通过T2CON中的EXEN2设置2个选项。如果EXEN2=0，定时器2作为一个16位定时器或计数器（由T2CON中C/T2位选择），溢出时置位TF2（定时器2溢出标志位）。该位可用于产生中断（通过使能IE寄存器中的定时器2中断使能位ET2）。如果EXEN2=1，与以上描述相同，但增加了一个特性，即外部输入T2EX由1变零时，将定时器2中TL2和TH2的当前值各自捕获到RCAP2L和RCAP2H。另外，T2EX的负跳变使T2CON中的EXF2置位，EXF2也像TF2一样能够产生中断（其向量与定时器2溢出中断地址相同，定时器2中断服务程序通过查询TF2和EXF2来确定引起中断的事件），捕获模式如下图所示。在该模式中，TL2和TH2无重新装载值，甚至当T2EX产生捕获事件时，计数器仍以T2EX 的负跳变或振荡频率的1/12（12时钟模式）或1/6（6时钟模式）计数。

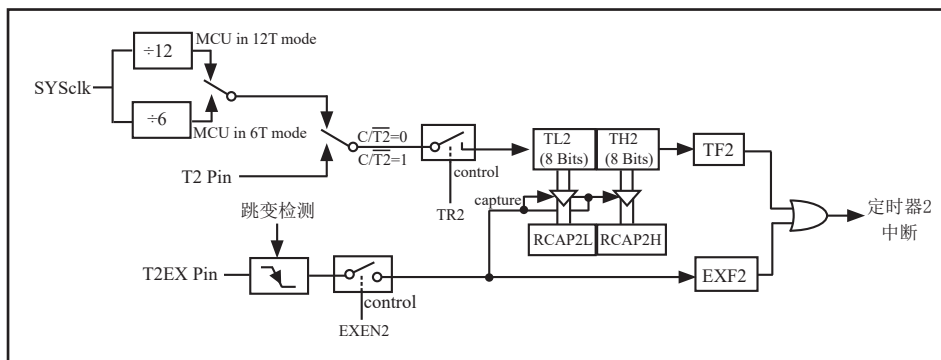


图1 定时器2捕获模式

7.2.2 定时器2的自动重装模式(递增/递减计数器)

16位自动重装模式中, 定时器2 可通过C/T2配置为定时器/计数器, 编程控制递增/递减计数。计数的方向是由DCEN(递减计数使能位)确定的, DCEN位于T2MOD寄存器中, T2MOD寄存器各位的功能描述如表3 所示。当DCEN=0 时, 定时器2 默认为向上计数; 当DCEN=1 时, 定时器2 可通过T2EX 确定递增或递减计数。图2 显示了当DCEN=0 时, 定时器2 自动递增计数。在该模式中, 通过设置EXEN2位进行选择。如果EXEN2=0, 定时器2 递增计数到0FFFFH, 并在溢出后将TF2置位, 然后将RCAP2L和RCAP2H 中的16位值作为重新装载值装入定时器2。RCAP2L和RCAP2H的值是通过软件预设的。

如果EXEN2=1, 16位重新装载可通过溢出或T2EX从1到0的负跳变实现。此负跳变同时EXF2置位。如果定时器2中断被使能, 则当TF2或EXF2置1时产生中断。在图3中, DCEN=1时, 定时器2可增或递减计数。此模式允许T2EX 控制计数的方向。当T2EX 置1 时, 定时器2 递增计数, 计数到0FFFFH后溢出并置位TF2, 还将产生中断(如果中断被使能)。定时器2的溢出将使RCAP2L 和RCAP2H中的16 位值作为重新装载值放入TL2和TH2。

当T2EX置零时, 将使定时器2递减计数。当TL2和TH2计数到等于RCAP2L和RCAP2H时, 定时器产生中断。

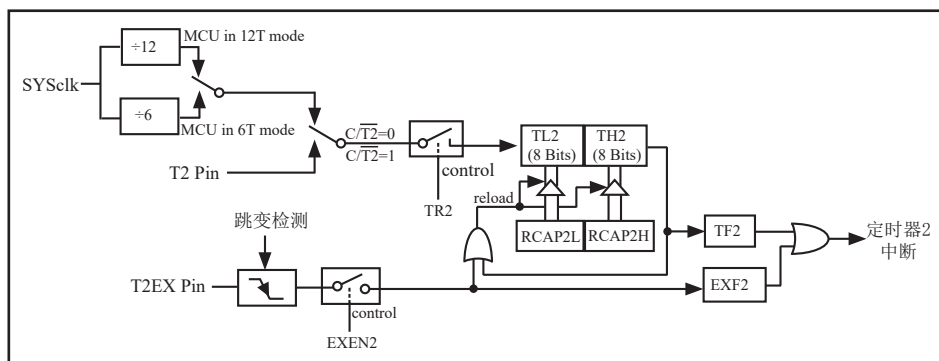


图2 定时器2的自动重装模式 (DCEN=0)

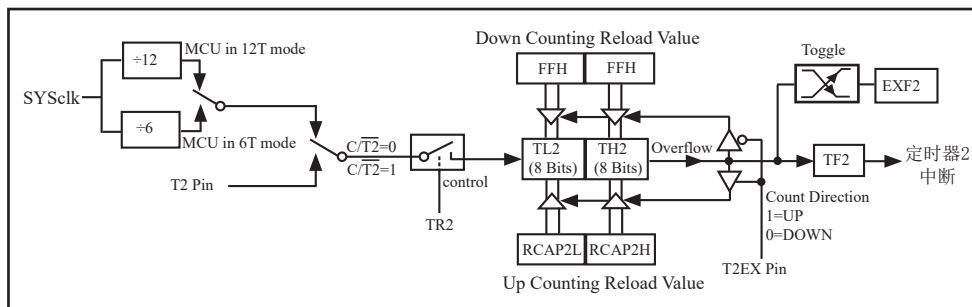


图3 定时器2的自动重装模式 (DCEN=1)

符号	描述	地址	位地址及其符号								复位值
			MSB				LSB				
T2CON	定时器2控制寄存器	C8H	TF2	EXF2	RCLK	TCLK	EXEN2	TR2	C/T2	CP/RL2	0000 0000B
T2MOD	定时器2模式寄存器	C9H	-	-	-	-	-	-	T2OE	DECN	xxxx xx00B

除了波特率发生器模式, T2CON不包括TR2位的设置, TR2位需单独设置来启动定时器。如下表列出了T2作为定时器和计数器的具体设置方法。

T2作定时器T2CON的设置		
模式	T2CON	
	内部控制	外部控制
16位重装	0000 0000B / 00H	0000 1000B / 08H
16位捕获	0000 0001B / 01H	0000 1001B / 09H
波特率发生器接收和发送相同波特率	0011 0100B / 34H	0011 0110B / 36H
只接收	0010 0100B / 24H	0010 0110B / 26H
只发送	0001 0100B / 14H	0001 0110B / 16H

T2作计数器T2MOD的设置		
模式	T2MOD	
	内部控制	外部控制
16位	0000 0010B / 02H	0000 1010B / 0AH
自动重装	0000 0011B / 03H	0000 1011B / 0BH

- (1) 内部控制: 仅当定时器溢出时进行捕获和重装。
- (2) 外部控制: 当定时/计数器溢出并且T2EX(P1. 1)发生电平负跳变时产生捕获和重装(定时器2用于波特率发生器模式时除外)。

7.2.3 定时器2作串行口波特率发生器及其测试程序(C程序及汇编程序)

寄存器T2CON 的位TCLK和（或）RCLK允许从定时器1或定时器2获得串行口发送和接收的波特率。当TCLK=0时，定时器1作为串行口发送波特率发生器；当TCLK=1时，定时器2作为串行口发送波特率发生器。RCLK对串行口接收波特率有同样的作用。通过这2位，串行口能得到不同的接收和发送波特率，一个通过定时器1产生，另一个通过定时器2产生。如图4所示为定时器2工作在波特率发生器模式。与自动重装模式相似，当TH2溢出时，波特率发生器模式使定时器2寄存器重新装载来自寄存器RCAP2H 和RCAP2L的16位的值，寄存器RCAP2H和RCAP2L的值由软件预置。当工作于模式1和模式3时，波特率由下面给出的公式所决定：

模式1 和模式3 的波特率=（定时器2溢出速率）/16

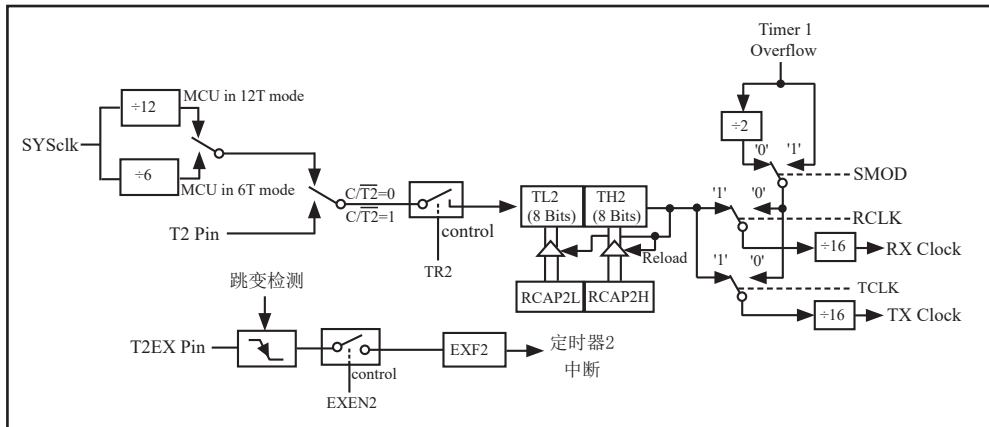


图4 定时器2的独立波特率发生器模式

定时器可配置成“定时”或“计数”方式，在许多应用上，定时器被设置在“定时”方式（C/T2=0）。当定时器2作为定时器时，它的操作不同于波特率发生器。通常定时器2作为定时器，它会在每个机器周期递增（1/6 或1/12 振荡频率）。当定时器2 作为波特率发生器时，它在6 时钟模式下，以振荡器频率递增（12时钟模式时为1/12振荡频率）。

这时的波特率公式如下：

$$\text{模式1和模式3的波特率} = \frac{\text{振荡器频率}}{n \times [65536 - (RCAP2H, RCAP2L)]}$$

式中：n=16（6时钟模式）或32（12时钟模式）；[RCAP2H, RCAP2L]是RCAP2H和RCAP2L的内容，为16 位无符号整数。

如图4所示，定时器2是作为波特率发生器，仅当寄存器T2CON中的RCLK和（或）TCLK=1时，定时器2作为波特率发生器才有效。注意：TH2溢出并不置位TF2，也不产生中断。这样当定时器2 作为波特率发生器时，定时器2中断不必被禁止。如果EXEN2（T2外部使能标志）被置位，在T2EX中由1 到0 的转换会置位EXF2（T2 外部标志位），但并不导致（TH2，TL2）重新装载（RCAP2H，RCAP2L）。

当定时器2用作波特率发生器时，如果需要，T2EX可用做附加的外部中断。当定时器工作在波特率发生器模式下，则不要对TH2和TL2 进行读/ 写，每隔一个状态时间（fosc/2）或由T2 进入的异步信号，定时器2 将加1。在此情况下对TH2 和TH1 进行读/ 写是不准确的；可对RCAP2寄存器进行读，但不要进行写，否则将导致自动重装错误。当对定时器2或寄存器RCAP进行访问时，应关闭定时器（清零TR2）。表4列出了常用的波特率和如何用定时器2得到这些波特率。

波特率公式汇总

定时器2工作在波特率发生器模式，外部时钟信号由T2脚进入，这时的波特率公式如下：

$$\text{模式1和模式3的波特率} = (\text{定时器2溢出速率}) / 16$$

如果定时器2采用内部时钟信号，则波特率公式如下：

$$\text{波特率} = \frac{\text{SYSclk}}{n \times [65536 - (\text{RCAP2H}, \text{RCAP2L})]}$$

式中：n=32(12时钟模式)或16(6 时钟模式)，SYSclk= 振荡器频率。

自动重装值可由下式得到：

$$\text{RCAP2H}, \text{RCAP2L} = 65536 - [\text{SYSclk} / (n \times \text{波特率})]$$

定时器2作串行口波特率发生器的测试程序(C程序及汇编程序)

1. C程序:

```

/*-----*/
/* --- STC MCU International Limited -----*/
/* --- 演示STC89xx系列单片机定时器2作波特率发生器测试程序---*/
/* 如果要在程序中使用或在文章中引用该程序, -----*/
/* 请在程序或文章中注明使用了宏晶科技的资料及程序 -----*/
/*-----*/

#include "reg51.h"
#include "intrins.h"

sfr T2CON = 0xC8;           //timer2 control register
sfr RCAP2L = 0xCA;
sfr RCAP2H = 0xCB;
sfr TL2 = 0xCC;
sfr TH2 = 0xCD;

typedef unsigned char BYTE;
typedef unsigned int WORD;

#define FOSC 1843200L        //System frequency
#define BAUD 115200         //UART baudrate

/*Define UART parity mode*/
#define NONE_PARITY 0       //None parity
#define ODD_PARITY 1        //Odd parity
#define EVEN_PARITY 2       //Even parity
#define MARK_PARITY 3       //Mark parity
#define SPACE_PARITY 4      //Space parity

#define PARITYBIT EVEN_PARITY //Testing even parity

sbit bit9 = P2^2;           //P2.2 show UART data bit9
bit busy;

void SendData(BYTE dat);
void SendString(char *s);

```

```
void main()
{
    #if (PARITYBIT == NONE_PARITY)
        SCON = 0x50;          //8-bit variable UART
    #elif (PARITYBIT == ODD_PARITY) || (PARITYBIT == EVEN_PARITY) || (PARITYBIT == MARK_PARITY)
        SCON = 0xda;          //9-bit variable UART, parity bit initial to 1
    #elif (PARITYBIT == SPACE_PARITY)
        SCON = 0xd2;          //9-bit variable UART, parity bit initial to 0
    #endif

    TL2 = RCAP2L = (65536-(FOSC/32/BAUD)); //Set auto-reload value
    TH2 = RCAP2H = (65536-(FOSC/32/BAUD)) >> 8;
    T2CON = 0x34;              //Timer2 start run
    ES = 1;                    //Enable UART interrupt
    EA = 1;                    //Open master interrupt switch

    SendString("STC89-90xx\r\nUart Test !\r\n");
    while(1);
}

/*-----
UART interrupt service routine
-----*/
void Uart_Isr() interrupt 4 using 1
{
    if (RI)
    {
        RI = 0;                //Clear receive interrupt flag
        P0 = SBUF;              //P0 show UART data
        bit9 = RB8;             //P2.2 show parity bit
    }
    if (TI)
    {
        TI = 0;                //Clear transmit interrupt flag
        busy = 0;              //Clear transmit busy flag
    }
}

/*-----
Send a byte data to UART
Input: dat (data to be sent)
Output:None
-----*/
```

```

void SendData(BYTE dat)
{
    while (busy);           //Wait for the completion of the previous data is sent
    ACC = dat;               //Calculate the even parity bit P (PSW.0)
    if (P)                   //Set the parity bit according to P
    {
        #if (PARITYBIT == ODD_PARITY)
            TB8 = 0;         //Set parity bit to 0
        #elif (PARITYBIT == EVEN_PARITY)
            TB8 = 1;         //Set parity bit to 1
        #endif
    }
    else
    {
        #if (PARITYBIT == ODD_PARITY)
            TB8 = 1;         //Set parity bit to 1
        #elif (PARITYBIT == EVEN_PARITY)
            TB8 = 0;         //Set parity bit to 0
        #endif
    }
    busy = 1;
    SBUF = ACC;              //Send data to UART buffer
}

/*-----
Send a string to UART
Input: s (address of string)
Output:None
-----*/
void SendString(char *s)
{
    while (*s)               //Check the end of the string
    {
        SendData(*s++);      //Send current char and increment string ptr
    }
}

```

2. 汇编程序：

```
/*-----*/
/* --- STC MCU International Limited -----*/
/* --- 演示STC89xx系列单片机定时器2作波特率发生器测试程序---*/
/* 如果要在程序中使用或在文章中引用该程序， -----*/
/* 请在程序中或文章中注明使用了宏晶科技的资料及程序 -----*/
/*-----*/

T2CON      EQU    0C8H      ;timer2 control register
TR2        BIT    T2CON.2

T2MOD      EQU    0C9H      ;timer2 mode register
RCAP2L     EQU    0CAH
RCAP2H     EQU    0CBH
TL2        EQU    0CCH
TH2        EQU    0CDH

;/*Define UART parity mode*/
#define NONE_PARITY  0      //None parity
#define ODD_PARITY   1      //Odd parity
#define EVEN_PARITY  2      //Even parity
#define MARK_PARITY  3      //Mark parity
#define SPACE_PARITY 4      //Space parity

#define PARITYBIT EVEN_PARITY //Testing even parity
;-----
BUSY BIT      20H.0      ;transmit busy flag
;-----
      ORG      0000H
      LJMP     MAIN

      ORG      0023H
      LJMP     UART_ISR
;-----
      ORG      0100H
MAIN:
      CLR      BUSY
      CLR      EA
      MOV      SP,    #3FH
```

```

#if (PARITYBIT == NONE_PARITY)
    MOV  SCON,    #50H                ;8-bit variable UART
#elif (PARITYBIT == ODD_PARITY) || (PARITYBIT == EVEN_PARITY) || (PARITYBIT == MARK_PARITY)
    MOV  SCON,    #0DAH                ;9-bit variable UART, parity bit initial to 1
#elif (PARITYBIT == SPACE_PARITY)
    MOV  SCON,    #0D2H                ;9-bit variable UART, parity bit initial to 0
#endif
;-----
    MOV  A,        #0FBH                ;65536-18432000/32/115200 = 0xfffb
    MOV  TL2,      A
    MOV  RCAP2L,   A
    MOV  A,        #0FFH
    MOV  TH2,      A                    ;Set auto-reload vaule
    MOV  RCAP2H,   A
    MOV  T2CON     ,#34H                ;Timer2 start run
    SETB ES                    ;Enable UART interrupt
    SETB EA                    ;Open master interrupt switch
;-----
    MOV  DPTR,     #TESTSTR              ;Load string address to DPTR
    LCALL SENDSTRING                    ;Send string
;-----
    SJMP  $
;-----
TESTSTR:                                ;Test string
    DB  "STC89-90xx Uart Test !",0DH,0AH,0
; /*-----
;UART2 interrupt service routine
;-----*/
UART_ISR:
    PUSH  ACC
    PUSH  PSW
    JNB   RI,CHECKTI                    ;Check RI bit
    CLR   RI                            ;Clear RI bit
    MOV   P0,SBUF                       ;P0 show UART data
    MOV   C,RB8
    MOV   P2.2,C                        ;P2.2 show parity bit
CHECKTI:
    JNB   TI,ISR_EXIT                  ;Check S2TI bit
    CLR   TI                            ;Clear S2TI bit
    CLR   BUSY                          ;Clear transmit busy flag
ISR_EXIT:
    POP   PSW
    POP   ACC
    RETI

```

```
;/*-----
;Send a byte data to UART
;Input: ACC (data to be sent)
;Output:None
;-----*/
SENDATA:
    JB     BUSY,$           ;Wait for the completion of the previous data is sent
    MOV    ACC,A           ;Calculate the even parity bit P (PSW.0)
    JNB    P,      EVEN1INACC ;Set the parity bit according to P
EVEN1INACC:
#if (PARITYBIT == ODD_PARITY)
    CLR    TB8             ;Set parity bit to 0
#elif (PARITYBIT == EVEN_PARITY)
    SETB   TB8             ;Set parity bit to 1
#endif
    SJMP   PARITYBITOK
EVEN1INACC:
#if (PARITYBIT == ODD_PARITY)
    SETB   TB8             ;Set parity bit to 1
#elif (PARITYBIT == EVEN_PARITY)
    CLR    TB8             ;Set parity bit to 0
#endif
#endif
PARITYBITOK:      ;Parity bit set completed
    SETB   BUSY
    MOV    SBUF,  A        ;Send data to UART buffer
    RET

;/*-----
;Send a string to UART
;Input: DPTR (address of string)
;Output:None
;-----*/
SENDSTRING:
    CLR    A
    MOVC   A,      @A+DPTR ;Get current char
    JZ     STRINGEND      ;Check the end of the string
    INC    DPTR           ;increment string ptr
    LCALL  SENDATA        ;Send current char
    SJMP   SENDSTRING     ;Check next
STRINGEND:
    RET
;-----
    END
```

7.2.4 定时器2作可编程时钟输出及其测试程序(C程序及汇编程序)

STC89C51RC/RD+ 系列单片机，可设定定时/计数器2，通过P1.0输出时钟。P1.0除作通用I/O口外还有两个功能可供选用：用于定时/计数器2的外部计数输入和定时/计数器2时钟信号输出。图5 为时钟输出和外部事件计数方式示意图。

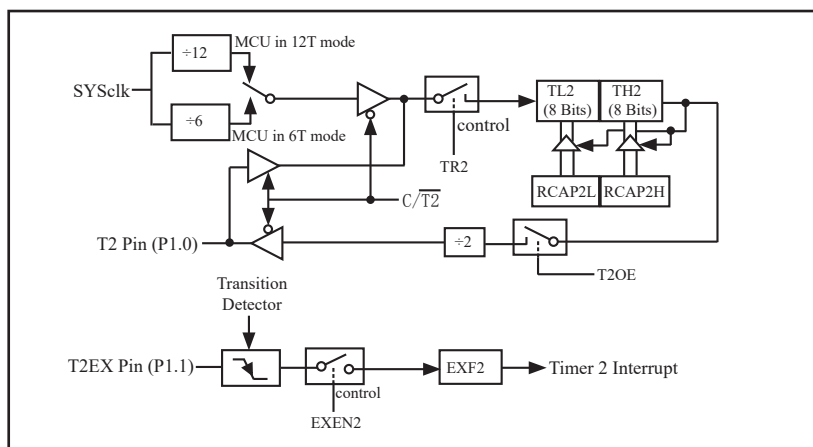


图5 定时器2的可编程时钟输出模式

通过软件对T2CON.1位C/T2复位为0，对T2MOD.1位T2OE置1就可将定时/计数器2选定为时钟信号发生器，而T2CON.2位TR2控制时钟信号输出开始或结束（TR2为启/停控制位）。由主振频率（SYSclk）和定时/计数器2定时、自动再装入方式的计数初值决定时钟信号的输出频率。其设置公式如下：

$$\text{模式1和模式3的波特率} = \frac{\text{SYSclk}}{n \times [65536 - (\text{RCAP2H}, \text{RCAP2L})]}$$

* n=2，6时钟/机器周期；n=4，12时钟/机器周期

从公式可见，在主振频率（SYSclk）设定后，时钟信号输出频率就取决于定时计数初值的设定。

在时钟输出模式下，计数器回0溢出不会产生中断请求。这种功能相当于定时/计数器2用作波特率发生器，同时又可以作时钟发生器。但必须注意，无论如何波特率发生器和时钟发生器不能单独确定各自不同的频率。原因是两者都用同一个陷阱寄存器RCAP2H、RCAP2L，不可能出现两个计数初值。

定时器2作可编程时钟输出演示程序

1、C程序清单：

```
/*-----*/
/* --- STC MCU International Limited -----*/
/* --- STC89-90xx Series Programmable Clock Output Demo -----*/
/* If you want to use the program or the program referenced in the */
/* article, please specify in which data and procedures from STC */
/*-----*/

#include "reg51.h"

typedef unsigned char BYTE;
typedef unsigned int WORD;
//-----
/* define constants */
#define FOSC 1843200L

#define F38_4KHz (65536-18432000/4/38400)

/* define SFR */

sfr T2CON = 0xc8;           //timer2 control register
sbit TF2 = T2CON^7;
sbit TR2 = T2CON^2;

sfr T2MOD = 0xc9;           //timer2 mode register
sfr RCAP2L = 0xca;
sfr RCAP2H = 0xcb;
sfr TL2 = 0xcc;
sfr TH2 = 0xcd;

sbit T2 = P1^0;             //Clock Output pin
//-----
/* main program */
void main()
{
    T2MOD = 0x02;           //enable timer2 output clock
    RCAP2L = TL2 = F38_4KHz; //initial timer2 low byte
    RCAP2H = TH2 = F38_4KHz >> 8; //initial timer2 high byte
    TR2 = 1;                //timer2 start running
    EA = 1;                 //open global interrupt switch

    while (1);              //loop
}
```

2、汇编程序清单：

```

/*-----*/
/* --- STC MCU International Limited -----*/
/* --- STC89-90xx Series Programmable Clock Output Demo -----*/
/* If you want to use the program or the program referenced in the */
/* article, please specify in which data and procedures from STC */
/*-----*/
;*/ define constants */
F38_4KHz EQU 0FF88H ;38.4KHz frequency calculation method of 12T mode (65536-18432000/4/38400)

;*/ define SFR */

T2CON EQU 0C8H ;timer2 control register
TF2 BIT T2CON.7
TR2 BIT T2CON.2

T2MOD EQU 0C9H ;timer2 mode register
RCAP2L EQU 0CAH
RCAP2H EQU 0CBH
TL2 EQU 0CCH
TH2 EQU 0CDH

T2 BIT P1.0 ;Clock Output pin
;-----
ORG 0000H
LJMP MAIN
;-----
;*/ main program */
MAIN:
MOV T2MOD, #02H ;enable timer2 output clock
MOV T2CON, #00H ;timer2 stop
MOV TL2, #00H ;initial timer2 low byte
MOV TH2, #00H ;initial timer2 high byte
MOV RCAP2L, #LOW F38_4KHz ;initial timer2 reload low byte
MOV RCAP2H, #HIGH F38_4KHz ;initial timer2 reload high byte
SETB TR2 ;timer2 start running
SJMP $
;-----
END

```

7.2.5 定时器/计数器2作定时器的测试程序(C程序及汇编程序)

1、C程序清单：

```
/*-----*/
/* --- STC MCU International Limited -----*/
/* --- STC89-90xx Series 16-bit Timer Demo -----*/
/* If you want to use the program or the program referenced in the */
/* article, please specify in which data and procedures from STC */
/*-----*/

#include "reg51.h"

typedef unsigned char BYTE;
typedef unsigned int WORD;
//-----

/* define constants */
#define FOSC 1843200L

#define T1MS (65536-FOSC/12/1000)           //1ms timer calculation method in 12T mode

/* define SFR */
sbit ET2 = IE^5;

sfr T2CON = 0xc8;                          //timer2 control register
sbit TF2 = T2CON^7;
sbit TR2 = T2CON^2;

sfr T2MOD = 0xc9;                          //timer2 mode register
sfr RCAP2L = 0xca;
sfr RCAP2H = 0xcb;
sfr TL2 = 0xcc;
sfr TH2 = 0xcd;

sbit TEST_LED = P1^0;                     //work LED, flash once per second

/* define variables */
WORD count;                               //1000 times counter
//-----
```

```

/* Timer2 interrupt routine */
void tm2_isr() interrupt 5 using 1
{
    TF2 = 0;
    if (count-- == 0)                //1ms * 1000 -> 1s
    {
        count = 1000;                //reset counter
        TEST_LED = ! TEST_LED;       //work LED flash
    }
}
//-----
/* main program */
void main()
{
    RCAP2L = TL2 = T1MS;              //initial timer2 low byte
    RCAP2H = TH2 = T1MS >> 8;         //initial timer2 high byte
    TR2 = 1;                          //timer2 start running
    ET2 = 1;                          //enable timer2 interrupt
    EA = 1;                           //open global interrupt switch
    count = 0;                        //initial counter

    while (1);                        //loop
}

```

2、汇编程序清单：

```

/*-----*/
/* --- STC MCU International Limited -----*/
/* --- STC89-90xx Series 16-bit Timer Demo -----*/
/* If you want to use the program or the program referenced in the */
/* article, please specify in which data and procedures from STC */
/*-----*/

;/* define constants */
T1MS    EQU    0FA00H                ;1ms(1000Hz) timer (65536-18432000/12/1000)

;/* define SFR */
ET2     BIT     IE.5

```

```
T2CON EQU    0C8H           ;timer2 control register
TF2    BIT    T2CON.7
TR2    BIT    T2CON.2

T2MOD EQU    0C9H           ;timer2 mode register
RCAP2L EQU    0CAH
RCAP2H EQU    0CBH
TL2    EQU    0CCH
TH2    EQU    0CDH

TEST_LED BIT P1.0           ;work LED, flash once per second

; /* define variables */
COUNT DATA 30H           ;1000 times counter (2 bytes)

;-----

ORG 0000H
LJMP MAIN
ORG 002BH
LJMP TM2_ISR

;-----

; /* main program */
MAIN:
    MOV    T2MOD,#00H        ;initial timer2 mode
    MOV    T2CON,#00H        ;timer2 stop
    MOV    TL2,#00H          ;initial timer2 low byte
    MOV    TH2,#00H          ;initial timer2 high byte
    MOV    RCAP2L,#LOW T1MS   ;initial timer2 reload low byte
    MOV    RCAP2H,#HIGH T1MS ;initial timer2 reload high byte
    SETB   TR2               ;timer2 start running
    SETB   ET2               ;enable timer2 interrupt
    SETB   EA                ;open global interrupt switch
    CLR    A
    MOV    COUNT,A
    MOV    COUNT+1,A          ;initial counter
    SJMP   $

;-----
```

```
;/* Timer2 interrupt routine */
```

```
TM2_ISR:
```

```
    PUSH    ACC
    PUSH    PSW
    CLR     TF2
    MOV     A,    COUNT
    ORL     A,    COUNT+1           ;check whether count(2byte) is equal to 0
    JNZ     SKIP
    MOV     COUNT, #LOW 1000        ;1ms * 1000 -> 1s
    MOV     COUNT+1,    #HIGH 1000
    CPL     TEST_LED               ;work LED flash
```

```
SKIP:
```

```
    CLR     C
    MOV     A,    COUNT           ;count--
    SUBB    A,    #1
    MOV     COUNT, A
    MOV     A,    COUNT+1
    SUBB    A,    #0
    MOV     COUNT+1,A
    POP     PSW
    POP     ACC
    RETI
```

```
;-----
```

```
END
```

第8章 串行口通信

STC89C51RC/RD+系列单片机内部集成有一个功能很强的全双工串行通信口，与传统8051单片机的串口完全兼容。设有2个互相独立的接收、发送缓冲器，可以同时发送和接收数据。发送缓冲器只能写入而不能读出，接收缓冲器只能读出而不能写入，，因而两个缓冲器可以共用一个地址码（99H）。两个缓冲器统称串行通信特殊功能寄存器SBUF。

串行通信设有4种工作方式，其中两种方式的波特率是可变的，另两种是固定的，以供不同应用场合选用。波特率由内部定时器/计数器产生，用软件设置不同的波特率和选择不同的工作方式。主机可通过查询或中断方式对接收/发送进行程序处理，使用十分灵活。

STC89C51RC/RD+系列单片机串行口对应的硬件部分对应的管脚是P3.0/RxD和P3.1/TxD。

STC89C51RC/RD+系列单片机的串行通信口，除用于数据通信外，还可方便地构成一个或多个并行I/O口，或作串一并转换，或用于扩展串行外设等。

8.1 串行口相关寄存器

符号	描述	地址	位地址及符号										复位值
			MSB					LSB					
SCON	Serial Control	98H	SM0/FE	SM1	SM2	REN	TB8	RB8	TI	RI	0000 0000B		
SBUF	Serial Buffer	99H											xxxx xxxxB
PCON	Power Control	87H	SMOD	SMOD0	-	POF	GF1	GF0	PD	IDL	00x1 0000B		
IE	Interrupt Enable	A8H	EA	-	ET2	ES	ET1	EX1	ET0	EX0	0x00 0000B		
IPH	中断优先级寄存器高	B7H	-	-	PT2H	PSH	PT1H	PX1H	PT0H	PX0H	xx00 0000B		
IP	中断优先级寄存器低	B8H	-	-	PT2	PS	PT1	PX1	PT0	PX0	xx00 0000B		
SADEN	Slave Address Mask	B9H											0000 0000B
SADDR	Slave Address	A9H											0000 0000B

1. 串行口控制寄存器SCON和PCON

STC89C51RC/RD+系列单片机的串行口设有两个控制寄存器：串行控制寄存器SCON和波特率选择特殊功能寄存器PCON。

串行控制寄存器SCON用于选择串行通信的工作方式和某些控制功能。其格式如下：

SCON：串行控制寄存器（可位寻址）

SFR name	Address	bit	B7	B6	B5	B4	B3	B2	B1	B0
SCON	98H	name	SM0/FE	SM1	SM2	REN	TB8	RB8	TI	RI

SM0/FE：当PCON寄存器中的SMOD0/PCON.6位为1时，该位用于帧错误检测。当检测到一个无效停止位时，通过UART接收器设置该位。它必须由软件清零。

当PCON寄存器中的SMOD0/PCON.6位为0时，该位和SM1一起指定串行通信的工作方式，如下表所示。

其中SM0、SM1按下列组合确定串行口的工作方式：

SM0	SM1	工作方式	功能说明	波特率
0	0	方式0	同步移位串行方式：移位寄存器	波特率是SYSclk/12,
0	1	方式1	8位UART, 波特率可变	$(2^{SMOD}/32) \times (\text{定时器1的溢出率})$
1	0	方式2	9位UART	$(2^{SMOD}/64) \times \text{SYSclk系统工作时钟频率}$
1	1	方式3	9位UART, 波特率可变	$(2^{SMOD}/32) \times (\text{定时器1的溢出率})$
当单片机工作在12T模式时，定时器1的溢出率 = SYSclk/12/(256 - TH1); 当单片机工作在6T模式时， 定时器1的溢出率 = SYSclk / 6 / (256 - TH1)				

- SM2：允许方式2或方式3多机通信控制位。在方式2或方式3时，如SM2位为1，REN位为1，则从机处于只有接收到RB8位为1（地址帧）时才激活中断请求标志位RI为1，并向主机请求中断处理。被确认为寻址的从机则复位SM2位为0，从而才接收RB8为0的数据帧。
 在方式1时，如果SM2位为1，则只有在接收到有效的停止位时才置位中断请求标志位RI为1；在方式0时，SM2 应为0。
- REN：允许/禁止串行接收控制位。由软件置位REN，即REN=1为允许串行接收状态，可启动串行接收器RxD，开始接收信息。软件复位REN，即REN=0，则禁止接收。
- TB8：在方式2或方式3，它为要发送的第9位数据，按需要由软件置位或清0。例如，可用作数据的校验位或多机通信中表示地址帧/数据帧的标志位。
- RB8：在方式2或方式3，是接收到的第9位数据。在方式1，若SM2=0，则RB8是接收到的停止位。方式0不用RB8。
- TI：发送中断请求中断标志位。在方式0，当串行发送数据第8位结束时，由内部硬件自动置位，即TI=1，向主机请求中断，响应中断后必须用软件复位，即TI=0。在其他方式中，则在停止位开始发送时由内部硬件置位，必须用软件复位。

RI: 接收中断请求标志位。在方式0，当串行接收到第8位结束时由内部硬件自动置位RI=1，向主机请求中断，响应中断后必须用软件复位，即RI=0。在其他方式中，串行接收到停止位的中间时刻由内部硬件置位，即RI=1（例外情况见SM2说明），必须由软件复位，即RI=0。

SCON的所有位可通过整机复位信号复位为全“0”。SCON的字节地址尾98H，可位寻址，各位地址为98H~9FH，可用软件实现位设置。当用指令改变SCON的有关内容时，其改变的状态将在下一条指令的第一个机器周期的S1P1状态发生作用。如果一次串行发送已经开始，则输出TB8将是原先的值，不是新改变的值。

串行通信的中断请求：当一帧发送完成，内部硬件自动置位TI，即TI=1，请求中断处理；当接收完一帧信息时，内部硬件自动置位RI，即RI=1，请求中断处理。由于TI和RI以“或逻辑”关系向主机请求中断，所以主机响应中断时事先并不知道是TI还是RI请求的中断，必须在中断服务程序中查询TI和RI进行判别，然后分别处理。因此，两个中断请求标志位均不能由硬件自动置位，必须通过软件清0，否则将出现一次请求多次响应的错误。

电源控制寄存器PCON中的SMOD/PCON.7用于设置方式1、方式2、方式3的波特率是否加倍。

电源控制寄存器PCON格式如下：

PCON：电源控制寄存器（不可位寻址）

SFR name	Address	bit	B7	B6	B5	B4	B3	B2	B1	B0
PCON	87H	name	SMOD	SMOD0	-	POF	GF1	GF0	PD	IDL

SMOD: 波特率选择位。当用软件置位SMOD，即SMOD=1，则使串行通信方式1、2、3的波特率加倍；SMOD=0，则各工作方式的波特率加倍。复位时SMOD=0。

SMOD0: 帧错误检测有效控制位。当SMOD0=1，SCON寄存器中的SM0/FE位用于FE（帧错误检测）功能；当SMOD0=0，SCON寄存器中的SM0/FE位用于SM0功能，和SM1一起指定串行口的工作方式。复位时SMOD0=0

2. 串行口数据缓冲寄存器SBUF

STC89xx系列单片机的串行口缓冲寄存器(SBUF)的地址是99H，实际是2个缓冲器，写SBUF的操作完成待发送数据的加载，读SBUF的操作可获得已接收到的数据。两个操作分别对应两个不同的寄存器，1个是只写寄存器，1个是只读寄存器。

串行通道内设有数据寄存器。在所有的串行通信方式中，在写入SBUF信号的控制下，把数据装入相同的9位移位寄存器，前面8位为数据字节，其最低位为移位寄存器的输出位。根据不同的工作方式会自动将“1”或TB8的值装入移位寄存器的第9位，并进行发送。

串行通道的接收寄存器是一个输入移位寄存器。在方式0时它的字长为8位，其他方式时为9位。当一帧接收完毕，移位寄存器中的数据字节装入串行数据缓冲器SBUF中，其第9位则装入SCON寄存器中的RB8位。如果由于SM2使得已接收到的数据无效时，RB8和SBUF中内容不变。

由于接收通道内设有输入移位寄存器和SBUF缓冲器，从而能使一帧接收完将数据由移位寄存器装入SBUF后，可立即开始接收下一帧信息，主机应在该帧接收结束前从SBUF缓冲器中将数据取走，否则前一帧数据将丢失。SBUF以并行方式送往内部数据总线。

3. 从机地址控制寄存器SADEN和SADDR

为了方便多机通信，STC89C51RC/RD+系列单片机设置了从机地址控制寄存器SADEN和SADDR。其中SADEN是从机地址掩模寄存器(地址为B9H，复位值为00H)，SADDR是从机地址寄存器(地址为A9H，复位值为00H)。

4. 与串行口中断相关的寄存器IE和IPH、IP

串行口中断允许位ES位于中断允许寄存器IE中，中断允许寄存器的格式如下：

IE：中断允许寄存器（可位寻址）

SFR name	Address	bit	B7	B6	B5	B4	B3	B2	B1	B0
IE	A8H	name	EA	-	ET2	ES	ET1	EX1	ET0	EX0

EA：CPU的总中断允许控制位，EA=1，CPU开放中断，EA=0，CPU屏蔽所有的中断申请。

EA的作用是使中断允许形成多级控制。即各中断源首先受EA控制；其次还受各中断源自己的中断允许控制位控制。

ES：串行口中断允许位，ES=1，允许串行口中断，ES=0，禁止串行口中断。

串行口中断优先级控制位PS/PSH位于中断优先级控制寄存器IP/IPH中，中断优先级控制寄存器的格式如下：

IPH：中断优先级控制寄存器高（不可位寻址）

SFR name	Address	bit	B7	B6	B5	B4	B3	B2	B1	B0
IPH	B7H	name	PX3H	PX2H	PT2H	PSH	PT1H	PX1H	PT0H	PX0H

IP：中断优先级控制寄存器低（可位寻址）

SFR name	Address	bit	B7	B6	B5	B4	B3	B2	B1	B0
IP	B8H	name	-	-	PT2	PS	PT1	PX1	PT0	PX0

PSH, PS：串口1中断优先级控制位。

当PSH=0且PS=0时，串口1中断为最低优先级中断(优先级0)

当PSH=0且PS=1时，串口1中断为较低优先级中断(优先级1)

当PSH=1且PS=0时，串口1中断为较高优先级中断(优先级2)

当PSH=1且PS=1时，串口1中断为最高优先级中断(优先级3)

8.2 串行口工作模式

STC89C51RC/RD+系列单片机的串行通信有4种工作模式，可通过软件编程对SCON中的SM0、SM1的设置进行选择。其中模式1、模式2和模式3为异步通信，每个发送和接收的字符都带有1个启动位和1个停止位。在模式0中，串行口被作为1个简单的移位寄存器使用。

8.2.1 串行口工作模式0：同步移位寄存器

在模式0状态，串行通信工作在同步移位寄存器模式，当单片机工作在6T模式时，其波特率固定为 $SYSClk/6$ 。当单片机工作在12T时，其波特率固定为 $SYSClk/12$ 。串行口数据由RxD(RxD/P3.0)端输入，同步移位脉冲(SHIFTCLOCK)由TxD(TxD/P3.1)输出，发送、接收的是8位数据，低位在先。

模式0的发送过程：当主机执行将数据写入发送缓冲器SBUF指令时启动发送，串行口即将8位数据以 $SYSClk/12$ 或 $SYSClk/6$ 的波特率从RxD管脚输出(从低位到高位)，发送完中断标志TI置“1”，TxD管脚输出同步移位脉冲(SHIFTCLOCK)。波形如图8-1中“发送”所示。

当写信号有效后，相隔一个时钟，发送控制端SEND有效(高电平)，允许RxD发送数据，同时允许TxD输出同步移位脉冲。一帧(8位)数据发送完毕时，各控制端均恢复原状态，只有TI保持高电平，呈中断申请状态。在再次发送数据前，必须用软件将TI清0。

模式0接收过程：模式0接收时，复位接收中断请求标志RI，即 $RI=0$ ，置位允许接收控制位REN=1时启动串行模式0接收过程。启动接收过程后，RxD为串行输入端，TxD为同步脉冲输出端。串行接收的波特率为 $SYSClk/12$ 或 $SYSClk/6$ 。其时序图如图8-1中“接收”所示。

当接收完成一帧数据(8位)后，控制信号复位，中断标志RI被置“1”，呈中断申请状态。当再次接收时，必须通过软件将RI清0。

工作于模式0时，必须清0多机通信控制位SM2，使不影响TB8位和RB8位。由于波特率固定为 $SYSClk/12$ 或 $SYSClk/6$ ，无需定时器提供，直接由单片机的时钟作为同步移位脉冲。

串行口工作模式0的示意图如图8-1所示

由示意图中可见，由TX和RX控制单元分别产生中断请求信号并置位 $TI=1$ 或 $RI=1$ ，经“或门”送主机请求中断，所以主机响应中断后必须软件判别是TI还是RI请求中断，必须软件清0中断请求标志位TI或RI。

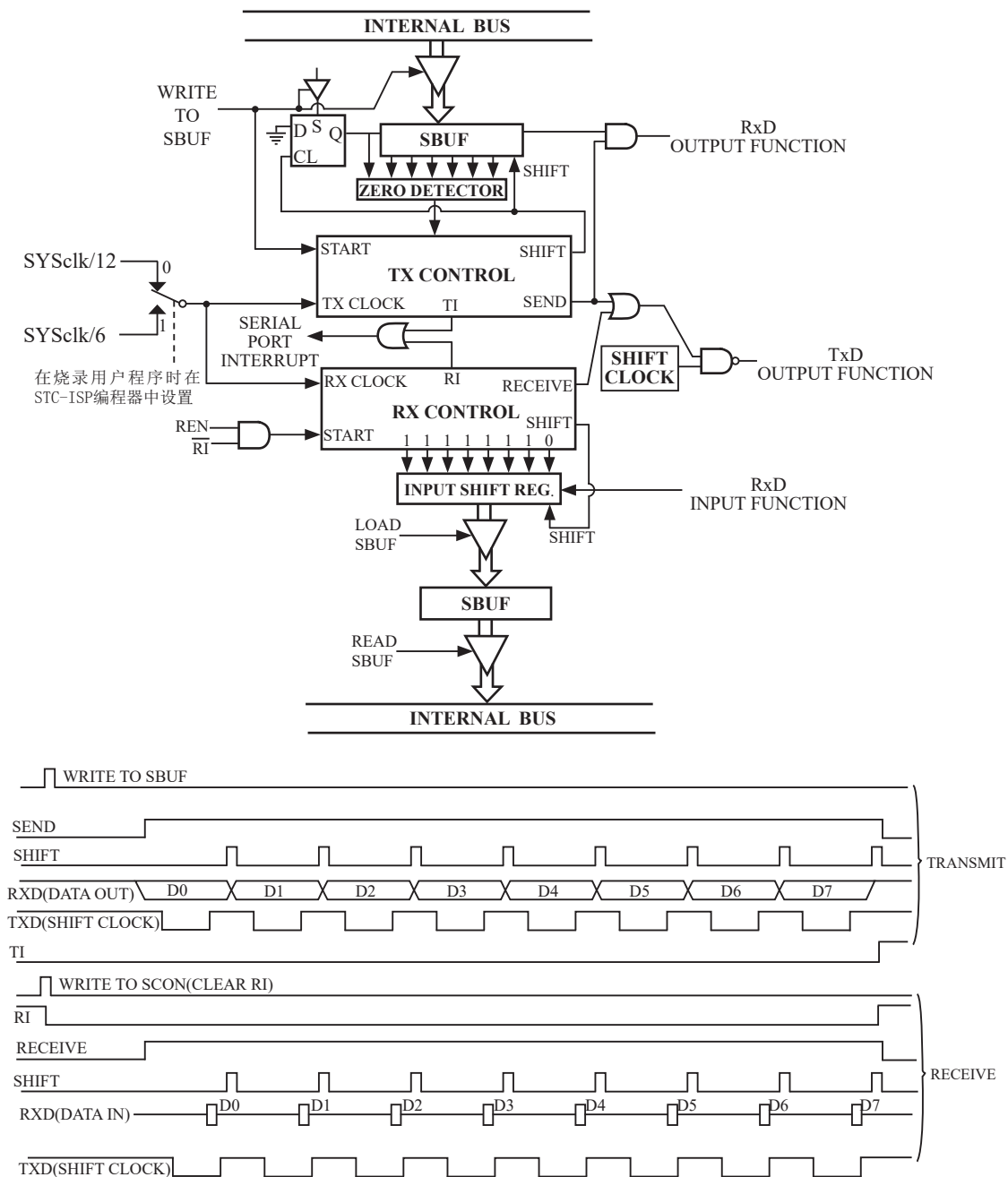


图8-1 串行口模式0功能结构及时序示意图

8.2.2 串行口工作模式1：8位UART，波特率可变

当软件设置SCON的SM0、SM1为“01”时，串行通信则以模式1工作。此模式为8位UART格式，一帧信息为10位：1位起始位，8位数据位（低位在先）和1位停止位。波特率可变，即可根据需要进行设置。TxD(TxD/P3.1)为发送信息，RxD(RxD/P3.0)为接收端接收信息，串行口为全双工接受/发送串行口。

图8-2为串行模式1的功能结构示意图及接收/发送时序图

模式1的发送过程：串行通信模式发送时，数据由串行发送端TxD输出。当主机执行一条写“SBUF”的指令就启动串行通信的发送，写“SBUF”信号还把“1”装入发送移位寄存器的第9位，并通知TX控制单元开始发送。发送各位的定时是由16分频计数器同步。

移位寄存器将数据不断右移送TxD端口发送，在数据的左边不断移入“0”作补充。当数据的最高位移到移位寄存器的输出位置，紧跟其后的是第9位“1”，在它的左边各位全为“0”，这个状态条件，使TX控制单元作最后一次移位输出，然后使允许发送信号“SEND”失效，完成一帧信息的发送，并置位中断请求位TI，即TI=1，向主机请求中断处理。

模式1的接收过程：当软件置位接收允许标志位REN，即REN=1时，接收器便以选定波特率的16分频的速率采样串行接收端口RxD，当检测到RxD端口从“1”→“0”的负跳变时就启动接收器准备接收数据，并立即复位16分频计数器，将1FFH值装入移位寄存器。复位16分频计数器是使它与输入位时间同步。

16分频计数器的16个状态是将1波特率（每位接收时间）均为16等份，在每位时间的7、8、9状态由检测器对RxD端口进行采样，所接收的值是这次采样直径“三中取二”的值，即3次采样至少2次相同的值，以此消除干扰影响，提高可靠性。在起始位，如果接收到的值不为“0”（低电平），则起始位无效，复位接收电路，并重新检测“1”→“0”的跳变。如果接收到的起始位有效，则将它输入移位寄存器，并接收本帧的其余信息。

接收的数据从接收移位寄存器的右边移入，已装入的1FFH向左边移出，当起始位“0”移到移位寄存器的最左边时，使RX控制器作最后一次移位，完成一帧的接收。若同时满足以下两个条件：

- RI=0;
- SM2=0或接收到的停止位为1。

则接收到的数据有效，实现装载入SBUF，停止位进入RB8，置位RI，即RI=1，向主机请求中断，若上述两条件不能同时满足，则接收到的数据作废并丢失，无论条件满足与否，接收器重又检测RxD端口上的“1”→“0”的跳变，继续下一帧的接收。接收有效，在响应中断后，必须由软件清0，即RI=0。通常情况下，串行通信工作于模式1时，SM2设置为“0”。

串行通信模式1的波特率是可变的，可变的波特由定时器/计数器1或独立波特率发生器产生。

串行通信模式1的波特率= $2^{\text{SMOD}}/32 \times (\text{定时器/计数器1溢出率})$

当单片机工作在12T模式时，定时器1的溢出率 = $\text{SYSclk}/12/(256 - \text{TH1})$;

当单片机工作在6T模式时，定时器1的溢出率 = $\text{SYSclk}/6/(256 - \text{TH1})$

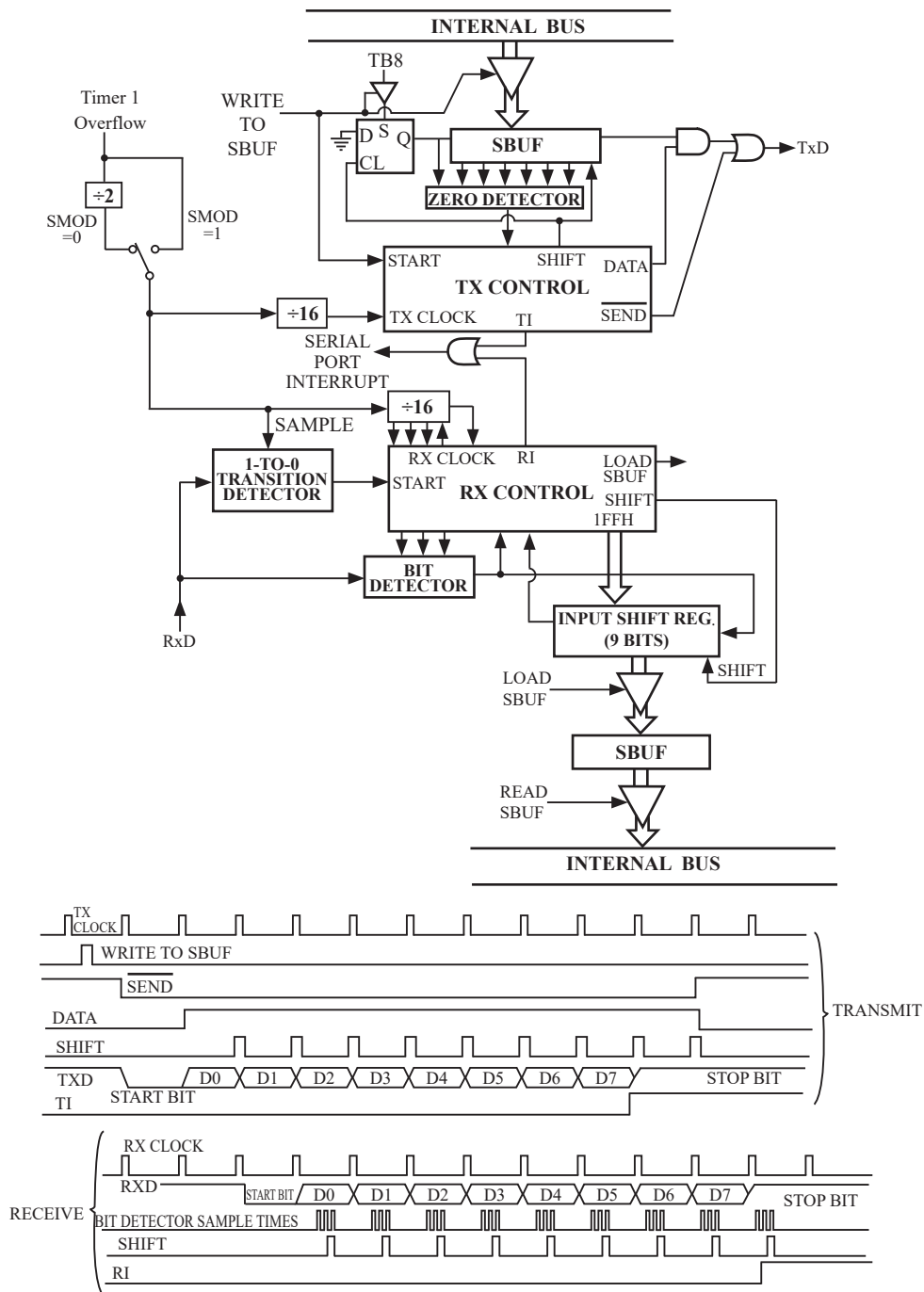


图8-2 串行口模式1功能结构示意图及接收/发送时序图

8.2.3 串行口工作模式2：9位UART，波特率固定

当SM0、SM1两位为10时，串行口工作在模式2。串行口工作模式2为9位数据异步通信UART模式，其一帧的信息由11位组成：1位起始位，8位数据位（低位在先），1位可编程位（第9位数据）和1位停止位。发送时可编程位（第9位数据）由SCON中的TB8提供，可软件设置为1或0，或者可将PSW中的奇/偶校验位P值装入TB8（TB8既可作为多机通信中的地址数据标志位，又可作为数据的奇偶校验位）。接收时第9位数据装入SCON的RB8。TxD为发送端口，RxD为接收端口，以全双工模式进行接收/发送。

模式2的波特率为：

串行通信模式2波特率 $=2^{\text{SMOD}}/64 \times (\text{SYSclk系统工作时钟频率})$

上述波特率可通过软件对PCON中的SMOD位进行设置，当SMOD=1时，选择1/32 (SYSclk)；当SMOD=0时，选择1/64 (SYSclk)，故而称SMOD为波特率加倍位。可见，模式2的波特率基本上是固定的。

图8-3为串行通信模式2的功能结构示意图及其接收/发送时序图。

由图8-3可知，模式2和模式1相比，除波特率发生源略有不同，发送时由TB8提供给移位寄存器第9数据位不同外，其余功能结构均基本相同，其接收/发送操作过程及时序也基本相同。

当接收器接收完一帧信息后必须同时满足下列条件：

- RI=0
- SM2=0或者SM2=1，并且接收到的第9数据位RB8=1。

当上述两条件同时满足时，才将接收到的移位寄存器的数据装入SBUF和RB8中，并置位RI=1，向主机请求中断处理。如果上述条件有一个不满足，则刚接收到移位寄存器中的数据无效而丢失，也不置位RI。无论上述条件满足与否，接收器又重新开始检测RxD输入端口的跳变信息，接收下一帧的输入信息。

在模式2中，接收到的停止位与SBUF、RB8和RI无关。

通过软件对SCON中的SM2、TB8的设置以及通信协议的约定，为多机通信提供了方便。

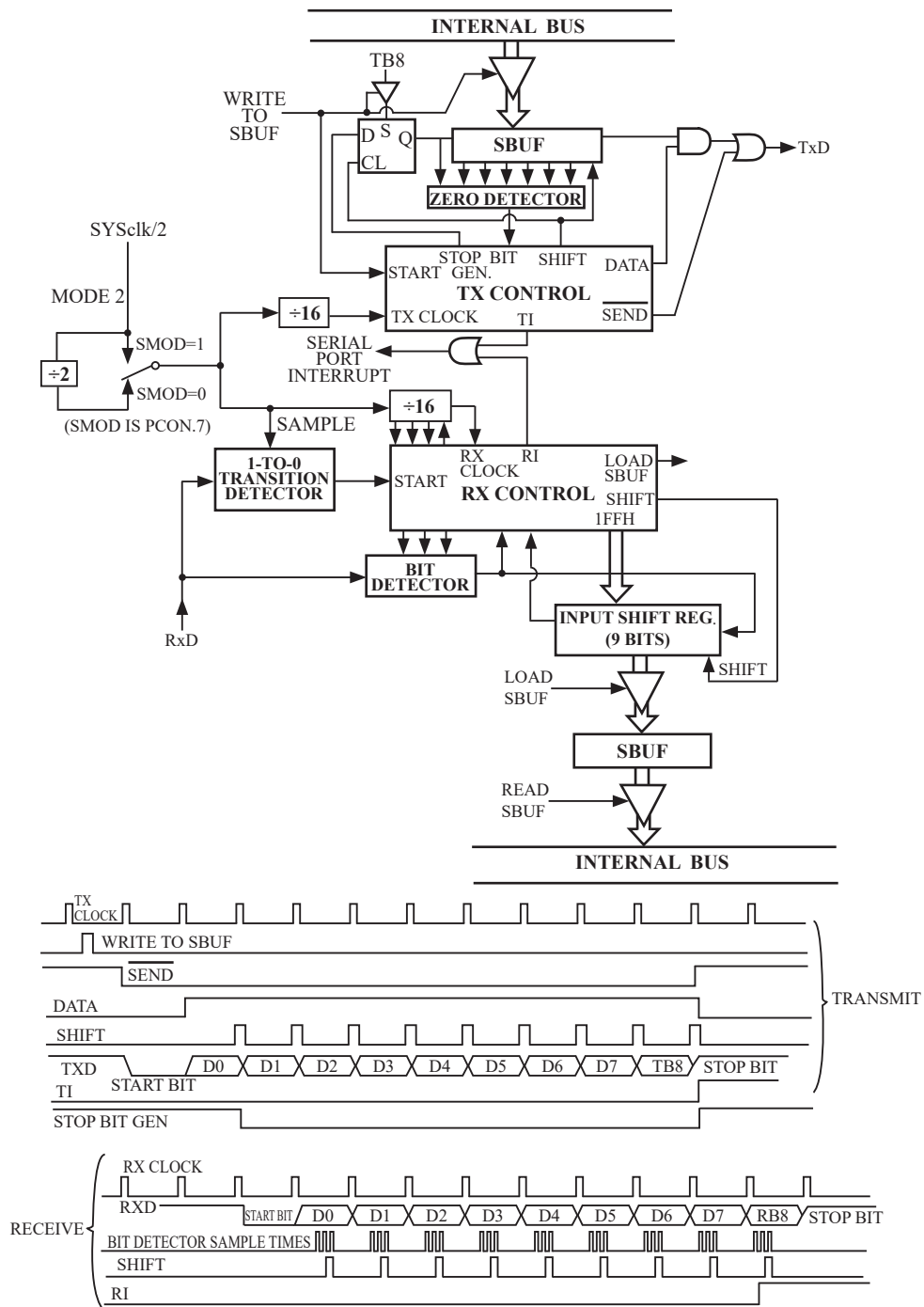


图8-3 串行口模式2功能结构示意图及接收/发送时序图

8.2.4 串行口工作模式3：9位UART，波特率可变

当SM0、SM1两位为11时，串行口工作在模式3。串行通信模式3为9位数据异步通信UART模式，其一帧的信息由11位组成：1位起始位，8位数据位（低位在先），1位可编程位（第9位数据）和1位停止位。发送时可编程位（第9位数据）由SCON中的TB8提供，可软件设置为1或0，或者可将PSW中的奇/偶校验位P值装入TB8（TB8既可作为多机通信中的地址数据标志位，又可作为数据的奇偶校验位）。接收时第9位数据装入SCON的RB8。TxD为发送端口，RxD为接收端口，以全双工模式进行接收/发送。

模式3的波特率为：

串行通信模式3波特率 $=2^{SMOD}/32 \times (\text{定时器/计数器1的溢出率})$

当单片机工作在12T模式时，定时器1的溢出率 $= \text{SYSclk}/12 / (256 - \text{TH1})$ ；

当单片机工作在6T模式时，定时器1的溢出率 $= \text{SYSclk} / 6 / (256 - \text{TH1})$

可见，模式3和模式1一样，其波特率可通过软件对定时器/计数器1或独立波特率发生器的设置进行波特率的选择，是可变的。

图8-4为串行口工作模式3的功能结构示意图及其接收/发送时序图。

由图8-4可知，模式3和模式1相比，除发送时由TB8提供给移位寄存器第9数据位不同外，其余功能结构均基本相同，其接收‘发送操作过程及时序也基本相同。

当接收器接收完一帧信息后必须同时满足下列条件：

- RI=0
- SM2=0或者SM2=1，并且接收到的第9数据位RB8=1。

当上述两条件同时满足时，才将接收到的移位寄存器的数据装入SBUF和RB8中，并置位RI=1，向主机请求中断处理。如果上述条件有一个不满足，则刚接收到移位寄存器中的数据无效而丢失，也不置位RI。无论上述条件满足与否，接收器又重新开始检测RxD输入端口的跳变信息，接收下一帧的输入信息。

在模式3中，接收到的停止位与SBUF、RB8和RI无关。

通过软件对SCON中的SM2、TB8的设置以及通信协议的约定，为多机通信提供了方便。

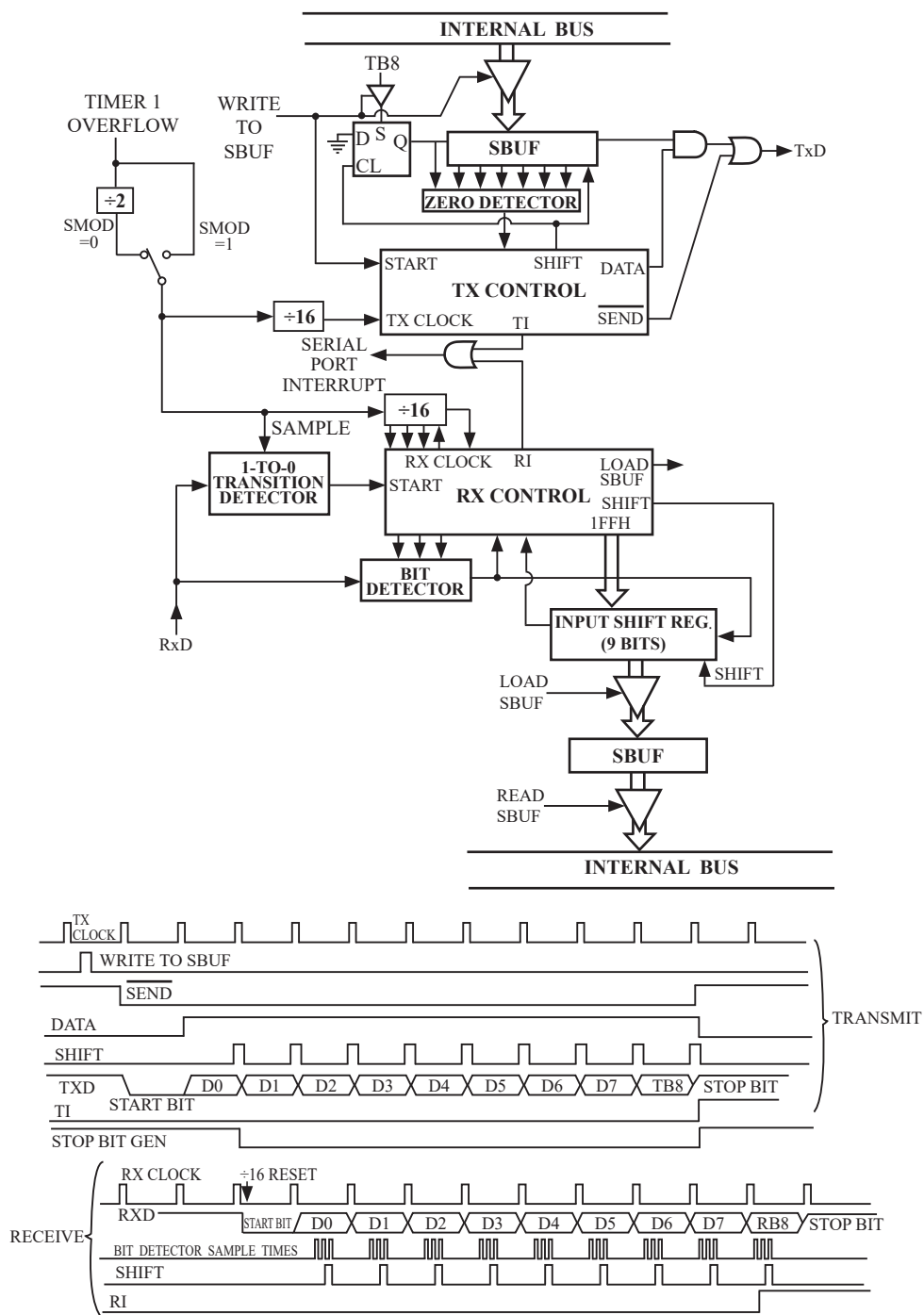


图8-4 串行口模式3功能结构示意图及接收/发送时序图

8.3 串行通信中波特率的设置

STC89C51RC/RD+系列单片机串行通信的波特率随所选工作模式的不同而异，对于工作模式0和模式2，其波特率与系统时钟频率SYSclk和PCON中的波特率选择位SMOD有关，而模式1和模式3的波特率除与SYSclk和PCON位有关外，还与定时器/计数器1或BRT独立波特率发生器设置有关。通过对定时器/计数器1或BRT独立波特率发生器的设置，可选择不同的波特率，所以这种波特率是可变的。

串行通信模式0，其波特率与系统时钟频率SYSclk有关。

当用户在烧录用户程序时在STC-ISP编程器中设置单片机为6T/双倍速时，其波特率 = SYSclk/12。

当用户在烧录用户程序时在STC-ISP编程器中设置单片机为12T/单倍速时，其波特率 = SYSclk/2。

一旦SYSclk选定且单片机在烧录用户程序时在STC-ISP编程器设置好，则串行通信工作模式0的波特率固定不变。

串行通信工作模式2，其波特率除与SYSclk有关外，还与SMOD位有关。

其基本表达式为：串行通信模式2波特率 = $2^{\text{SMOD}}/64 \times (\text{SYSclk系统工作时钟频率})$

当SMOD=1时，波特率 = $2/64(\text{SYSclk}) = 1/32(\text{SYSclk})$ ；

当SMOD=0时，波特率 = $1/64(\text{SYSclk})$ 。

当SYSclk选定后，通过软件设置PCON中的SMOD位，可选择两种波特率。所以，这种模式的波特率基本固定。

串行通信模式1和3，其波特率是可变的：

模式1、3波特率 = $2^{\text{SMOD}}/32 \times (\text{定时器/计数器1的溢出率或BRT独立波特率发生器的溢出率})$

当单片机工作在12T模式时，定时器1的溢出率 = $\text{SYSclk}/12 / (256 - \text{TH1})$ ；

当单片机工作在6T模式时，定时器1的溢出率 = $\text{SYSclk}/6 / (256 - \text{TH1})$

通过对定时器/计数器1和BRT独立波特率发生器的设置，可灵活地选择不同的波特率。在实际应用中多半选用串行模式1或串行模式3。显然，为选择波特率，关键在于定时器/计数器1和BRT独立波特率发生器的溢出率的计算。SMOD的选择，只需根据需要执行下列指令就可实现SMOD=0或1；

```
MOV    PCON, #00H      ; 使SMOD=0
MOV    PCON, #80H      ; 使SMOD=1
```

SMOD只占用电源控制寄存器PCON的最高一位，其他各位的具体设置应根据实际情况而定。

为选择波特率，关键在于定时器/计数器1的溢出率。下面介绍如何计算定时器/计数器1的溢出率。

定时器/计数器1的溢出率定义为：单位时间（秒）内定时器/计数器1回0溢出的次数，即定时器/计数器1的溢出率=定时器/计数器1的溢出次数/秒。

STC89C51RC/RD+系列单片机设有两个定时器/计数器，因定时器/计数器1具有4种工作方式,而常选用定时器/计数器1的工作方式2（8位自动重装）作为波特率的溢出率。

设置定时器/计数器1工作于定时模式的工作方式2（8位自动重装），TL1的计数输入来自于SYSc1k经12分频或不分频的脉冲。当单片机工作在12T模式，TL1的计数输入来自于SYSc1k经12分频的脉冲；当单片机工作在6T模式，TL1的计数输入来自于SYSc1k经6分频的脉冲。可见，定时器/计数器1的溢出率与SYSc1k和自动重装值N有关，SYSc1k越大，特别是N越大，溢出率也就越高。对于一般情况下，

当单片机工作在12T模式时时，定时器/计数器1溢出一次所需的时间为：

$$(2^8-N) \times 12\text{时钟} = (2^8-N) \times 12 \times \frac{1}{\text{SYSc1k}}$$

当单片机工作在6T模式时，定时器/计数器1溢出一次所需的时间为：

$$(2^8-N) \times 6\text{时钟} = (2^8-N) \times 6 \times \frac{1}{\text{SYSc1k}}$$

于是得定时器/计数器每秒溢出的次数，即

当单片机工作在12T模式时，定时器/计数器1的溢出率=SYSc1k/12×(2⁸-N) (次/秒)

当单片机工作在6T模式时，定时器/计数器1的溢出率=SYSc1k×6×(2⁸-N) (次/秒)

式中SYSc1k为系统时钟频率，N为再装入时间常数。

显然，选用定时器/计数器0作波特率的溢出率也一样。选用不同工作方式所获得波特率的范围不同。因为不同方式的计数位数不同，N取值范围不同，且计数方式较复杂。

下表给出各种常用波特率与定时器/计数器1各参数之间的关系。

常用波特率与定时器/计数器1各参数关系（T1x12/AUXR. 6=0）

常用波特率		系统时钟频率 (MHz)	SMOD	定时器1		
				C/T	方式	重新装入值
方式0 MAX: 1M		12	×	×	×	×
方式2 MAX: 375K		12	1	×	×	×
方式1和3	62.5K	12	1	0	2	FFH
	19.2K	11.059	1	0	2	FDH
	9.6K	11.059	0	0	2	FDH
	4.8K	11.059	0	0	2	FAH
	2.4K	11.059	0	0	2	F4H
	1.2K	11.059	0	0	2	F8H
	137.5	11.986	0	0	2	1DH
	110	6	0	0	2	72H
	110	12	0	0	1	FFFBH

设置波特率的初始化程序段如下：

```

      :
MOV   TMOD, #20H      ; 设置定时器/计数器1定时、工作方式2
MOV   TH1,   #××H     ; 设置定时常数N
MOV   TL1,   #××H     ;
SETB  TR1          ; 启动定时器/计数器1
MOV   PCON,  #80H     ; 设置SMOD=1
MOV   SCON,  #50H     ; 设置串行通信方式1
      :
```

执行上述程序段后，即可完成对定时器/计数器1的操作方式及串行通信的工作方式和波特率的设置。

由于用其他方式设置波特率计算方法较复杂，一般应用较少，故不一一论述。

8.4 串行口的测试程序(C程序及汇编程序)

1. C程序:

```

/*-----*/
/* --- STC MCU International Limited -----*/
/* --- 演示STC89xx系列单片机串行口功能 (8-bit/9-bit) -----*/
/* 如果要在程序中使用或在文章中引用该程序, -----*/
/* 请在程序或文章中注明使用了宏晶科技的资料及程序 -----*/
/*-----*/

#include "reg51.h"
#include "intrins.h"

typedef unsigned char BYTE;
typedef unsigned int WORD;

#define FOSC 1843200L           //System frequency
#define BAUD 9600              //UART baudrate

/*Define UART parity mode*/
#define NONE_PARITY    0       //None parity
#define ODD_PARITY     1       //Odd parity
#define EVEN_PARITY    2       //Even parity
#define MARK_PARITY    3       //Mark parity
#define SPACE_PARITY   4       //Space parity

#define PARITYBIT EVEN_PARITY  //Testing even parity

sbit bit9 = P2^2;              //P2.2 show UART data bit9
bit busy;

void SendData(BYTE dat);
void SendString(char *s);

void main()
{
    #if (PARITYBIT == NONE_PARITY)
        SCON = 0x50;           //8-bit variable UART
    #elif (PARITYBIT == ODD_PARITY) || (PARITYBIT == EVEN_PARITY) || (PARITYBIT == MARK_PARITY)
        SCON = 0xda;           //9-bit variable UART, parity bit initial to 1
    #elif (PARITYBIT == SPACE_PARITY)
        SCON = 0xd2;           //9-bit variable UART, parity bit initial to 0
    #endif

```

```
        TMOD = 0x20;                                //Set Timer1 as 8-bit auto reload mode
        TH1 = TL1 = -(FOSC/12/32/BAUD);              //Set auto-reload vaule
        TR1 = 1;                                     //Timer1 start run
        ES = 1;                                       //Enable UART interrupt
        EA = 1;                                       //Open master interrupt switch

        SendString("STC89-90xx\r\nUart Test !\r\n");
        while(1);
    }

    /*-----
    UART interrupt service routine
    -----*/
    void Uart_Isr() interrupt 4 using 1
    {
        if (RI)
        {
            RI = 0;                                //Clear receive interrupt flag
            P0 = SBUF;                              //P0 show UART data
            bit9 = RB8;                             //P2.2 show parity bit
        }
        if (TI)
        {
            TI = 0;                                //Clear transmit interrupt flag
            busy = 0;                              //Clear transmit busy flag
        }
    }

    /*-----
    Send a byte data to UART
    Input: dat (data to be sent)
    Output:None
    -----*/
    void SendData(BYTE dat)
    {
        while (busy);                              //Wait for the completion of the previous data is sent
        ACC = dat;                                  //Calculate the even parity bit P (PSW.0)
        if (P)                                       //Set the parity bit according to P
        {
            #if (PARITYBIT == ODD_PARITY)
                TB8 = 0;                            //Set parity bit to 0
            #elif (PARITYBIT == EVEN_PARITY)
                TB8 = 1;                            //Set parity bit to 1
            #endif
        }
    }
```

```
    else
    {
        #if (PARITYBIT == ODD_PARITY)
            TB8 = 1;                //Set parity bit to 1
        #elif (PARITYBIT == EVEN_PARITY)
            TB8 = 0;                //Set parity bit to 0
        #endif
    }
    busy = 1;
    SBUF = ACC;                    //Send data to UART buffer
}

/*-----
Send a string to UART
Input: s (address of string)
Output:None
-----*/
void SendString(char *s)
{
    while (*s)                    //Check the end of the string
    {
        SendData(*s++);          //Send current char and increment string ptr
    }
}
```

2. 汇编程序:

```
/*-----*/
/* --- STC MCU International Limited -----*/
/* --- 演示STC89xx系列单片机串行口功能 (8-bit/9-bit) -----*/
/* 如果要在程序中使用或在文章中引用该程序, -----*/
/* 请在程序中或文章中注明使用了宏晶科技的资料及程序 -----*/
/*-----*/

;*/Define UART parity mode*/
#define NONE_PARITY    0           //None parity
#define ODD_PARITY     1           //Odd parity
#define EVEN_PARITY    2           //Even parity
#define MARK_PARITY    3           //Mark parity
#define SPACE_PARITY   4           //Space parity

#define PARITYBIT EVEN_PARITY      //Testing even parity
;-----
        BUSY    BIT        20H.0      ;transmit busy flag
;-----
        ORG      0000H
        LJMP     MAIN

        ORG      0023H
        LJMP     UART_ISR
;-----
        ORG      0100H
MAIN:
        CLR      BUSY
        CLR      EA
        MOV      SP,    #3FH
#if (PARITYBIT == NONE_PARITY)
        MOV      SCON,  #50H           ;8-bit variable UART
#elif (PARITYBIT == ODD_PARITY) || (PARITYBIT == EVEN_PARITY) || (PARITYBIT == MARK_PARITY)
        MOV      SCON,  #0DAH         ;9-bit variable UART, parity bit initial to 1
#elif (PARITYBIT == SPACE_PARITY)
        MOV      SCON,  #0D2H         ;9-bit variable UART, parity bit initial to 0
#endif
;-----
```

```

MOV    TMOD, #20H                ;Set Timer1 as 8-bit auto reload mode
MOV    A,    #0FBH                ;256-18432000/12/32/9600
MOV    TH1,   A                ;Set auto-reload vaule
MOV    TL1,   A
SETB   TR1                      ;Timer1 start run
SETB   ES                      ;Enable UART interrupt
SETB   EA                      ;Open master interrupt switch
;-----
MOV    DPTR, #TESTSTR            ;Load string address to DPTR
LCALL  SENDSTRING                ;Send string
;-----
SJMP   $
;-----
TESTSTR:
    DB  "STC89-90xx Uart Test !",0DH,0AH,0

; /*-----
;UART2 interrupt service routine
;-----*/
UART_ISR:
    PUSH  ACC
    PUSH  PSW
    JNB   RI,    CHECKTI          ;Check RI bit
    CLR   RI          ;Clear RI bit
    MOV   P0,    SBUF            ;P0 show UART data
    MOV   C,     RB8
    MOV   P2.2,  C                ;P2.2 show parity bit
CHECKTI:
    JNB   TI,    ISR_EXIT        ;Check S2TI bit
    CLR   TI          ;Clear S2TI bit
    CLR   BUSY      ;Clear transmit busy flag
ISR_EXIT:
    POP   PSW
    POP   ACC
    RETI

; /*-----
;Send a byte data to UART
;Input: ACC (data to be sent)
;Output:None
;-----*/

```

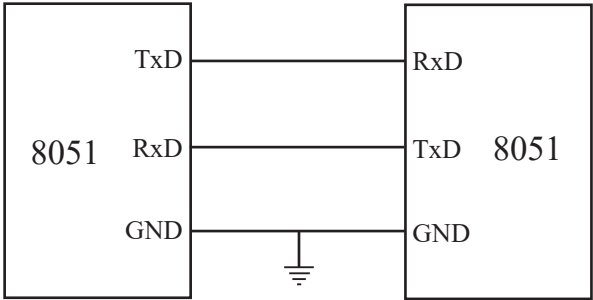
```
SENDATA:
    JB     BUSY,  $           ;Wait for the completion of the previous data is sent
    MOV    ACC,   A           ;Calculate the even parity bit P (PSW.0)
    JNB    P,     EVEN1INACC  ;Set the parity bit according to P
ODD1INACC:
    #if (PARITYBIT == ODD_PARITY)
        CLR    TB8           ;Set parity bit to 0
    #elif (PARITYBIT == EVEN_PARITY)
        SETB    TB8          ;Set parity bit to 1
    #endif
    SJMP    PARITYBITOK
EVEN1INACC:
    #if (PARITYBIT == ODD_PARITY)
        SETB    TB8          ;Set parity bit to 1
    #elif (PARITYBIT == EVEN_PARITY)
        CLR    TB8           ;Set parity bit to 0
    #endif
    PARITYBITOK:              ;Parity bit set completed
        SETB    BUSY
        MOV    SBUF,  A       ;Send data to UART buffer
        RET

;-----
;Send a string to UART
;Input: DPTR (address of string)
;Output:None
;-----*/
SENDSTRING:
    CLR    A
    MOVC   A,    @A+DPTR      ;Get current char
    JZ     STRINGEND         ;Check the end of the string
    INC    DPTR              ;increment string ptr
    LCALL  SENDATA           ;Send current char
    SJMP   SENDSTRING        ;Check next
STRINGEND:
    RET
;-----
END
```

8.5 双机通信

STC89C51RC/RD+系列单片机的串行通信根据其应用可分为双机通信和多机通信两种。下面先介绍双机通信。

如果两个8051应用系统相距很近，可将它们的串行端口直接相连（TXD—RXD，RXD—TXD，GND—GND—地），即可实现双机通信。为了增加通信距离，减少通道及电源干扰，可采用RS—232C或RS—422、RS—485标准进行双机通信，两通信系统之间采用光—电隔离技术，以减少通道及电源的干扰，提高通信可靠性。



为确保通信成功，通信双方必须在软件上有系列的约定通常称为软件通信“协议”。现举例简介双机异步通信软件“协议”如下：

通信双方均选用2400波特的传输速率，设系统的主频SYSclk=6MHz,甲机发送数据，乙机接收数据。在双机开始通信时，先由甲机发送一个呼叫信号（例如“06H”），以询问乙机是否可以接收数据；乙机接收到呼叫信号后，若同意接收数据，则发回“00H”作为应答信号，否则发“05H”表示暂不能接收数据，；甲机只有在接收到乙机的应答信号“00H”后才可将存储在外数据存储器中的内容逐一发送给乙机，否则继续向乙机发呼叫信号，直到乙机同意接收。其发送数据格式如下：

字节数n	数据1	数据2	数据3	…	数据n	累加校验和
------	-----	-----	-----	---	-----	-------

字节数n：甲机向乙机发送的数据个数；

数据1~数据n：甲机将向乙机发送的n帧数据；

累加校验和：为字节数n、数据1、…、数据n,这(n+1)个字节内容的算术累加和。

乙机根据接收到的“校验和”判断已接收到的n个数据是否正确。若接收正确,向甲机回发“0FH”信号,否则回发“F0H”信号。甲机只有在接收到乙机发回的“0FH”信号才算完成发送任务，返回被调用的程序，否则继续呼叫，重发数据。

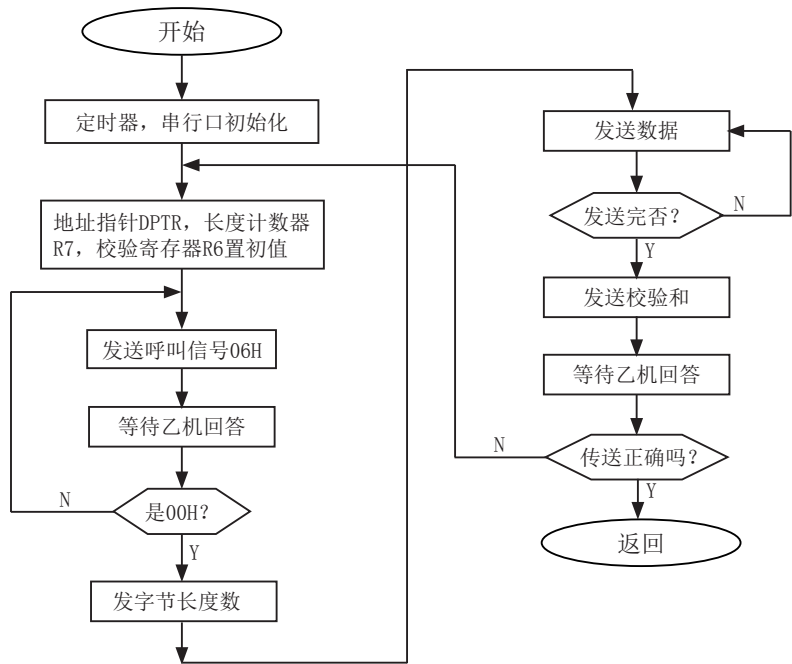
不同的通信要求，软件“协议”内容也不一样，有关需甲、乙双方共同遵守的约定应尽量完善，以防止通信不能正确判别而失败。

STC89C51RC/RD+系列单片机的串行通信，可直接采用查询法，也可采用自动中断法。

(1) 查询方式双机通信软件举例

①甲机发送子程序段

下图为甲机发送子程序流程图。



甲机发送程序设置：

- (a) 波特率设置：选用定时器/计数器1定时模式、工作方式2，计数常数F3H，SMOD=1。波特率为2400（位/秒）；
- (b) 串行通信设置：异步通信方式1，允许接收；
- (c) 内部RAM和工作寄存器设置：31H和30H单元存放发送的数据块首地址；2FH单元存放发送的数据块个数；R6为累加和寄存器。

甲机发送子程序清单：

```

START:
    MOV    TMOD, #20H        ; 设置定时器/计数器1定时、工作方式2
    MOV    TH1,  #0F3H      ; 设置定时计数常数
    MOV    TL1,  #0F3H      ;
    MOV    SCON, #50H        ; 串口初始化
    MOV    PCON, #80H        ; 设置SMOD=1
    SETB   TR1               ; 启动定时

ST-RAM:
    MOV    DPH,   31H        ; 设置外部RAM数据指针
    MOV    DPL,   30H        ; DPTR初值
    MOV    R7,    2FH        ; 发送数据块数送R7
    MOV    R6,    #00H       ; 累加和寄存器R6清0

TX-ACK:
    MOV    A,     #06H        ;
    MOV    SBUF,  A           ; } 发送呼叫信号“06H”

WAIT1:
    JBC    TI,    RX-YES      ; 等待发送完呼叫信号
    SJMP   WAIT1             ; 未发送完转WAIT1

RX-YES:
    JBC    RI,    NEXT1       ; 判断乙机回答信号
    SJMP   RX-YES            ; 未收到回答信号，则等待

NEXT1:
    MOV    A,     SBUF        ; 接收回答信号送A
    CJNE   A,     #00H, TX-ACK ; 判断是否“00H”，否则重发呼叫信号

TX-BYT:
    MOV    A,     R7           ;
    MOV    SBUF,  A           ; } 发送数据块数n
    ADD    A,     R6
    MOV    R6,    A

WAIT2:
    JBC    TI,    TX-NES      ;
    JMP    WAIT2             ; } 等待发送完

TX-NES:
    MOVX   A,     @DPTR       ; 从外部RAM取发送数据
    MOV    SBUF,  A           ; 发送数据块
    ADD    A,     R6
    MOV    R6,    A
    INC    DPTR              ; DPTR指针加1

```

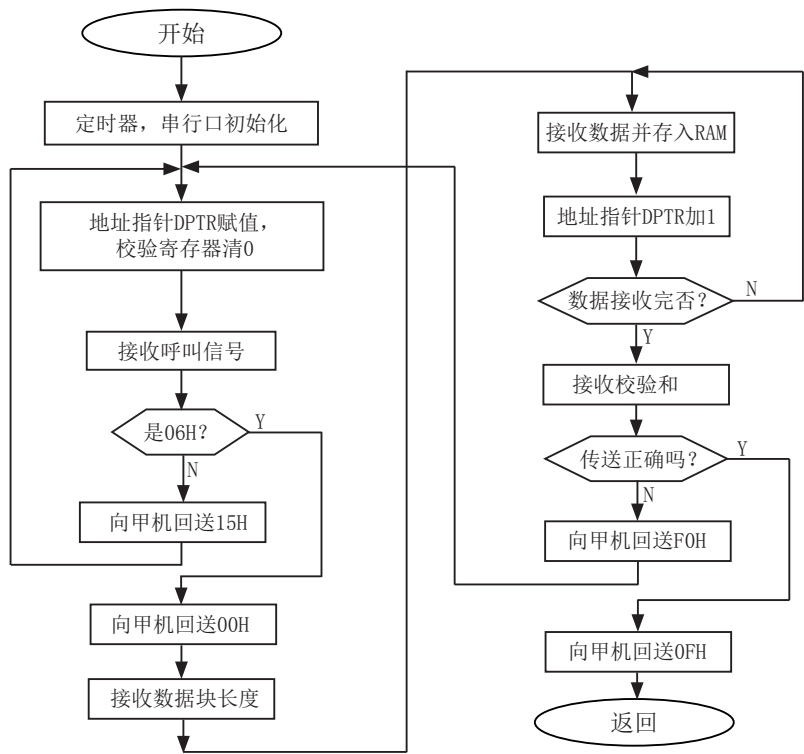
```
WAIT3:
    JBC    TI,      NEXT2      ; 判断一数据块发送完否
    SJMP   WAIT3              ; 等待发送完
NEXT2:
    DJNZ   R7,      TX-NES     ; 判断发送全部结束否
TX-SUM:
    MOV    A,       R6         ; 发送累加和给乙机
    MOV    SBUF,    A
WAIT4:
    JBC    TI,      RX-0FH     ; }
    SJMP   WAIT4              ; } 等待发送完
RX-0FH:
    JBC    RI,      IF-0FH     ; }
    SJMP   RX-0FH             ; } 等待接收乙机回答信号
IF-0FH:
    MOV    A,       SBUF;      ; }
    CJNE   A,       #0FH,    ST-RAM ; } 判断传输是否正确，否则重新发送
    RET                                ; 返回
```

乙机接收子程序段

接收程序段的设置：

- (a) 波特率设置初始化：同发送程序；
- (b) 串行通信初始化：同发送程序；
- (c) 寄存器设置：
内部RAM 31H、30H单元存放接收数据缓冲区首地址。
R7——数据块个数寄存器。
R6——累加和寄存器。
- (d) 向甲机回答信号：“0FH”为接收正确，“F0H”为传送出错，“00H”为同意接收数据，“05H”为暂不接收。

下图为双机通信查询方式乙机接收子程序流程图。



接收子程序清单:

TART:

MOV	TMOD,	#20H	
MOV	TH1,	#0F3H	
			}
MOV	TL1,	#0F3H	; 定时器/计数器1设置
SETB	TR1		; 启动定时器/计数器1
MOV	SCON,	#50H	; 置串行通信方式1, 允许接收
			}
MOV	PCON,	#80H	; SMOD置位
			}
ST-RAM:			
MOV	DPH,	31H	
			}
MOV	DPL,	30H	; 设置DPTR首地址
MOV	R6,	#00H	; 校验和寄存器清0

RX-ACK:

JBC	RI,	IF-06H	; 判断接收呼叫信号
SJMP	RX-ACK		; 等待接收呼叫信号

IF-06H:

MOV	A,	SBUF	; 呼叫信号送A
CJNEA	#06H,	TX-05H	; 判断呼叫信号正确否?

TX-00H:

MOV	A,	#00H	;
MOV	SBUF,	A	; } 向甲机发送“00H”，同意接收

WAIT1:

JBC	TI,	RX-BYS	; 等待应答信号发送完
SJMP	WAIT1		

TX-05H:

MOV	A,	#05H	; 向甲机发送“05H”呼叫
MOV	SBUF,	A	; 不正确信号

WAIT2:

JBC	TI,	HAVE1	; 等待发送完
SJMP	WAIT2		

HAVE1:

LJMP	RX-ACK		; 因呼叫错，返回重新接收呼叫
------	--------	--	-----------------

RX-BYS:

JBC	RI,	HAVE2	; 等待接收数据块个数
SJMP	RX-BYS		;

HAVE2:

MOV	A,	SBUF	;
MOV	R7,	A	; 数据块个数帧送R7,R6
MOV	R6,	A	;

RX-NES:

JBC	RI,	HAVE3	;
SJMP	RX-NES		; } 接收数据帧

HAVE3:

MOV	A,	SBUF	;
MOVX	@DPTR,	A	; 接收到的数据存入外部RAM
INC	DPTR		;
ADD	A,	R6	;
MOV	R6,	A	; } 形成累加和
DJNZ	R7,	RX-NES	; 判断数据是否接收完

```
RX-SUM:
    JBC    RI,    HAVE4                ; }
    SJMP   RX-SUM                    ; } 等待接收校验和
HAVE4:
    MOV    A,    SBUF                ; }
    CJNE   A,    R6,    TX-ERR        ; } 判断传输是否正确
TX-RIT:
    MOV    A,    #0FH                ; }
    MOV    SBUF, A                    ; } 向甲机发送接收正确信息
WAIT3:
    JBC    TI,    GOOD                ; }
    SJMP   WAIT3                     ; } 等待发送结束
TX-ERR:
    MOV    A,    #0F0H                ; 向甲机发送传输有误信号
    MOV    SBUF, A
WAIT4:
    JBC    TI,    AGAIN                ; 等待发送完
    SJMP   WAIT4
AGAIN:
    LJMP   ST-RAM                    ; 返回重新开始接收
GOOD:
    RET                                ; 传输正确返回
```

(2) 中断方式双机通信软件举例

在很多应用场合，双机通信的双方或一方采用中断方式以提高通信效率。由于STC-89C51RC/RD+系列单片机的串行通信是双工的，且中断系统只提供一个中断矢量入口地址，所以实际上是中断和查询必须相结合，即接收/发送均可各自请求中断，响应中断时主机并不知道是谁请求中断，统一转入同一个中断矢量入口，必须由中断服务程序查询确定并转入对应的服务程序进行处理。

这里，任以上述协议为例，甲方（发送方）任以查询方式通信（从略），乙方（接收方）则改用中断—查询方式进行通信。

在中断接收服务程序中，需设置三个标志位来判断所接收的信息是呼叫信号还是数据块个数，是数据还是校验和。增设寄存器：内部RAM32H单元为数据块个数寄存器，33H单元为校验和寄存器，位地址7FH、7EH、7DH为标志位。

乙机接收中断服务程序清单

采用中断方式时，应在主程序中安排定时器/计数器、串行通信等初始化程序。通信接收的数据存放在外部RAM的首地址也需在主程序中确定。

主程序：

```

    ORG    0000H
    AJMP   START                ; 转至主程序起始处
    ORG    0023H
    LIMP   SERVE                ; 转中断服务程序处
    .
    .
    .

START:
    MOV    TMOD, #20H           ; 定义定时器/计数器1定时、工作方式2
    MOV    TH1,  #0F3H         ;
    MOV    TL1,  #0F3H         ; } 设置波特率为2400位/秒
    MOV    SCON, #50H          ; 设置串行通信方式1，允许接收
    MOV    PCON, #80H          ; 设置SMOD=1
    SETB   TR1                 ; 启动定时器
    SETB   7FH                 ;
    SETB   7EH                 ; 设置标志位为1
    SETB   7DH                 ;
    MOV    31H, #10H           ; 规定接收的数据存储于外部RAM的
                                ;
    MOV    30H, #00H           ; } 起始地址1000H
    MOV    33H, #00H           ; } 累加和单元清0
    SETB   EA                 ;
    SETB   ES                 ; } 开中断
    .
    .
    .
```

中断服务程序:

SERVE:

```

    CLR    EA                ; 关中断
    CLR    RI                ; 清除接收中断请求标志
    PUSH   DPH               ;
    PUSH   DPL               ; 现场保护
    PUSH   A                 ;
    JB     7FH,    RXACK      ; 判断是否是呼叫信号
    JB     7EH,    RXBYS      ; 判断是否是数据块数据
    JB     7DH,    RXDATA     ; 判断是否是接收数据帧

```

RXSUM:

```

    MOV    A,    SBUF        ; 接收到的校验和
    CJNE   A,    33H,    TXERR ; 判断传输是否正确

```

TXRI:

```

    MOV    A,    #0FH        ;
    MOV    SBUF,  A          ; } 向甲机发送接收正确信号“0FH”

```

WAIT1:

```

    JNB    TI,    WAITI      ; 等待发送完毕
    CLR    TI                ; 清除发送中断请求标志位
    SJMP   AGAIN            ; 转结束处理

```

TXERR:

```

    MOV    A,    #0F0H       ;
    MOV    SBUF,  A          ; } 向甲机发送接收出错信号“F0H”

```

WAIT2:

```

    JNB    TI,    WAIT2      ; 等待发送完毕
    CLR    TI                ; 清除发送中断请求标志
    SJMP   AGAIN            ; 转结束处理

```

RXACK:

```

    MOV    A,    SBUF        ; 判断是否是呼叫信号“06H”
    XRL    A,    #06H        ; 异或逻辑处理
    JZ     TXREE             ; 是呼叫, 则转TXREE

```

TXNACK:

```

    MOV    A,    #05H        ; 接收到的不是呼叫信号, 则向甲机发送
    MOV    SBUF,  A          ; “05H”, 要求重发呼叫

```

WAIT3:

```
JNB    TI,      WAIT3      ; 等待发送结束
CLR     TI
SJMP    RETURN             ; 转恢复现场处理
```

TXREE:

```
MOV     A,      #00H        ; 接收到的是呼叫信号，发送“00H”
MOV     SBUF,   A           ; 接收到的是呼叫信号，发送“00H”
```

WAIT4:

```
JNB     TI,      WAIT4      ; 等待发送完毕
CLR      TI       ; 清除TI标志
CLR      7FH      ; 清除呼叫标志
SJMP     RETURN    ; 转恢复现场处理
```

RXBYS:

```
MOV     A,      SBUF        ; 接收到数据块数
MOV     32H,    A           ; 存入32H单元
ADD     A,      33H          ; }
MOV     33H,    A           ; } 形成累加和
CLR      7EH      ; 清除数据块数标志
SJMP     RETURN    ; 转恢复现场处理
```

RXDATA:

```
MOV     DPH,    31H          ; }
MOV     DPL,    30H          ; } 设置存储数据地址指针
MOV     A,      SBUF        ; 读取数据帧
MOVX    @DPTR, A             ; 将数据存外部RAM
INC     DPTR      ; 地址指针加1
MOV     31H,    DPH          ; }
MOV     30H,    DPL          ; } 保存地址指针值
ADD     A,      33H          ; }
MOV     33H,    A           ; } 形成累加和
DJNZ    32H,    RETURN      ; 判断数据接收完否
CLR      7DH      ; 清数据接收完标志
SJMP     RETURN    ; 转恢复现场处理
```

AGAIN:

```
SETB 7FH ;
SETB 7EH ; 恢复标志位
SETB 7DH ;
MOV 33H, #00H ; 累加和单元清0
MOV 31H, #10H ;
MOV 30H, #00H ; } 恢复接收数据缓冲区首地址
```

RETURN:

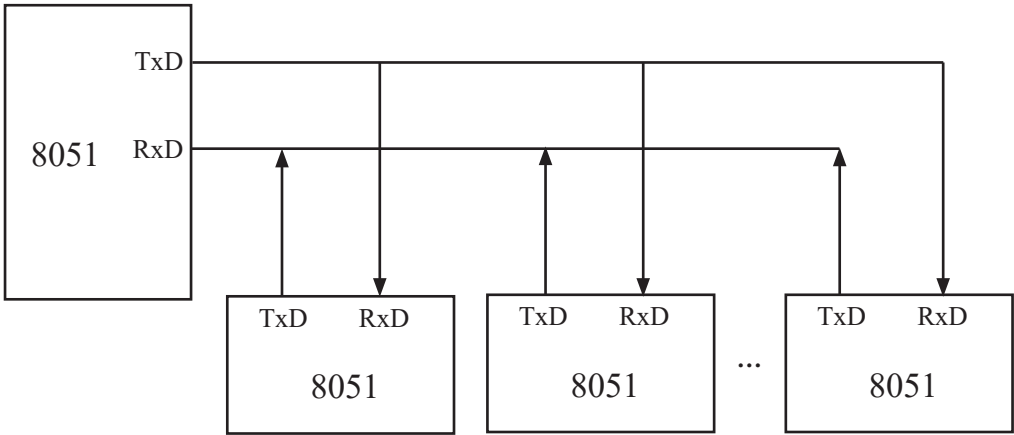
```
POP A ;
POP DPL ; 恢复现场
POP DPH ;
SETB EA ; 开中断
RET1 ; 返回
```

上述程序清单中，ORG为程序段说明伪指令，在程序汇编时，它向汇编程序说明该程序段的起始地址。

在实际应用中情况多种多样，而且是两台独立的计算机之间进行信息传输。因此，应周密考虑通信协议，以保证通信的正确性和成功率

8.6 多机通信

在很多实际应用系统中，需要多台微计算机协调工作。STC89C51RC/RD+系列单片机的串行通信方式2和方式3具有多机通信功能，可构成各种分布式通信系统。下图为全双工主从式多机通信系统的连接框图。



上图为一台主机和几台从机组成的全双工多机通信系统。主机可与任一从机通信，而从机之间的通信必须通过知己转发。

（1）多机通信的基本原理

在多机通信系统中，为保证主机（发送）与多台从机（接收）之间能可靠通信，串行通信必须具备识别能力。MCS-51系列单片机的串行通信控制寄存器SCON中设有多机通信选择位SM2。当程序设置SM2=1，串行通信工作于方式2或方式8，发送端通过对TB8的设置以区别于发送的是地址帧（TB8=1）还是数据帧（TB8=0），接收端通过对接收到RB8进行识别：当SM2=1，若接收到RB8=1，则被确认为呼叫地址帧，将该帧内容装入SBUF中，并置位RI=1，向CPU请求中断，进行地址呼叫处理；若RB8=0为数据帧，将不予理睬，接收的信息被丢弃。若SM2=0，则无论是地址帧还是数据帧均接收，并置位RI=1，向CPU请求中断，将该帧内容装入SBUF。据此原理，可实现多机通信。

对于上图的从机式多机通信系统，从机的地址为0，1，2，…，n。实现多机通信的过程如下：

- ① 置全部从机的SM2=1，处于只接收地址帧状态。
- ② 主机首先发送呼叫地址帧信息，将TB8设置为1，以表示发送的是 呼叫地址帧。
- ③ 所有从机接收到呼叫地址帧后，各自将接收到的主机呼叫的地址与本机的地址相比较：若比较结果相等，则为被寻址从机，清除SM2=0，准备接收从主机发送的数据帧，直至全部数据传输完；若比较不相等，则为非寻址从机，任维持SM2=1不变，对其后发来的数据帧不予理睬，即接收到的数据帧内容不装入SBUF，不置位，RI=0，不会产生中断请求，直至被寻址为止。

④ 主机在发送完呼叫地址帧后，接着发送一连串的数据帧，其中的TB8=0，以表示为数据帧。

⑤ 当主机改变从机通信时间则再发呼叫地址帧，寻呼其他从机，原先被寻址的从机经分析得知主机在寻呼其他从机时，恢复其SM2=1，对其后主机发送的数据帧不予理睬。

上述过程均在软件控制下实现。

(2) 多机通信协议简述

由于串行通信是在二台或多台各自完全独立的系统之间进行信息传

输这就需要根据时间通信要求制定某些约定，作为通信规范遵照执行，协议要求严格、完善，不同的通信要求，协议的内容也不相同。在多机通信系统中要考虑的问题较多，协议内容比较复杂。这里仅例举几条作一说明。

上图的主从式多机通信系统，允许配置255台从机，各从机的地址分别为00H~FEH。

① 约定地址FFH为全部从机的控制命令，命令各从机恢复SM2=1状态，准备接收主机的地址呼叫。

② 主机和从机的联络过程约定：主机首先发送地址呼叫帧，被寻址的从机回送本机地址给主机，经验证地址相符后主机再向被寻址的从机发送命令字，被寻址的从机根据命令字要求回送本机的状态，若主机判断状态正常，主机即开始发送或接收数据帧，发送或接收的第一帧为传输数据块长度。

③ 约定主机发送的命令字为：

00H：要求从机接收数据块；

01H：要求从机发送数据块；

·
·
·

其他：非法命令。

④ 从机的状态字格式约定为：

B7	B6	B5	B4	B3	B2	B1	B0
ERR	0	0	0	0	0	TRDY	RRDY

定义： 若ERR=1，从机接收到非法命令；

若TRDY=1，从机发送准备就绪；

若RRDY=1，从机接收准备就绪；

⑤ 其他：如传输出错措施等。

(3) 程序举例

在实际应用中如传输波特率不太高，系统实时性有一定要求以及希望提高通信效率，则多半采用中断控制方式，但程序调试较困难，这就要求提高程序编制的正确性。采用查询方式，则程序调试较方便。这里仅以中断控制方式为例简单介绍主—从机之间一对一通信软件。

① 主机发送程序

该主机要发送的数据存放在内部RAM中，数据块的首地址为51H，数据块长度存放做50H单元中，有关发送前的初始化、参数设置等采用子程序格式，所有信息发送均由中断服务程序完成。当主机需要发送时，在完成发送子程序的调用之后，随即返回主程序继续执行。以后只需查询PSW·5的P0标志位的状态即可知道数据是否发送完毕。

要求主机向#5从机发送数据，中断服务程序选用工作寄存器区1的R0~R7。

主机发送程序清单：

```

        ORG      0000H
        AJMP     MAIN                      ; 转主程序
        ORG      0023H                    ; 发送中断服务程序入口
        LJMP     SERVE                    ; 转中断服务程序
        :
        :
MAIN:    . . . . .                      ; 主程序
        :
        :
        ORG      1000H                    ; 发送子程序入口
TXCALL:
        MOV      TMOD, #20H                ; 设置定时器/计数器1定时、方式2
        MOV      TH1,  #0F3H              ; 设置波特率为2400位/秒
        MOV      TL1,  #0F3H              ; 置位SMOD
        MOV      PCON, #80H                ;
        SETB     TR1                      ; 启动定时器/计数器1
        MOV      SCON, #0D8H              ; 串行方式8，允许接收，TB8=1
        SETB     EA                        ; 开中断总控制位
        CLR      ES                        ; 禁止串行通信中断
TXADDR:
        MOV      SBUF, #05H                ; 发送呼叫从机地址
WAIT1:
        JNB      TI,      WAIT1            ; 等待发送完毕
        CLR      TI                      ; 复位发送中断请求标志
```

RXADDR:

JNB	RI,	RXADDR	; 等待从机回答本机地址
CLR	TI		; 复位接收中断请求标志
MOV	A,	SBUF	; 读取从机回答的本机地址
CJNE	A,	#05H, TXADDR	; 判断呼叫地址符否, 否则重发
CLR	TB8		; 地址相符, 复位TB8=0, 准备发数据
CLR	PSW.5		; 复位F0=0标志位
MOV	08H,	#50H	; 发送数据地址指针送R0
MOV	0CH,	50H	; 数据块长度送R4
INC	0CH		; 数据块长度加1
SETB	ES		; 允许串行通信中断
RET			; 返回主程序
:			
:			

SERVE:

CLR	TI	; 中断服务程序段, 清中断请求标志TI
PUSH	PSW	;
PUSH	A	; } 现场入栈保护
CLR	RS1	; }
SETB	RS0	; } 选择工作寄存器区1

TXDATA:

MOV	SBUF,	@R0	; 发送数据块长度及数据
-----	-------	-----	--------------

WAIT2:

JNB	TI,	WAIT2	; 等待发送完毕
CLR	TI		; 复位TI=0
INC	R0		; 地址指针加1
DJNZ	R4,	RETURN	; 数据块未发送完, 转返回
SETB	PSW.5		; 已发送完毕置位F0=1
CLR	ES		; 关闭串行中断

RETURN:

POP	A	; }
POP	PSW	; } 恢复现场
RETI		; 返回

②从机接收程序

主机发送的地址呼叫帧，所有的从机均接收，若不是呼叫本机地址即从中断返回；若是本机地址，则回送本机地址给主机作为应答，并开始接收主机发送来的数据块长度帧，并存放于内部RAM的60H单元中，紧接着接收的数据帧存放于61H为首地址的内部RAM单元中，程序中还选用20·0H、20·1H位作标志位，用来判断接收的是地址、数据块长度还是数据，选用了2FH、2EH两个字节单元用于存放数据字节数和存储数据指针。#5从机的接收程序如下，供参考。

#5从机接收程序清单：

```

    ORG    0000H
    AJMP   START                ; 转主程序段
    ORG    0023H
    LJMP   SERVE                ; 从中断入口转中断服务程序
    ORG    0100H

START:
    MOV    TMOD, #20H          ; 主程序段：初始化程序，设置定时
    MOV    TH1,  #0F3H         ; 器/计数器1定时、工作方式2，设
    MOV    TL1,  #0F3H         ; 置波特率为2400位/秒的有关初值
    MOV    PCON, #80H          ; 置位SMOD
    MOV    SCON, #0F0H         ; 设置串行方式3，允许接收，SM2=1
    SETB   TR1                 ; 启动定时器/计数器1
    SETB   20·0                ; }
    SETB   20·1                ; } 置标志位为1
    SETB   EA                  ; }
    SETB   ES                  ; } 开中断
    .
    .
    ORG    1000H

SERVE:
    CLR    RI                  ; 清接收请求中断标志RI=0
    PUSH   A                   ; }
    PUSH   PSW                 ; } 现场保护
    CLR    RS1                 ; }
    SETB   RS0                 ; } 选择工作寄存器区1
    JB     20·0H,  ISADDR       ; 判断是否是地址帧
    JB     20·1H,  ISBYTE       ; 判断是否是数据块长度帧
```

ISDATA:

```

MOV    R0,    2EH           ; 数据指针送R0
MOV    A,     SBUF           ; 接收数据
MOV    @R0,   A
INC     2EH                 ; 数据指针加1
DJNZ   2FH,   RETURN        ; 判断数据接收完否?
SETB   20·0H                ;
SETB   20·1H                ; 恢复标志位
SETB   SM2                  ;
SJMP   RETURN               ; 转入恢复现场, 返回

```

ISADDR:

```

MOV    A,     SBUF           ; 是地址呼叫, 判断与本机地址
                                }
CJNE   A,     #05H,  RETURN  ; 相符否, 不符则转返回
MOV    SBUF,  #01H           ; 相符, 发回答信号“01H”

```

WAIT:

```

JNB    TI,    WAIT          ; 等待发送结束
CLR    TI      ; 清0TI, 20·0, SM2
CLR    20·0H   ; 清0TI, 20·0, SM2
CLR    SM2     ; 清0TI, 20·0, SM2
SJMP   RETURN  ; 转返回

```

ISBYTES:

```

MOV    A,     SBUF           ; 接收数据块长度帧
MOV    R0,    #60H           ;
MOV    @R0,   A              ; 将数据块长度存入内部RAM
MOV    2FH,   A              ; 60H单元及2FH单元
MOV    2EH,   #61H           ; 置首地址61H于2EH单元
CLR    20·1H                ; 清20·1H标志, 表示以后接收的为数据

```

RETURN:

```

POP    PSW      ; }
POP    A        ; } 恢复现场
RETI                   ; 返回

```

多机通信方式可多种多样, 上例仅以最简单的住一从式作了简单介绍, 仅供参考。

对于串行通信工作方式0的同步方式, 常用于通过移位寄存器进行扩展并行I/O口, 或配置某些串行通信接口的外部设备。例如, 串行打印机、显示器等。这里就不一一举例了。

第9章 STC89C51RC/RD+系列EEPROM的应用

STC89C51RC/RD+系列单片机内部集成了的EEPROM是与程序空间是分开的，利用ISP/IAP技术可将内部Data Flash当EEPROM，擦写次数在10万次以上。EEPROM可分为若干个扇区，每个扇区包含512字节。使用时，建议同一次修改的数据放在同一个扇区，不是同一次修改的数据放在不同的扇区，不一定要用满。数据存储器的擦除操作是按扇区进行的。

EEPROM可用于保存一些需要在应用过程中修改并且掉电不丢失的参数数据。在用户程序中，可以对EEPROM进行字节读/字节编程/扇区擦除操作。在工作电压Vcc偏低时，建议不要进行EEPROM/IAP操作。

9.1 IAP及EEPROM新增特殊功能寄存器介绍

符号	描述	地址	位地址及符号								复位值
			MSB				LSB				
ISP_DATA	ISP/IAP Flash Data Register	E2H									1111 1111B
ISP_ADDRH	ISP/IAP Flash Address High	E3H									0000 0000B
ISP_ADDRL	ISP/IAP Flash Address Low	E4H									0000 0000B
ISP_CMD	ISP/IAP Flash Command Register	E5H	-	-	-	-	-	-	MS1	MS0	xxxx xx00B
ISP_TRIG	ISP/IAP Flash Command Trigger	E6H									xxxx xxxxB
ISP_CONTR	ISP/IAP Control Register	E7H	ISPEN	SWBS	SWRST	-	-	WT2	WT1	WT0	000x x000B

1. ISP/IAP数据寄存器ISP_DATA

ISP_DATA：ISP/IAP操作时的数据寄存器。
 ISP/IAP 从Flash读出的数据放在此处，向Flash写的数据也需放在此处

2. ISP/IAP地址寄存器ISP_ADDRH和ISP_ADDRL

ISP_ADDRH：ISP/IAP 操作时的地址寄存器高八位。该寄存器地址为E3H, 复位后值为00H。
 ISP_ADDRL：ISP/IAP 操作时的地址寄存器低八位。该寄存器地址为E4H, 复位后值为00H。

3. ISP/IAP命令寄存器ISP_CMD

ISP/IAP命令寄存器IAP_CMD格式如下：

SFR name	Address	bit	B7	B6	B5	B4	B3	B2	B1	B0
ISP_CMD	E5H	name	-	-	-	-	-	-	MS1	MS0

MS2	MS1	MS0	命令 / 操作 模式选择
0	0	0	Standby 待机模式，无ISP操作
0	0	1	从用户的应用程序区对“Data Flash/EEPROM区”进行字节读
0	1	0	从用户的应用程序区对“Data Flash/EEPROM区”进行字节编程
0	1	1	从用户的应用程序区对“Data Flash/EEPROM区”进行扇区擦除

程序在系统ISP程序区时可以对用户应用程序区/数据Flash区 (EEPROM) 进行字节读/字节编程/扇区擦除；程序在用户应用程序区时，仅可以对数据Flash 区 (EEPROM) 进行字节读/字节编程/扇区擦除。已经固化有ISP引导码，并设置为上电复位进入ISP

4. ISP/IA命令触发寄存器ISP_TRIG

ISP_TRIG: ISP/IAP 操作时的命令触发寄存器。
 在ISPEN(ISP_CONTR.7) = 1 时, 对ISP_TRIG先写入46h, 再写入B9h, ISP/IAP 命令才会生效。

ISP/IAP操作完成后，ISP地址高八位寄存器ISP_ADDRH、ISP地址低八位寄存器ISP_ADDRL和ISP命令寄存器ISP_CMD的内容不变。如果接下来要对下一个地址的数据进行ISP/IAP操作，需手动将该地址的高8位和低8位分别写入ISP_ADDRH和ISP_ADDRL寄存器。

每次ISP操作时，都要对ISP_TRIG先写入46H，再写入B9H，ISP/IAP命令才会生效。

5. ISP/IAP命令寄存器ISP_CONTR

ISP/IAP控制寄存器IAP_CONTR格式如下：

SFR name	Address	bit	B7	B6	B5	B4	B3	B2	B1	B0
IAP_CONTR	E7H	name	ISPEN	SWBS	SWRST	-	-	WT2	WT2	WT0

ISPEN: ISP/IAP功能允许位。0：禁止IAP/ISP读/写/擦除Data Flash/EEPROM

1：允许IAP/ISP读/写/擦除Data Flash/EEPROM

SWBS: 软件选择从用户应用程序区启动(送0)，还是从系统ISP监控程序区启动(送1)。

要与SWRST直接配合才可以实现

SWRST: 0：不操作； 1：产生软件系统复位，硬件自动复位。

；在用户应用程序区(AP区)软件复位并从系统ISP监控程序区开始执行程序

MOV ISP_CONTR, #01100000B ;SWBS = 1(选择ISP区)，SWRST = 1(软复位)

；在系统ISP监控程序区软件复位并从用户应用程序区(AP 区)开始执行程序

MOV ISP_CONTR, #00100000B ;SWBS = 0(选择AP 区)，SWRST = 1(软复位)

设置等待时间			CPU等待时间(机器周期), (1个机器周期=12个CPU工作时钟)			
WT2	WT1	WT0	Read/读	Program/编程 (=72uS)	Sector Erase 扇区擦除 (=13.1304ms)	Recommended System Clock 跟等待参数对应的推荐系统 时钟
0	1	1	6个机器周期	30个机器周期	5471个机器周期	5MHz
0	1	0	11个机器周期	60个机器周期	10942个机器周期	10MHz
0	0	1	22个机器周期	120个机器周期	21885个机器周期	20MHz
0	0	0	43个机器周期	240个机器周期	43769个机器周期	40MHz

9.2 STC89C51RC/RD+系列单片机EEPROM空间大小及地址

STC89C51RC/RD+系列单片机内部可用EEPROM的地址与程序空间是分开的：程序在用户应用程序区时，可以对EEPROM 进行IAP/ISP操作。

具体某个型号单片机内部EEPROM大小及详细地址请参阅：

- 1. [STC89C51RC/RD+系列单片机内部EEPROM详细地址表](#)
- 2. [STC89C51RC/RD+系列单片机内部EEPROM空间大小选型一览表](#)

STC89C51RC/RD+系列单片机内部EEPROM选型一览表				
型号	EEPROM字节数	扇区数	起始扇区首地址	结束扇区末尾地址
STC89C51RC STC89LE51RC	4K	8	2000h	2FFFh
STC89C52RC STC89LE52RC	4K	8	2000h	2FFFh
STC89C54RD+ STC89LE54RD+	45K	90	4000h	F3FFh
STC89C58RD+ STC89LE58RD+	29K	58	8000h	F3FFh
STC89C510RD+ STC89LE510RD+	21K	42	A000h	F3FFh
STC89C512RD+ STC89LE512RD+	13K	26	C000h	F3FFh
STC89C514RD+ STC89LE514RD+	5K	10	E000h	F3FFh

STC89C51RC系列单片机内部EEPROM详细地址表								
具体某型号有多少扇区的EEPROM, 参照前面的EEPROM空间大小选型一览表， 每个扇区0.5 K字节								
第一扇区		第二扇区		第三扇区		第四扇区		每个扇区 512字节
起始地址	结束地址	起始地址	结束地址	起始地址	结束地址	起始地址	结束地址	
2000h	21FFh	2200h	23FFh	2400h	25FFh	2600h	27FFh	
第五扇区		第六扇区		第七扇区		第八扇区		建议同一次修改的 数据放在同一扇区，不是同一次 修改的数据放在不同的扇区，不必用 满，当然可全用
起始地址	结束地址	起始地址	结束地址	起始地址	结束地址	起始地址	结束地址	
2800h	29FFh	2A00h	2BFFh	2C00h	2DFFh	2E00h	2FFFh	

STC89C58RD+系列单片机内部EEPROM详细地址表							
具体某型号有多少扇区的EEPROM, 参照前面的EEPROM空间大小选型一览表, 每个扇区0.5 K字节							
第一扇区		第二扇区		第三扇区		第四扇区	
起始地址	结束地址	起始地址	结束地址	起始地址	结束地址	起始地址	结束地址
8000h	81FFh	8200h	83FFh	8400h	85FFh	8600h	87FFh
第五扇区		第六扇区		第七扇区		第八扇区	
起始地址	结束地址	起始地址	结束地址	起始地址	结束地址	起始地址	结束地址
8800h	89FFh	8A00h	8BFFh	8C00h	8DFFh	8E00h	8FFFh
第九扇区		第十扇区		第十一扇区		第十二扇区	
起始地址	结束地址	起始地址	结束地址	起始地址	结束地址	起始地址	结束地址
9000h	91FFh	9200h	93FFh	9400h	95FFh	9600h	97FFh
第十三扇区		第十四扇区		第十五扇区		第十六扇区	
起始地址	结束地址	起始地址	结束地址	起始地址	结束地址	起始地址	结束地址
9800h	99FFh	1A00h	9BFFh	9C00h	9DFFh	9E00h	9FFFh
第十七扇区		第十八扇区		第十九扇区		第二十扇区	
起始地址	结束地址	起始地址	结束地址	起始地址	结束地址	起始地址	结束地址
A000h	A1FFh	A200h	A3FFh	A400h	A5FFh	A600h	A7FFh
第二十一扇区		第二十二扇区		第二十三扇区		第二十四扇区	
起始地址	结束地址	起始地址	结束地址	起始地址	结束地址	起始地址	结束地址
A800h	A9FFh	AA00h	ABFFh	AC00h	ADFFh	AE00h	AFFFh
第二十五扇区		第二十六扇区		第二十七扇区		第二十八扇区	
起始地址	结束地址	起始地址	结束地址	起始地址	结束地址	起始地址	结束地址
B000h	B1FFh	B200h	B3FFh	B400h	B5FFh	B600h	B7FFh
第二十九扇区		第三十扇区		第三十一扇区		第三十二扇区	
起始地址	结束地址	起始地址	结束地址	起始地址	结束地址	起始地址	结束地址
B800h	B9FFh	BA00h	BBFFh	BC00h	BDFFh	BE00h	BFFFh
第三十三扇区		第三十四扇区		第三十五扇区		第三十六扇区	
起始地址	结束地址	起始地址	结束地址	起始地址	结束地址	起始地址	结束地址
C000h	C1FFh	C200h	C3FFh	C400h	C5FFh	C600h	C7FFh
第三十七扇区		第三十八扇区		第三十九扇区		第四十扇区	
起始地址	结束地址	起始地址	结束地址	起始地址	结束地址	起始地址	结束地址
C800h	C9FFh	CA00h	CBFFh	CC00h	CDFFh	CE00h	CFFFh
第四十一扇区		第四十二扇区		第四十三扇区		第四十四扇区	
起始地址	结束地址	起始地址	结束地址	起始地址	结束地址	起始地址	结束地址
D000h	D1FFh	D200h	D3FFh	D400h	D5FFh	D600h	D7FFh
第四十五扇区		第四十六扇区		第四十七扇区		第四十八扇区	
起始地址	结束地址	起始地址	结束地址	起始地址	结束地址	起始地址	结束地址
D800h	D9FFh	DA00h	DBFFh	DC00h	DDFFh	DE00h	DFFFh
第四十九扇区		第五十扇区		第五十一扇区		第五十二扇区	
起始地址	结束地址	起始地址	结束地址	起始地址	结束地址	起始地址	结束地址
E000h	E1FFh	E200h	E3FFh	E400h	E5FFh	E600h	E7FFh

每个扇区
512字节

建议同一次修改的数据放在同一扇区，不是同一次修改的数据放在不同的扇区，当然可全用

STC89C58RD+系列单片机内部EEPROM详细地址表							
具体某型号有多少扇区的EEPROM, 参照前面的EEPROM空间大小选型一览表， 每个扇区0.5 K字节							
第五十三扇区		第五十四扇区		第五十五扇区		第五十六扇区	
起始地址	结束地址	起始地址	结束地址	起始地址	结束地址	起始地址	结束地址
E800h	E9FFh	EA00h	EBFFh	EC00h	EDFFh	EE00h	EFFH
第五十七扇区		第五十八扇区					
起始地址	结束地址	起始地址	结束地址				
F000h	F1FFh	F200h	F3FFh				
每个扇区512字节							
建议同一次修改的数据放在同一扇区，不是同一次修改的数据放在不同的扇区，不必用满，当然可全用							

9.3 IAP及EEPROM汇编简介

;用DATA还是EQU声明新增特殊功能寄存器地址要看你用的汇编器/编译器

IAP_DATA	DATA	0E2h;	或	IAP_DATA	EQU	0E2h
IAP_ADDRH	DATA	0E3h;	或	IAP_ADDRH	EQU	0E3h
IAP_ADDRL	DATA	0E4h;	或	IAP_ADDRL	EQU	0E4h
IAP_CMD	DATA	0E5h;	或	IAP_CMD	EQU	0E5h
IAP_TRIG	DATA	0E6h;	或	IAP_TRIG	EQU	0E6h
IAP_CONTR	DATA	0E7h;	或	IAP_CONTR	EQU	0E7h

;定义ISP/IAP命令及等待时间

ISP_IAP_BYTE_READ	EQU	1	;字节读
ISP_IAP_BYTE_PROGRAM	EQU	2	;字节编程, 前提是该字节是空, 0FFh
ISP_IAP_SECTOR_ERASE	EQU	3	;扇区擦除, 要某字节为空, 要擦一扇区
WAIT_TIME	EQU	0	;设置等待时间, 30MHz以下0, 24M以下1, ;20MHz以下2, 12M以下3, 6M以下4, 3M以下5, 2M以下6, 1M以下7,

;字节读

MOV	IAP_ADDRH,	#BYTE_ADDR_HIGH	;送地址高字节	} 地址需要改变时 才需重新送地址
MOV	IAP_ADDRL,	#BYTE_ADDR_LOW	;送地址低字节	
MOV	IAP_CONTR,	#WAIT_TIME	;设置等待时间	} 此两句可以合成一句, 并且只送一次就够了
ORL	IAP_CONTR,	#10000000B	;允许ISP/IAP操作	
MOV	IAP_CMD,	#ISP_IAP_BYTE_READ		
			;送字节读命令, 命令不需改变时, 不需重新送命令	
MOV	IAP_TRIG,	#46h	;先送46h, 再送B9h到ISP/IAP触发寄存器, 每次都需如此	
MOV	IAP_TRIG,	#0B9h	;送完B9h后, ISP/IAP命令立即被触发动	

;CPU等待IAP动作完成后, 才会继续执行程序。

NOP	;数据读出到IAP_DATA寄存器后, CPU继续执行程序			
MOV	A,	ISP_DATA	;将读出的数据送往Acc	

;以下语句可不用,只是出于安全考虑而已

```
MOV    IAP_CONTR,    #00000000B    ;禁止ISP/IAP操作
MOV    IAP_CMD,      #00000000B    ;去除ISP/IAP命令
;MOV   IAP_TRIG,     #00000000B    ;防止ISP/IAP命令误触发
;MOV   IAP_ADDRH,    #0FFh         ;送地址高字节单元为00,指向非EEPROM区
;MOV   IAP_ADDRL,    #0FFh         ;送地址低字节单元为00,防止误操作
```

;字节编程,该字节为FFh/空时,可对其编程,否则不行,要先执行扇区擦除

```
MOV    IAP_DATA,     #ONE_DATA      ;送字节编程数据到IAP_DATA,
                                      ;只有数据改变时才需重新送

MOV    IAP_ADDRH,    #BYTE_ADDR_HIGH ;送地址高字节
MOV    IAP_ADDRL,    #BYTE_ADDR_LOW  ;送地址低字节
MOV    IAP_CONTR,    #WAIT_TIME      ;设置等待时间
ORL    IAP_CONTR,    #10000000B      ;允许ISP/IAP操作
MOV    IAP_CMD,      #ISP_IAP_BYTE_PROGRAM ;送字节编程命令
MOV    IAP_TRIG,     #46h            ;先送46h,再送B9h到ISP/IAP触发寄存器,每次都需如此
MOV    IAP_TRIG,     #0B9h          ;送完B9h后,ISP/IAP命令立即被触发起动
```

} 地址需要改变时才需重新送地址
 } 此两句可合成一句,并且只送一次就够了

;CPU等待IAP动作完成后,才会继续执行程序.

```
NOP                                     ;字节编程成功后,CPU继续执行程序
```

;以下语句可不用,只是出于安全考虑而已

```
MOV    IAP_CONTR,    #00000000B    ;禁止ISP/IAP操作
MOV    IAP_CMD,      #00000000B    ;去除ISP/IAP命令
;MOV   IAP_TRIG,     #00000000B    ;防止ISP/IAP命令误触发
;MOV   IAP_ADDRH,    #0FFh         ;送地址高字节单元为00,指向非EEPROM区,防止误操作
;MOV   IAP_ADDRL,    #0FFh         ;送地址低字节单元为00,指向非EEPROM区,防止误操作
```

;扇区擦除，没有字节擦除，只有扇区擦除，512字节/扇区, 每个扇区用得越少越方便
;如果要对某个扇区进行擦除，而其中有些字节的内容需要保留，则需将其先读到单片机
;内部的RAM中保存，再将该扇区擦除，然后将须保留的数据写回该扇区，所以每个扇区
;中用的字节数越少越好，操作起来越灵活越快。
;扇区中任意一个字节的地址都是该扇区的地址, 无需求出首地址.

```
MOV    IAP_ADDRH,    #SECTOR_FIRST_BYTE_ADDR_HIGH ;送扇区起始地址高字节
MOV    IAP_ADDRL,    #SECTOR_FIRST_BYTE_ADDR_LOW  ;送扇区起始地址低字节
                                           ;地址需要改变时才需重新送地址
MOV    IAP_CONTR,    #WAIT_TIME                  ;设置等待时间
ORL    IAP_CONTR,    #10000000B                  ;允许ISP/IAP
MOV    IAP_CMD,      #ISP_IAP_SECTOR_ERASE
                                           ;送扇区擦除命令, 命令不需改变时, 不需重新送命令
MOV    IAP_TRIG,     #46h
                                           ;先送46h, 再送B9h到ISP/IAP触发寄存器, 每次都需如此
MOV    IAP_TRIG,     #0B9h                      ;送完B9h后, ISP/IAP命令立即被触发起动
;CPU等待IAP动作完成后, 才会继续执行程序.
```

```
NOP                                           ;扇区擦除成功后, CPU继续执行程序
```

;以下语句可不用, 只是出于安全考虑而已

```
MOV    IAP_CONTR,    #00000000B                ;禁止ISP/IAP操作
MOV    IAP_CMD,      #00000000B                ;去除ISP/IAP命令
;MOV   IAP_TRIG,     #00000000B                ;防止ISP/IAP命令误触发
;MOV   IAP_ADDRH,    #0FFh                      ;送地址高字节单元为00, 指向非EEPROM区
;MOV   IAP_ADDRL,    #0FFh                      ;送地址低字节单元为00, 防止误操作
```

小常识：（STC单片机的Data Flash 当EEPROM功能使用）

3个基本命令——字节读，字节编程，扇区擦除

字节编程：将“1”写成“1”或“0”，将“0”写成“0”。如果某字节是FFH,才可对其进行字节编程。如果该字节不是FFH，则须先将整个扇区擦除，因为只有“扇区擦除”才可以将“0”变为“1”。

扇区擦除：只有“扇区擦除”才可能将“0”擦除为“1”。

大建议：

1. 同一次修改的数据放在同一扇区中，不是同一次修改的数据放在另外的扇区,就不须读出保护。
2. 如果一个扇区只用一个字节，那就是真正的EEPROM, STC单片机的Data Flash比外部EEPROM要快很多，读一个字节/编程一个字节大概是10uS/60uS/10mS。
3. 如果在一个扇区中存放了大量的数据，某次只需要修改其中的一个字节或部分字节时，则另外的不需要修改的数据须先读出放在STC单片机的RAM中，然后擦除整个扇区，再将需要保留的数据和需修改的数据按字节逐字节写回该扇区中(只有字节写命令，无连续字节写命令)。这时每个扇区使用的字节数是使用的越少越方便(不需读出一大堆需保留数据)。

常问的问题：

1：IAP指令完成后，地址是否会自动“加1”或“减1”？

答：不会

2：送46和B9触发后，下一次IAP命令是否还需要送46和B9触发？

答：是，一定要。

9.4 EEPROM测试程序(C程序及汇编程序)

1. C程序:

[;STC89C51RC/RD+系列单片机EEPROM/IAP 功能测试程序演示](#)

```
/*-----*/
/* --- STC MCU International Limited -----*/
/* --- 演示STC89xx系列单片机 EEPROM/IAP功能-----*/
/* 如果要在程序中使用或在文章中引用该程序, -----*/
/* 请在程序中或文章中注明使用了宏晶科技的资料及程序 -----*/
/*-----*/
```

```
#include "reg51.h"
```

```
#include "intrins.h"
```

```
typedef unsigned char BYTE;
```

```
typedef unsigned int WORD;
```

```
/*Declare SFR associated with the IAP */
```

```
sfr IAP_DATA    = 0xE2;    //Flash data register
sfr IAP_ADDRH   = 0xE3;    //Flash address HIGH
sfr IAP_ADDRL   = 0xE4;    //Flash address LOW
sfr IAP_CMD     = 0xE5;    //Flash command register
sfr IAP_TRIG    = 0xE6;    //Flash command trigger
sfr IAP_CONTR   = 0xE7;    //Flash control register
```

```
/*Define ISP/IAP/EEPROM command*/
```

```
#define CMD_IDLE 0          //Stand-By
#define CMD_READ 1          //Byte-Read
#define CMD_PROGRAM 2       //Byte-Program
#define CMD_ERASE 3         //Sector-Erase
```

```
/*Define ISP/IAP/EEPROM operation const for IAP_CONTR*/
```

```
//#define ENABLE_IAP 0x80    //if SYSCLK<40MHz
#define ENABLE_IAP 0x81    //if SYSCLK<20MHz
//#define ENABLE_IAP 0x82    //if SYSCLK<10MHz
//#define ENABLE_IAP 0x83    //if SYSCLK<5MHz
```

```
//Start address for STC89C58xx EEPROM
```

```
#define IAP_ADDRESS 0x08000
```

```
void Delay(BYTE n);
```

```
void IapIdle();
```

```
BYTE IapReadByte(WORD addr);
```

```
void IapProgramByte(WORD addr, BYTE dat);
```

```
void IapEraseSector(WORD addr);
```



```

void main()
{
    WORD i;

    P1 = 0xfe;                //1111,1110 System Reset OK
    Delay(10);                //Delay
    IapEraseSector(IAP_ADDRESS); //Erase current sector
    for (i=0; i<512; i++)      //Check whether all sector data is FF
    {
        if (IapReadByte(IAP_ADDRESS+i) != 0xff)
            goto Error;        //If error, break
    }
    P1 = 0xfc;                //1111,1100 Erase successful
    Delay(10);                //Delay
    for (i=0; i<512; i++)      //Program 512 bytes data into data flash
    {
        IapProgramByte(IAP_ADDRESS+i, (BYTE)i);
    }
    P1 = 0xf8;                //1111,1000 Program successful
    Delay(10);                //Delay
    for (i=0; i<512; i++)      //Verify 512 bytes data
    {
        if (IapReadByte(IAP_ADDRESS+i) != (BYTE)i)
            goto Error;        //If error, break
    }
    P1 = 0xf0;                //1111,0000 Verify successful
    while (1);
Error:
    P1 &= 0x7f;                //0xxx,xxxxx IAP operation fail
    while (1);
}

/*-----
Software delay function
-----*/
void Delay(BYTE n)
{
    WORD x;

    while (n--)
    {
        x = 0;
        while (++x);
    }
}

```

```
/*-----
```

Disable ISP/IAP/EEPROM function

Make MCU in a safe state

```
-----*/
```

```
void IapIdle()
```

```
{
    IAP_CONTR = 0;           //Close IAP function
    IAP_CMD = 0;             //Clear command to standby
    IAP_TRIG = 0;            //Clear trigger register
    IAP_ADDRH = 0x80;        //Data ptr point to non-EEPROM area
    IAP_ADDRL = 0;           //Clear IAP address to prevent misuse
}
```

```
/*-----
```

Read one byte from ISP/IAP/EEPROM area

Input: addr (ISP/IAP/EEPROM address)

Output:Flash data

```
-----*/
```

```
BYTE IapReadByte(WORD addr)
```

```
{
    BYTE dat;                //Data buffer

    IAP_CONTR = ENABLE_IAP;  //Open IAP function, and set wait time
    IAP_CMD = CMD_READ;      //Set ISP/IAP/EEPROM READ command
    IAP_ADDRL = addr;        //Set ISP/IAP/EEPROM address low
    IAP_ADDRH = addr >> 8;   //Set ISP/IAP/EEPROM address high
    IAP_TRIG = 0x46;         //Send trigger command1 (0x46)
    IAP_TRIG = 0xb9;         //Send trigger command2 (0xb9)
    _nop();                  //MCU will hold here until ISP/IAP/EEPROM operation complete
    dat = IAP_DATA;          //Read ISP/IAP/EEPROM data
    IapIdle();               //Close ISP/IAP/EEPROM function

    return dat;              //Return Flash data
}
```

```
/*-----
```

Program one byte to ISP/IAP/EEPROM area

Input: addr (ISP/IAP/EEPROM address)

dat (ISP/IAP/EEPROM data)

Output:-

```
-----*/
```

```

void IapProgramByte(WORD addr, BYTE dat)
{
    IAP_CONTR = ENABLE_IAP;           //Open IAP function, and set wait time
    IAP_CMD = CMD_PROGRAM;            //Set ISP/IAP/EEPROM PROGRAM command
    IAP_ADDRL = addr;                 //Set ISP/IAP/EEPROM address low
    IAP_ADDRH = addr >> 8;            //Set ISP/IAP/EEPROM address high
    IAP_DATA = dat;                   //Write ISP/IAP/EEPROM data
    IAP_TRIG = 0x46;                  //Send trigger command1 (0x46)
    IAP_TRIG = 0xb9;                  //Send trigger command2 (0xb9)
    _nop();                           //MCU will hold here until ISP/IAP/EEPROM operation complete
    IapIdle();
}

/*-----
Erase one sector area
Input: addr (ISP/IAP/EEPROM address)
Output:-
-----*/
void IapEraseSector(WORD addr)
{
    IAP_CONTR = ENABLE_IAP;           //Open IAP function, and set wait time
    IAP_CMD = CMD_ERASE;              //Set ISP/IAP/EEPROM ERASE command
    IAP_ADDRL = addr;                 //Set ISP/IAP/EEPROM address low
    IAP_ADDRH = addr >> 8;            //Set ISP/IAP/EEPROM address high
    IAP_TRIG = 0x46;                  //Send trigger command1 (0x46)
    IAP_TRIG = 0xb9;                  //Send trigger command2 (0xb9)
    _nop();                           //MCU will hold here until ISP/IAP/EEPROM operation complete
    IapIdle();
}

```

2. 汇编程序:

;STC89C51RC/RD+系列单片机EEPROM/IAP 功能测试程序演示

```
/*-----*/
/* --- STC MCU International Limited -----*/
/* --- 演示STC89xx系列单片机 EEPROM/IAP功能-----*/
/* 如果要在程序中使用或在文章中引用该程序, -----*/
/* 请在程序中或文章中注明使用了宏晶科技的资料及程序 -----*/
/*-----*/

;*/Declare SFR associated with the IAP */
IAP_DATA EQU 0E2H ;Flash data register
IAP_ADDRH EQU 0E3H ;Flash address HIGH
IAP_ADDRL EQU 0E4H ;Flash address LOW
IAP_CMD EQU 0E5H ;Flash command register
IAP_TRIG EQU 0E6H ;Flash command trigger
IAP_CONTR EQU 0E7H ;Flash control register

;*/Define ISP/IAP/EEPROM command*/
CMD_IDLE EQU 0 ;Stand-By
CMD_READ EQU 1 ;Byte-Read
CMD_PROGRAM EQU 2 ;Byte-Program
CMD_ERASE EQU 3 ;Sector-Erase

;*/Define ISP/IAP/EEPROM operation const for IAP_CONTR*/
;ENABLE_IAP EQU 80H ;if SYSCLK<40MHz
ENABLE_IAP EQU 81H ;if SYSCLK<20MHz
;ENABLE_IAP EQU 82H ;if SYSCLK<10MHz
ENABLE_IAP EQU 83H ;if SYSCLK<5MHz
;//Start address for STC89C58xx EEPROM

IAP_ADDRESS EQU 08000H
;-----
ORG 0000H
LJMP MAIN
;-----

ORG 0100H
MAIN:
MOV P1,#0FEH ;1111,1110 System Reset OK
LCALL DELAY ;Delay
```

```

;-----
MOV    DPTR, #IAP_ADDRESS    ;Set ISP/IAP/EEPROM address
LCALL  IAP_ERASE              ;Erase current sector
;-----
MOV    DPTR, #IAP_ADDRESS    ;Set ISP/IAP/EEPROM address
MOV    R0,    #0              ;Set counter (512)
MOV    R1,    #2
CHECK1:                          ;Check whether all sector data is FF
LCALL  IAP_READ                ;Read Flash
CJNE   A,      #0FFH, ERROR    ;If error, break
INC    DPTR                  ;Inc Flash address
DJNZ   R0,     CHECK1          ;Check next
DJNZ   R1,     CHECK1          ;Check next
;-----
MOV    P1,     #0FCH          ;1111,1100 Erase successful
LCALL  DELAY                  ;Delay
;-----
MOV    DPTR, #IAP_ADDRESS    ;Set ISP/IAP/EEPROM address
MOV    R0,    #0              ;Set counter (512)
MOV    R1,    #2
MOV    R2,    #0              ;Initial test data
NEXT:                          ;Program 512 bytes data into data flash
MOV    A,      R2              ;Ready IAP data
LCALL  IAP_PROGRAM            ;Program flash
INC    DPTR                  ;Inc Flash address
INC    R2                    ;Modify test data
DJNZ   R0,     NEXT           ;Program next
DJNZ   R1,     NEXT           ;Program next
;-----
MOV    P1,     #0F8H          ;1111,1000 Program successful
LCALL  DELAY                  ;Delay
;-----
MOV    DPTR, #IAP_ADDRESS    ;Set ISP/IAP/EEPROM address
MOV    R0,    #0              ;Set counter (512)
MOV    R1,    #2
MOV    R2,    #0
CHECK2:                          ;Verify 512 bytes data
LCALL  IAP_READ                ;Read Flash
CJNE   A,2,ERROR              ;If error, break
INC    DPTR                  ;Inc Flash address
INC    R2                    ;Modify verify data
DJNZ   R0,     CHECK2          ;Check next
DJNZ   R1,     CHECK2          ;Check next

```

```
;-----  
      MOV    P1,    #0F0H          ;1111,0000 Verify successful  
      SJMP   $  
;-----  
ERROR:  
      MOV    P0,    R0  
      MOV    P2,    R1  
      MOV    P3,    R2  
      CLR    P1.7          ;0xxx,xxxx IAP operation fail  
      SJMP   $  
  
;/*-----  
;Software delay function  
;-----*/  
DELAY:  
      CLR    A  
      MOV    R0,    A  
      MOV    R1,    A  
      MOV    R2,    #20H  
DELAY1:  
      DJNZ   R0,    DELAY1  
      DJNZ   R1,    DELAY1  
      DJNZ   R2,    DELAY1  
      RET  
  
;/*-----  
;Disable ISP/IAP/EEPROM function  
;Make MCU in a safe state  
;-----*/  
IAP_IDLE:  
      MOV    IAP_CONTR,    #0          ;Close IAP function  
      MOV    IAP_CMD, #0          ;Clear command to standby  
      MOV    IAP_TRIG, #0          ;Clear trigger register  
      MOV    IAP_ADDRH,    #80H        ;Data ptr point to non-EEPROM area  
      MOV    IAP_ADDRL,    #0          ;Clear IAP address to prevent misuse  
      RET  
  
;/*-----  
;Read one byte from ISP/IAP/EEPROM area  
;Input: DPTR(ISP/IAP/EEPROM address)  
;Output:ACC (Flash data)  
;-----*/
```

IAP_READ:

```

MOV IAP_CONTR,    #ENABLE_IAP      ;Open IAP function, and set wait time
MOV IAP_CMD,      #CMD_READ        ;Set ISP/IAP/EEPROM READ command
MOV IAP_ADDRL,    DPL               ;Set ISP/IAP/EEPROM address low
MOV IAP_ADDRH,    DPH               ;Set ISP/IAP/EEPROM address high
MOV IAP_TRIG,     #46H              ;Send trigger command1 (0x46)
MOV IAP_TRIG,     #0B9H             ;Send trigger command2 (0xb9)
NOP                ;MCU will hold here until ISP/IAP/EEPROM operation complete
MOV A,            IAP_DATA          ;Read ISP/IAP/EEPROM data
LCALL IAP_IDLE    ;Close ISP/IAP/EEPROM function
RET

```

```

; /*-----

```

```

;Program one byte to ISP/IAP/EEPROM area

```

```

;Input: DPAT(ISP/IAP/EEPROM address)

```

```

; ACC (ISP/IAP/EEPROM data)

```

```

;Output:-

```

```

;-----*/

```

IAP_PROGRAM:

```

MOV IAP_CONTR,    #ENABLE_IAP      ;Open IAP function, and set wait time
MOV IAP_CMD,      #CMD_PROGRAM     ;Set ISP/IAP/EEPROM PROGRAM command
MOV IAP_ADDRL,    DPL               ;Set ISP/IAP/EEPROM address low
MOV IAP_ADDRH,    DPH               ;Set ISP/IAP/EEPROM address high
MOV IAP_DATA,     A                ;Write ISP/IAP/EEPROM data
MOV IAP_TRIG,     #46H              ;Send trigger command1 (0x46)
MOV IAP_TRIG,     #0B9H             ;Send trigger command2 (0xb9)
NOP                ;MCU will hold here until ISP/IAP/EEPROM operation complete
LCALL IAP_IDLE    ;Close ISP/IAP/EEPROM function
RET

```

```

; /*-----

```

```

;Erase one sector area

```

```

;Input: DPTR(ISP/IAP/EEPROM address)

```

```

;Output:-

```

```

;-----*/

```

IAP_ERASE:

```

MOV IAP_CONTR,    #ENABLE_IAP      ;Open IAP function, and set wait time
MOV IAP_CMD,      #CMD_ERASE       ;Set ISP/IAP/EEPROM ERASE command
MOV IAP_ADDRL,    DPL               ;Set ISP/IAP/EEPROM address low
MOV IAP_ADDRH,    DPH               ;Set ISP/IAP/EEPROM address high
MOV IAP_TRIG,     #46H              ;Send trigger command1 (0x46)
MOV IAP_TRIG,     #0B9H             ;Send trigger command2 (0xb9)
NOP                ;MCU will hold here until ISP/IAP/EEPROM operation complete
LCALL IAP_IDLE    ;Close ISP/IAP/EEPROM function
RET

```

```

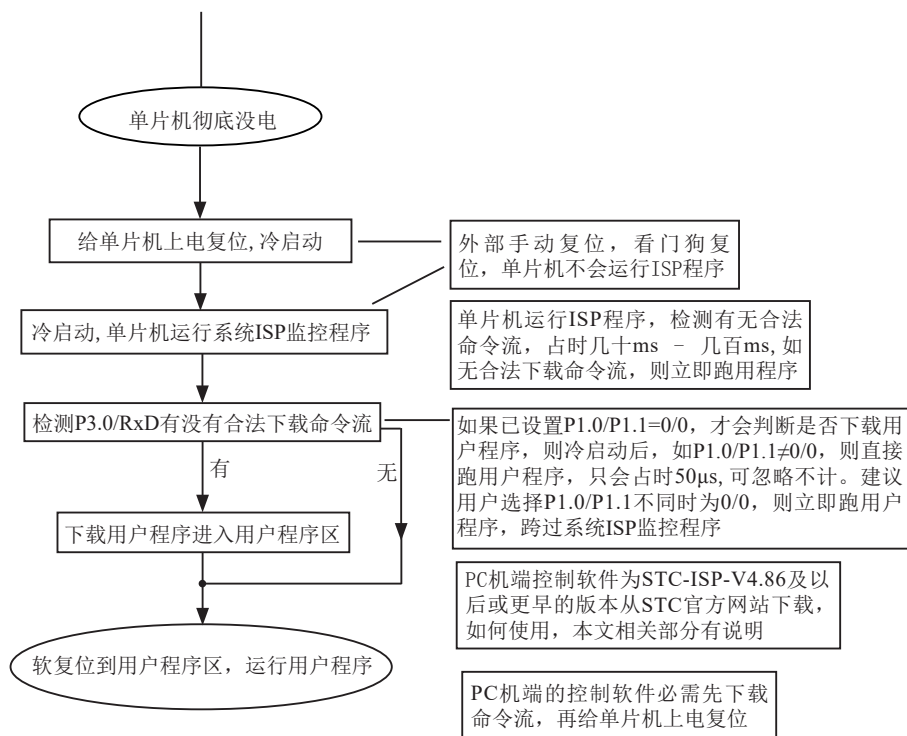
END

```

第10章 STC10系列单片机开发/编程工具说明

10.1 在系统可编程(ISP)原理，官方演示工具使用说明

10.1.1 在系统可编程(ISP)原理使用说明



为什么有些用户下载程序不成功(在宏晶提供的下载板上)

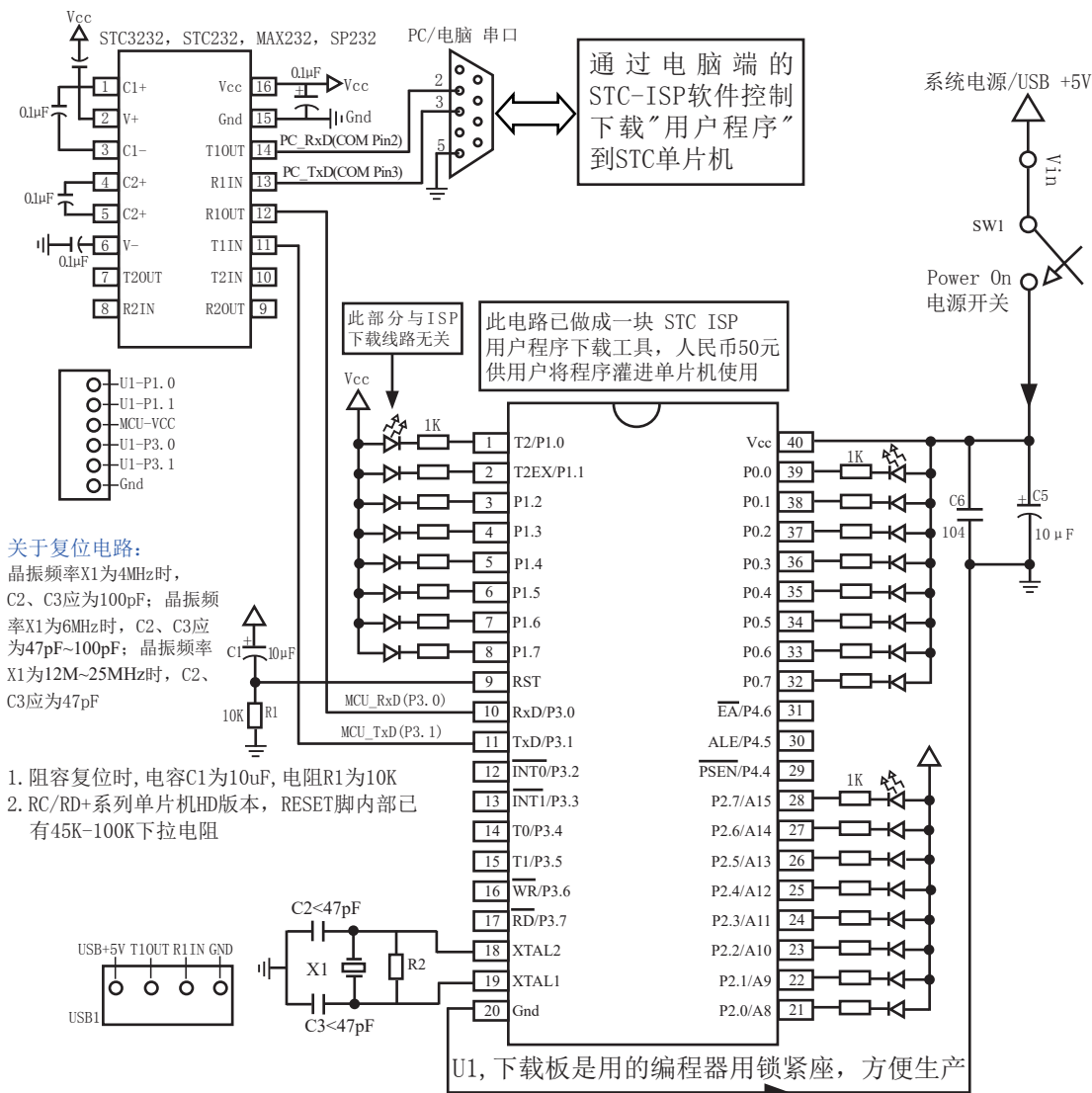
1. 可能电脑端的STC-ISP 控制软件要升级，现须升级到STC-ISP-V4.7
2. 现在单片机端(下位机)ISP 软件是3.2C, 解决了少数电脑慢，通信连不上的问题.
3. 运行用户程序时，可到40M/80MHz, 但ISP下载程序以前的版本软件只能到33M/66MHz
4. 少数客户的PLCC-44, PQFP-44转DIP-40的转换座走线过长, 造成时钟振荡不稳定, 下载不成功.
5. 也有电脑USB电源供电不足的，可用万用表测一下，看5V部分是否在4.5V以上。
6. 可能单片机内部没有ISP引导码，或PC串口波特率达不到115200，选57600试一下。
7. 有些客人的笔记本电脑没有串口, 用的是USB扩展串口, 有些不兼容, 我们可以提供经过宏晶科技认可的USB 扩展串口线, 人民币50 元一条。

为什么有些用户下载程序不成功(在用户自己的系统上)

1. 可能用户板上有外部看门狗，需不让其起作用，另要查时钟是否起振、复位是否正常。
2. 可能用户板上P3.0/RxD，P3.1/TxD除了接RS-232转换器外，还接了RS-485等其它电路，需要将其它电路断开, 防止在ISP下载编程时受到其它电路的影响。用户系统接了RS-485/RS-232电路的，推荐在选项中选择下次冷启动时需P1.0/P1.1=0.0 才判 是否下载程序。

10.1.2 STC89C51RC/RD+系列在系统可编程(ISP)典型应用线路图

STC 单片机在线编程线路，STC RS-232 转换器



关于EA(管脚已内部上拉到Vcc)：

1. 如外部不加上拉，或外部上拉到Vcc，上电复位后单片机从内部开始执行程序；
2. 如外部下拉到地，上电复位后单片机从外部开始执行程序

STC89C51RC/RD+系列单片机具有在系统可编程(ISP)特性, ISP的好处是: 省去购买通用编程器, 单片机在用户系统上即可下载/烧录用户程序, 而无须将单片机从已生产好的产品上拆下, 再用通用编程器将程序代码烧录进单片机内部。有些程序尚未定型的产品可以一边生产, 一边完善, 加快了产品进入市场的速度, 减小了新产品由于软件缺陷带来的风险。由于可以在用户的目标系统上将程序直接下载进单片机看运行结果对错, 故无须仿真器。

STC89系列单片机内部固化有ISP系统引导固件, 配合PC端的控制程序即可将用户的程序代码下载进单片机内部, 故无须编程器(速度比通用编程器快, 几秒一片)。

如何获得及使用STC 提供的ISP 下载工具(STC-ISP.exe 软件):

(1). 获得STC提供的ISP下载工具(软件)

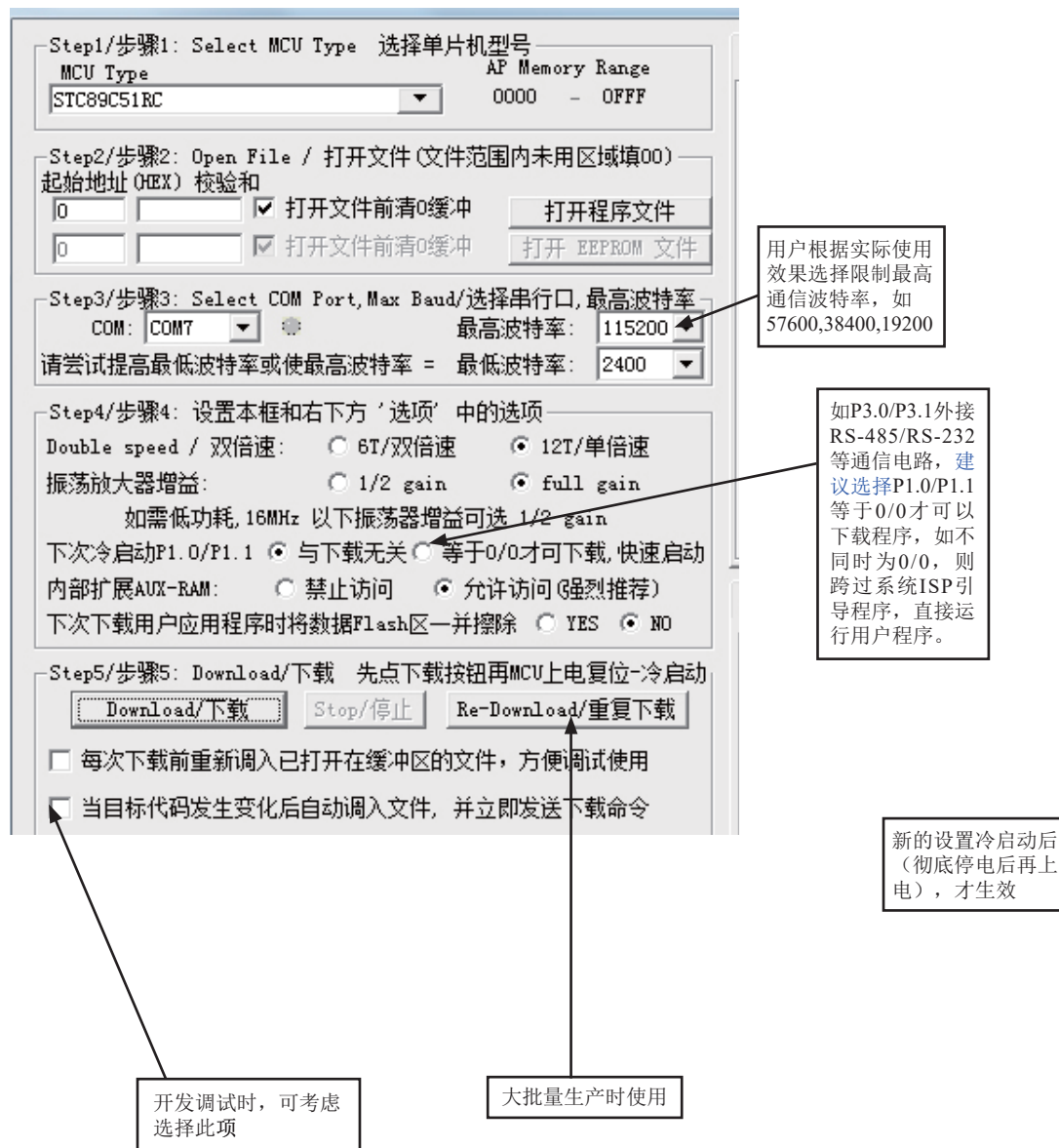
登陆 [STC官方网站](#), 从STC半导体专栏下载PC(电脑)端的ISP程序, 然后将其自解压, 再安装即可(执行setup.exe), 注意随时更新软件。

(2). 使用STC-ISP下载工具(软件), 请随时更新, 目前已到Ver4.86版本以上, 支持*.bin, *.hex(Intel 16 进制格式)文件, 少数*.hex 文件不支持的话, 请转换成*.bin 文件, 请随时注意升级PC(电脑)端的STC-ISP.EXE 程序。

(3). 已经固化有ISP 引导码, 并设置为上电复位进入ISP 的STC89C51RC/RD+ 系列单片机出厂时就已完全加密, 需要单片机内部的电放光后上电复位(冷起动)才运行系统ISP 程序。

(4). 可能用户板上P3.0/RxD, P3.1/TxD 除了接RS-232 转换器外, 还接了RS-485 等电路, 需要将其断开。用户系统接了RS-485 电路的, 推荐在选项中选择下次冷启动时需P1.0/P1.1=0.0 才判是否下载程序。

10.1.3 电脑端的ISP控制软件界面使用说明



Step1/步骤1: 选择你所使用的单片机型号, 如STC89C51RC等

Step2/步骤2: 打开文件, 要烧录用户程序, 必须调入用户的程序代码 (*.bin, *.hex)

Step3/步骤3: 选择串行口, 你所使用的电脑串口, 如串行口1--COM1, 串行口2--COM2, ...

有些新式笔记本电脑没有RS-232串行口, 可买一条USB-RS232转接器, 人民币50元左右。

有些USB-RS232转接器, 不能兼容, 可让宏晶帮你购买经过测试的转换器。

Step4/步骤4: 设置是否双倍速, 双倍速选中Double Speed 即可

STC89C51RC/RD+ 系列可以反复设置 双倍速/ 单倍速, 新的设置停电后重新冷启动后才能生效
STC89C51RC/RD+系列出厂时为单倍速, 用户可指定设为双倍速, 如想从双倍速恢复成单倍速, 则需用通用编程器擦除整个晶片方可, 这会将单片机内部已烧录的ISP 引导程序擦除。一般使用缺省设置即可, 无须设置。

OSCDN: 单片机时钟振荡器增益降一半

选1/2gain为降一半, 降低EMI; 选 full gain (全增益) 为正常状态。

Step5/步骤5, 也可选择 “Re-Download/重复下载” 按钮

下载时注意看提示, 主要看是否要给单片机上电或复位, 下载速度比一般通用编程器快。

一定要先选择 “Download/下载” 按钮, 然后再给单片机上电复位(先彻底断电), 而不要先上电, 先上电, 检测不到合法的下载命令流, 单片机就直接跑用户程序了。

关于硬件连接:

- (1). MCU/单片机 RXD (P3.0) --- RS-232转换器 --- PC/电脑 TXD (COM Port Pin3)
- (2). MCU/单片机 TXD (P3.1) --- RS-232转换器 --- PC/电脑 RXD (COM Port Pin2)
- (3). MCU/单片机 GND ----- PC/电脑 GND (COM Port Pin5)
- (4). STC89LE516AD/X2系列单片机冷启动时需要P1.0, P1.1 = 0, 0; 上电复位才进入ISP模式, 下载完后释放P1.0, P1.1, STC89LE516AD/X2 运行用户程序。

STC89C51RC/RD+ 系列单片机不需要P1.0, P1.1 = 0, 0, 但软件可选下次需要。

STC89LE516AD, STC89LE516X2, STC89LE58AD, STC89LE54AD 必需要P1.0, P1.1 = 0, 0

- (5). RS-232转换器可选用

STC232/MAX232/SP232 (4.5-5.5V), STC3232/MAX3232/SP3232 (3V-5.5V).

STC232/MAX232/SP232 尽量选用SOP封装(窄体, STC232ESE, STC3232ESE)。

10.1.4 宏晶科技的ISP下载编程工具硬件使用说明

如用户系统没有RS-232接口，

可使用STC-ISP Ver 3.0A PCB演示板作为编程工具

STC-ISP Ver 3.0A PCB板可以焊接3种电路，分别支持STC12系列16Pin / 20Pin / 28Pin / 32Pin。我们在下载板的反面贴了一张标签纸，说明它是支持16Pin / 20Pin / 28Pin / 32Pin中的哪一种，用户要特别注意。在正面焊的编程烧录用锁紧座都是40Pin的，锁紧座第20-Pin接的是地线，请将单片机的地线对着锁紧座的地线插。

在STC-ISP Ver 3.0A PCB 板完成下载编程用户程序的工作：

关于硬件连接：

- (1). 根据单片机的工作电压选择单机电源电压
 - A. 5V单片机, 短接JP1的MCU-VCC, +5V电源管脚
 - B. 3V单片机, 短接JP1的MCU-VCC, 3.3V电源管脚
 - (2). 连接线(宏晶提供)
 - A. 将一端有9芯连接座的插头插入PC/电脑RS-232串行接口插座用于通信
 - B. 将同一端的USB插头插入PC/电脑USB接口用于取电
 - C. 将只有一个USB插头的一端插入宏晶的STC-ISP Ver 3.0A PCB板USB1插座用于RS-232通信和供电, 此时USB +5V Power灯亮(D43, USB接口有电)
 - (3). 其他插座不需连接
 - (4). SW1开关处于非按下状态, 此时MCU-VCC Power灯不亮(D41), 没有给单片机通电
 - (5). SW3开关
 - 处于非按下状态, P1.0, P1.1 = 1, 1, 不短接到地。
 - 处于按下状态, P1.0, P1.1 = 0, 0, 短接到地。
- 如果单片机已被设成“下次冷启动P1.0/P1.1 = 0,0才判P3.0有无合法下载命令流”就必须将SW3开关处于按下状态, 让单片机的P1.0/P1.1短接到地
- (6). 将单片机插进U1-Socket锁紧座, 锁紧单片机, 注意单片机是8-Pin/20-Pin/28-Pin, 而U1-Socket锁紧座是40-Pin, 我们的设计是靠下插, 靠近晶体的那一端插。
 - (7). 关于软件: 选择“Download/下载”(必须在给单片机上电之前让PC先发一串合法下载命令)
 - (8). 按下SW1开关, 给单片机上电复位, 此时MCU-VCC Power灯亮(D41)
此时STC单片机进入ISP模式(STC12系列冷启动进入ISP)
 - (9). 下载成功后, 再按SW1开关, 此时SW1开关处于非按下状态, MCU-VCC Power灯不亮(D41), 给单片机断电, 取下单片机, 换上新的单片机。

10.1.5 若无RS-232转换器，如何用宏晶的ISP下载板做RS-232通信转换

利用STC-ISP Ver 3.0A PCB 板进行RS-232转换

单片机在用户自己的板上完成下载/烧录：

1. U1-Socket锁紧座不得插入单片机
2. 将用户系统上的电源(MCU-VCC, GND)及单片机的P3. 0, P3. 1接入转换板CN2插座
这样用户系统上的单片机就具备了与PC/电脑进行通信的能力
3. 将用户系统的单片机的P1. 0, P1. 1接入转换板CN2插座(如果需要的话)
4. 如须P1.0, P1.1 = 0, 0, 短接到地，可在用户系统上将其短接到地，或将P1.0/P1.1也从用户系统上引到STC-ISP Ver3.0A PCB 板上，将SW3开关按下，则P1.0/P1.1=0,0。
5. 关于软件：选择“Download/下载”
6. 给单片机系统上电复位(注意是从用户系统自供电，不要从电脑USB取电, 电脑USB座不插)
7. 下载程序时，如用户板有外部看门狗电路，不得启动，单片机必须有正确的复位, 但不能在ISP下载程序时被外部看门狗复位, 如有，可将外部看门狗电路WDI端/或WDO端浮空。
8. 如有RS-485晶片连到P3. 0, P3. 1, 或其他线路，在下载时应将其断开。

10.2 编译器/汇编器，编程器，仿真器

STC 单片机应使用何种编译器/汇编器：

1. 任何老的编译器/汇编器都可以支持，流行用Keil C51
2. 把STC单片机，当成Intel的8052/87C52/87C54/87C58, Philips的P87C52/P87C54/P87C58就可以了。
3. 如果要用到扩展的专用特殊功能寄存器，直接对该地址单元设置就行了，当然先声明特殊功能寄存器的地址较好。

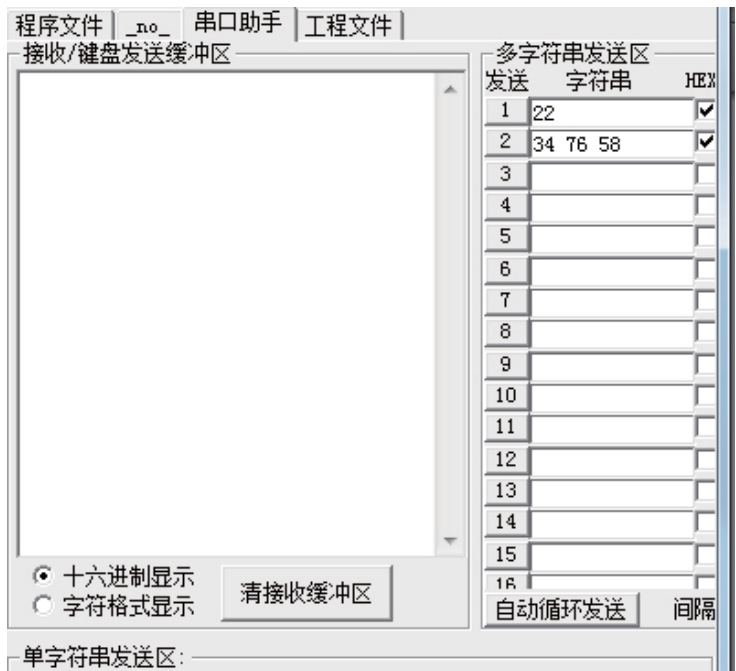
编程烧录器：

我们有：STC89C51RC/RD+系列ISP经济型下载编程工具(人民币50元，可申请免费样品)

注意：有专门下载28PIN/20PIN的不同演示板，
28PIN是28PIN的演示板，20PIN是20PIN的演示板

仿真器：如您已有老的仿真器，可仿真普通8052的基本功能

STC89C51RC/RD+系列单片机扩展功能如它仿不了，可以用 STC-ISP. EXE 直接下载用户程序看运行结果就可以了，如需观察变量，可自己写一小段测试程序通过串口输出到电脑端的STC-ISP. EXE的“串口助手”来显示，也很方便。无须添加新的设备。



无仿真器如何调试/开发用户程序

1. 首先参照本手册当中的“用定时器1做波特率发生器”，调通串口程序，这样，要观察变量就可以自己写一小段测试程序将变量通过串口输出到电脑端的STC-ISP.EXE的“串口调试助手”来显示,也很方便。
2. 调通按键扫描程序(到处都有大量的参考程序)
3. 调通用户系统的显示电路程序，此时变量/寄存器也可以通过用户系统的显示电路显示了
4. 调通A/D检测电路(我们用户手册里面有完整的参考程序)
5. 调通PWM 等电路(我们用户手册里面有完整的参考程序)

这样分步骤模块化调试用户程序，有些系统，熟练的8051用户，三天就可以调通了，难度不大的系统，一般一到二周就可以调通。

用户的串口输出显示程序可以在输出变量/寄存器的值之后，继续全速运行用户程序，也可以等待串口送来的“继续运行命令”，方可继续运行用户程序，这就相当于断点。这种断点每设置一个地方，就必须调用一次该显示寄存器/变量的程序，有点麻烦，但却很实用。

附录A：汇编语言编程

INTRODUCTION

Assembly language is a computer language lying between the extremes of machine language and high-level language like Pascal or C use words and statements that are easily understood by humans, although still a long way from "natural" language. Machine language is the binary language of computers. A machine language program is a series of binary bytes representing instructions the computer can execute.

Assembly language replaces the binary codes of machine language with easy to remember "mnemonics" that facilitate programming. For example, an addition instruction in machine language might be represented by the code "10110011". It might be represented in assembly language by the mnemonic "ADD". Programming with mnemonics is obviously preferable to programming with binary codes.

Of course, this is not the whole story. Instructions operate on data, and the location of the data is specified by various "addressing modes" embedded in the binary code of the machine language instruction. So, there may be several variations of the ADD instruction, depending on what is added. The rules for specifying these variations are central to the theme of assembly language programming.

An assembly language program is not executable by a computer. Once written, the program must undergo translation to machine language. In the example above, the mnemonic "ADD" must be translated to the binary code "10110011". Depending on the complexity of the programming environment, this translation may involve one or more steps before an executable machine language program results. As a minimum, a program called an "assembler" is required to translate the instruction mnemonics to machine language binary codes. A further step may require a "linker" to combine portions of program from separate files and to set the address in memory at which the program may execute. We begin with a few definitions.

An assembly language program is a program written using labels, mnemonics, and so on, in which each statement corresponds to a machine instruction. Assembly language programs, often called source code or symbolic code, cannot be executed by a computer.

A machine language program is a program containing binary codes that represent instructions to a computer. Machine language programs, often called object code, are executable by a computer.

An assembler is a program that translates an assembly language program into a machine language program. The machine language program (object code) may be in "absolute" form or in "relocatable" form. In the latter case, "linking" is required to set the absolute address for execution.

A linker is a program that combines relocatable object programs (modules) and produces an absolute object program that is executable by a computer. A linker is sometimes called a "linker/locator" to reflect its separate functions of combining relocatable modules (linking) and setting the address for execution (locating).

A segment is a unit of code or data memory. A segment may be relocatable or absolute. A relocatable segment has a name, type, and other attributes that allow the linker to combine it with other partial segments, if required, and to correctly locate the segment. An absolute segment has no name and cannot be combined with other segments.

A module contains one or more segments or partial segments. A module has a name assigned by the user. The module definitions determine the scope of local symbols. An object file contains one or more modules. A module may be thought of as a "file" in many instances.

A program consists of a single absolute module, merging all absolute and relocatable segments from all input modules. A program contains only the binary codes for instructions (with address and data constants) that are understood by a computer.

ASSEMBLER OPERATION

There are many assembler programs and other support programs available to facilitate the development of applications for the 8051 microcontroller. Intel's original MCS-51 family assembler, ASM51, is no longer available commercially. However, it set the standard to which the others are compared.

ASM51 is a powerful assembler with all the bells and whistles. It is available on Intel development systems and on the IBM PC family of microcomputers. Since these "host" computers contain a CPU chip other than the 8051, ASM51 is called a cross assembler. An 8051 source program may be written on the host computer (using any text editor) and may be assembled to an object file and listing file (using ASM51), but the program may not be executed. Since the host system's CPU chip is not an 8051, it does not understand the binary instruction in the object file. Execution on the host computer requires either hardware emulation or software simulation of the target CPU. A third possibility is to download the object program to an 8051-based target system for execution.

ASM51 is invoked from the system prompt by

ASM51 source_file [assembler_controls]

The source file is assembled and any assembler controls specified take effect. The assembler receives a source file as input (e.g., PROGRAM.SRC) and generates an object file (PROGRAM.OBJ) and listing file (PROGRAM.LST) as output. This is illustrated in Figure 1.

Since most assemblers scan the source program twice in performing the translation to machine language, they are described as two-pass assemblers. The assembler uses a location counter as the address of instructions and the values for labels. The action of each pass is described below.

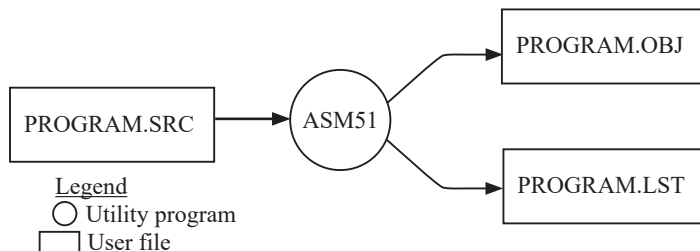


Figure 1 Assembling a source program

Pass one

During the first pass, the source file is scanned line-by-line and a symbol table is built. The location counter defaults to 0 or is set by the ORG (set origin) directive. As the file is scanned, the location counter is incremented by the length of each instruction. Define data directives (DBs or DWs) increment the location counter by the number of bytes defined. Reserve memory directives (DSs) increment the location counter by the number of bytes reserved.

Each time a label is found at the beginning of a line, it is placed in the symbol table along with the current value of the location counter. Symbols that are defined using equate directives (EQUs) are placed in the symbol table along with the "equated" value. The symbol table is saved and then used during pass two.

Pass two

During pass two, the object and listing files are created. Mnemonics are converted to opcodes and placed in the output files. Operands are evaluated and placed after the instruction opcodes. Where symbols appear in the operand field, their values are retrieved from the symbol table (created during pass one) and used in calculating the correct data or addresses for the instructions.

Since two passes are performed, the source program may use "forward references", that is, use a symbol before it is defined. This would occur, for example, in branching ahead in a program.

The object file, if it is absolute, contains only the binary bytes (00H-0FH) of the machine language program. A relocatable object file will also contain a symbol table and other information required for linking and locating. The listing file contains ASCII text codes (02H-7EH) for both the source program and the hexadecimal bytes in the machine language program.

A good demonstration of the distinction between an object file and a listing file is to display each on the host computer's CRT display (using, for example, the TYPE command on MS-DOS systems). The listing file clearly displays, with each line of output containing an address, opcode, and perhaps data, followed by the program statement from the source file. The listing file displays properly because it contains only ASCII text codes. Displaying the object file is a problem, however. The output will appear as "garbage", since the object file contains binary codes of an 8051 machine language program, rather than ASCII text codes.

ASSEMBLY LANGUAGE PROGRAM FORMAT

Assembly language programs contain the following:

- Machine instructions
- Assembler directives
- Assembler controls
- Comments

Machine instructions are the familiar mnemonics of executable instructions (e.g., ANL). Assembler directives are instructions to the assembler program that define program structure, symbols, data, constants, and so on (e.g., ORG). Assembler controls set assembler modes and direct assembly flow (e.g., \$TITLE). Comments enhance the readability of programs by explaining the purpose and operation of instruction sequences.

Those lines containing machine instructions or assembler directives must be written following specific rules understood by the assembler. Each line is divided into "fields" separated by space or tab characters. The general format for each line is as follows:

[label:] mnemonic [operand] [, operand] [...] [;comment]

Only the mnemonic field is mandatory. Many assemblers require the label field, if present, to begin on the left in column 1, and subsequent fields to be separated by space or tab characters. With ASM51, the label field needn't begin in column 1 and the mnemonic field needn't be on the same line as the label field. The operand field must, however, begin on the same line as the mnemonic field. The fields are described below.

Label Field

A label represents the address of the instruction (or data) that follows. When branching to this instruction, this label is used in the operand field of the branch or jump instruction (e.g., SJMP SKIP).

Whereas the term "label" always represents an address, the term "symbol" is more general. Labels are one type of symbol and are identified by the requirement that they must terminate with a colon(:). Symbols are assigned values or attributes, using directives such as EQU, SEGMENT, BIT, DATA, etc. Symbols may be addresses, data constants, names of segments, or other constructs conceived by the programmer. Symbols do not terminate with a colon. In the example below, PAR is a symbol and START is a label (which is a type of symbol).

PAR	EQU	500			;"PAR" IS A SYMBOL WHICH
					;REPRESENTS THE VALUE 500
START:	MOV	A,	#0FFH		;"START" IS A LABEL WHICH
					;REPRESENTS THE ADDRESS OF
					;THE MOV INSTRUCTION

A symbol (or label) must begin with a letter, question mark, or underscore (_); must be followed by letters, digit, "?", or "_"; and can contain up to 31 characters. Symbols may use upper- or lowercase characters, but they are treated the same. Reserved words (mnemonics, operators, predefined symbols, and directives) may not be used.

Mnemonic Field

Instruction mnemonics or assembler directives go into mnemonic field, which follows the label field. Examples of instruction mnemonics are ADD, MOV, DIV, or INC. Examples of assembler directives are ORG, EQU, or DB.

Operand Field

The operand field follows the mnemonic field. This field contains the address or data used by the instruction. A label may be used to represent the address of the data, or a symbol may be used to represent a data constant. The possibilities for the operand field are largely dependent on the operation. Some operations have no operand (e.g., the RET instruction), while others allow for multiple operands separated by commas. Indeed, the possibilities for the operand field are numerous, and we shall elaborate on these at length. But first, the comment field.

Comment Field

Remarks to clarify the program go into comment field at the end of each line. Comments must begin with a semicolon (;). Each line may be a comment line by beginning them with a semicolon. Subroutines and large sections of a program generally begin with a comment block—several lines of comments that explain the general properties of the section of software that follows.

Special Assembler Symbols

Special assembler symbols are used for the register-specific addressing modes. These include A, R0 through R7, DPTR, PC, C and AB. In addition, a dollar sign (\$) can be used to refer to the current value of the location counter. Some examples follow.

```
SETB    C
INC      DPTR
JNB      TI, $
```

The last instruction above makes effective use of ASM51's location counter to avoid using a label. It could also be written as

```
HERE:    JNB      TI, HERE
```

Indirect Address

For certain instructions, the operand field may specify a register that contains the address of the data. The commercial "at" sign (@) indicates address indirection and may only be used with R0, R1, the DPTR, or the PC, depending on the instruction. For example,

```
ADD      A, @R0
MOVC     A, @A+PC
```

The first instruction above retrieves a byte of data from internal RAM at the address specified in R0. The second instruction retrieves a byte of data from external code memory at the address formed by adding the contents of the accumulator to the program counter. Note that the value of the program counter, when the add takes place, is the address of the instruction following MOVC. For both instructions above, the value retrieved is placed into the accumulator.

Immediate Data

Instructions using immediate addressing provide data in the operand field that become part of the instruction. Immediate data are preceded with a pound sign (#). For example,

```
CONSTANT      EQU      100
               MOV      A,      #0FEH
               ORL      40H,    #CONSTANT
```

All immediate data operations (except MOV DPTR,#data) require eight bits of data. The immediate data are evaluated as a 16-bit constant, and then the low-byte is used. All bits in the high-byte must be the same (00H or FFH) or the error message "value will not fit in a byte" is generated. For example, the following instructions are syntactically correct:

```
MOV      A,      #0FF00H
MOV      A,      #00FFH
```

But the following two instructions generate error messages:

```
MOV      A,      #0FE00H
MOV      A,      #01FFH
```

If signed decimal notation is used, constants from -256 to +255 may also be used. For example, the following two instructions are equivalent (and syntactically correct):

```
MOV      A,      #-256
MOV      A,      #0FF00H
```

Both instructions above put 00H into accumulator A.

Data Address

Many instructions access memory locations using direct addressing and require an on-chip data memory address (00H to 7FH) or an SFR address (80H to 0FFH) in the operand field. Predefined symbols may be used for the SFR addresses. For example,

```
MOV      A,      45H
MOV      A,      SBUF          ;SAME AS MOV A, 99H
```

Bit Address

One of the most powerful features of the 8051 is the ability to access individual bits without the need for masking operations on bytes. Instructions accessing bit-addressable locations must provide a bit address in internal data memory (00h to 7FH) or a bit address in the SFRs (80H to 0FFH).

There are three ways to specify a bit address in an instruction: (a) explicitly by giving the address, (b) using the dot operator between the byte address and the bit position, and (c) using a predefined assembler symbol. Some examples follow.

```
SETB     0E7H          ;EXPLICIT BIT ADDRESS
SETB     ACC.7         ;DOT OPERATOR (SAME AS ABOVE)
JNB       TI, $         ;"TI" IS A PRE-DEFINED SYMBOL
JNB       99H, $        ;(SAME AS ABOVE)
```

Code Address

A code address is used in the operand field for jump instructions, including relative jumps (SJMP and conditional jumps), absolute jumps and calls (ACALL, AJMP), and long jumps and calls (LJMP, LCALL).

The code address is usually given in the form of a label.

ASM51 will determine the correct code address and insert into the instruction the correct 8-bit signed offset, 11-bit page address, or 16-bit long address, as appropriate.

Generic Jumps and Calls

ASM51 allows programmers to use a generic JMP or CALL mnemonic. "JMP" can be used instead of SJMP, AJMP or LJMP; and "CALL" can be used instead of ACALL or LCALL. The assembler converts the generic mnemonic to a "real" instruction following a few simple rules. The generic mnemonic converts to the short form (for JMP only) if no forward references are used and the jump destination is within -128 locations, or to the absolute form if no forward references are used and the instruction following the JMP or CALL instruction is in the same 2K block as the destination instruction. If short or absolute forms cannot be used, the conversion is to the long form.

The conversion is not necessarily the best programming choice. For example, if branching ahead a few instructions, the generic JMP will always convert to LJMP even though an SJMP is probably better. Consider the following assembled instructions sequence using three generic jumps.

LOC	OBJ	LINE	SOURCE		
1234		1		ORG	1234H
1234	04	2	START:	INC	A
1235	80FD	3		JMP	START ;ASSEMBLES AS SJMP
12FC		4		ORG	START + 200
12FC	4134	5		JMP	START ;ASSEMBLES AS AJMP
12FE	021301	6		JMP	FINISH ;ASSEMBLES AS LJMP
1301	04	7	FINISH:	INC	A
		8		END	

The first jump (line 3) assembles as SJMP because the destination is before the jump (i.e., no forward reference) and the offset is less than -128. The ORG directive in line 4 creates a gap of 200 locations between the label START and the second jump, so the conversion on line 5 is to AJMP because the offset is too great for SJMP. Note also that the address following the second jump (12FEH) and the address of START (1234H) are within the same 2K page, which, for this instruction sequence, is bounded by 1000H and 17FFH. This criterion must be met for absolute addressing. The third jump assembles as LJMP because the destination (FINISH) is not yet defined when the jump is assembled (i.e., a forward reference is used). The reader can verify that the conversion is as stated by examining the object field for each jump instruction.

ASSEMBLE-TIME EXPRESSION EVALUATION

Values and constants in the operand field may be expressed three ways: (a) explicitly (e.g.,0EFH), (b) with a pre-defined symbol (e.g., ACC), or (c) with an expression (e.g.,2 + 3). The use of expressions provides a powerful technique for making assembly language programs more readable and more flexible. When an expression is used, the assembler calculates a value and inserts it into the instruction.

All expression calculations are performed using 16-bit arithmetic; however, either 8 or 16 bits are inserted into the instruction as needed. For example, the following two instructions are the same:

```
MOV DPTR, #04FFH + 3
MOV DPTR, #0502H ;ENTIRE 16-BIT RESULT USED
```

If the same expression is used in a "MOV A,#data" instruction, however, the error message "value will not fit in a byte" is generated by ASM51. An overview of the rules for evaluating expressions follows.

Number Bases

The base for numeric constants is indicated in the usual way for Intel microprocessors. Constants must be followed with "B" for binary, "O" or "Q" for octal, "D" or nothing for decimal, or "H" for hexadecimal. For example, the following instructions are the same:

```
MOV    A, #15H
MOV    A, #1111B
MOV    A, #0FH
MOV    A, #17Q
MOV    A, #15D
```

Note that a digit must be the first character for hexadecimal constants in order to differentiate them from labels (i.e., "0A5H" not "A5H").

Charater Strings

Strings using one or two characters may be used as operands in expressions. The ASCII codes are converted to the binary equivalent by the assembler. Character constants are enclosed in single quotes (''). Some examples follow.

```
CJNE   A, #'Q', AGAIN
SUBB   A, #'0'           ;CONVERT ASCII DIGIT TO BINARY DIGIT
MOV    DPTR, #'AB'
MOV    DPTR, #4142H      ;SAME AS ABOVE
```

Arithmetic Operators

The arithmetic operators are

+	addition
-	subtraction
*	multiplication
/	division
MOD	modulo (remainder after division)

For example, the following two instructions are same:

```
MOV    A, 10 + 10H
MOV    A, #1AH
```

The following two instructions are also the same:

```
MOV    A, #25 MOD 7
MOV    A, #4
```

Since the MOD operator could be confused with a symbol, it must be seperated from its operands by at least one space or tab character, or the operands must be enclosed in parentheses. The same applies for the other operators composed of letters.

Logical Operators

The logical operators are

OR	logical	OR
AND	logical	AND
XOR	logical	Exclusive OR
NOT	logical	NOT (complement)

The operation is applied on the corresponding bits in each operand. The operator must be separated from the operands by space or tab characters. For example, the following two instructions are the same:

```
MOV    A, # '9' AND  0FH
MOV    A, #9
```

The NOT operator only takes one operand. The following three MOV instructions are the same:

```
THREE      EQU    3
MINUS_THREE EQU    -3
MOV        A,      # (NOT THREE) + 1
MOV        A,      #MINUS_THREE
MOV        A,      #11111101B
```

Special Operators

The special operators are

```
SHR    shift right
SHL    shift left
HIGH   high-byte
LOW    low-byte
()     evaluate first
```

For example, the following two instructions are the same:

```
MOV    A, #8 SHL 1
MOV    A, #10H
```

The following two instructions are also the same:

```
MOV    A, #HIGH 1234H
MOV    A, #12H
```

Relational Operators

When a relational operator is used between two operands, the result is always false (0000H) or true (FFFFH).

The operators are

```
EQ    =      equals
NE    <>     not equals
LT    <      less than
LE    <=     less than or equal to
GT    >      greater than
GE    >=     greater than or equal to
```

Note that for each operator, two forms are acceptable (e.g., "EQ" or "="). In the following examples, all relational tests are "true":

```
MOV    A, #5 = 5
MOV    A, #5 NE 4
MOV    A, # 'X' LT 'Z'
MOV    A, # 'X' >= 'X'
MOV    A, # $ > 0
MOV    A, #100 GE 50
```

So, the assembled instructions are equal to

```
MOV    A, #0FFH
```

Even though expressions evaluate to 16-bit results (i.e., 0FFFFH), in the examples above only the low-order eight bits are used, since the instruction is a move byte operation. The result is not considered too big in this case, because as signed numbers the 16-bit value FFFFH and the 8-bit value FFH are the same (-1).

Expression Examples

The following are examples of expressions and the values that result:

Expression	Result
'B' - 'A'	0001H
8/3	0002H
155 MOD 2	0001H
4 * 4	0010H
8 AND 7	0000H
NOT 1	FFFEH
'A' SHL 8	4100H
LOW 65535	00FFH
(8 + 1) * 2	0012H
5 EQ 4	0000H
'A' LT 'B'	FFFFH
3 <= 3	FFFFHss

A practical example that illustrates a common operation for timer initialization follows: Put -500 into Timer 1 registers TH1 and TL1. In using the HIGH and LOW operators, a good approach is

```
VALUE    EQU    -500
          MOV    TH1, #HIGH  VALUE
          MOV    TL1, #LOW  VALUE
```

The assembler converts -500 to the corresponding 16-bit value (FE0CH); then the HIGH and LOW operators extract the high (FEH) and low (0CH) bytes. as appropriate for each MOV instruction.

Operator Precedence

The precedence of expression operators from highest to lowest is

```
( )
HIGH LOW
* / MOD SHL SHR
+ -
EQ NE LT LE GT GE = <> < <= > >=
NOT
AND
OR XOR
```

When operators of the same precedence are used, they are evaluated left to right.

Examples:

Expression	Value
HIGH ('A' SHL 8)	0041H
HIGH 'A' SHL 8	0000H
NOT 'A' - 1	FFBFH
'A' OR 'A' SHL 8	4141H

ASSEMBLER DIRECTIVES

Assembler directives are instructions to the assembler program. They are not assembly language instructions executable by the target microprocessor. However, they are placed in the mnemonic field of the program. With the exception of DB and DW, they have no direct effect on the contents of memory.

ASM51 provides several categories of directives:

Assembler state control (ORG, END, USING)

Symbol definition (SEGMENT, EQU, SET, DATA, IDATA, XDATA, BIT, CODE)

Storage initialization/reservation (DS, DBIT, DB, DW)

Program linkage (PUBLIC, EXTRN, NAME)

Segment selection (RSEG, CSEG, DSEG, ISEG, ESEG, XSEG)

Each assembler directive is presented below, ordered by category.

Assembler State Control

ORG (Set Origin) The format for the ORG (set origin) directive is

ORG expression

The ORG directive alters the location counter to set a new program origin for statements that follow. A label is not permitted. Two examples follow.

```
ORG 100H ;SET LOCATION COUNTER TO 100H
ORG ($ + 1000H) AND 0F00H ;SET TO NEXT 4K BOUNDARY
```

The ORG directive can be used in any segment type. If the current segment is absolute, the value will be an absolute address in the current segment. If a relocatable segment is active, the value of the ORG expression is treated as an offset from the base address of the current instance of the segment.

End The format of the END directive is

END

END should be the last statement in the source file. No label is permitted and nothing beyond the END statement is processed by the assembler.

Using The format of the END directive is

USING expression

This directive informs ASM51 of the currently active register bank. Subsequent uses of the predefined symbolic register addresses AR0 to AR7 will convert to the appropriate direct address for the active register bank. Consider the following sequence:

```
USING 3
PUSH AR7
USING 1
PUSH AR7
```

The first push above assembles to PUSH 1FH (R7 in bank 3), whereas the second push assembles to PUSH 0FH (R7 in bank 1).

Note that USING does not actually switch register banks; it only informs ASM51 of the active bank. Executing 8051 instructions is the only way to switch register banks. This is illustrated by modifying the example above as follows:

```
MOV    PSW, #00011000B      ;SELECT REGISTER BANK 3
USING  3
PUSH   AR7                  ;ASSEMBLE TO PUSH 1FH
MOV    PSW, #00001000B      ;SELECT REGISTER BANK 1
USING  1
PUSH   AR7                  ;ASSEMBLE TO PUSH 0FH
```

Symbol Definition

The symbol definition directives create symbols that represent segment, registers, numbers, and addresses. None of these directives may be preceded by a label. Symbols defined by these directives may not have been previously defined and may not be redefined by any means. The SET directive is the only exception. Symbol definition directives are described below.

Segment The format for the SEGMENT directive is shown below.

```
symbol          SEGMENT      segment_type
```

The symbol is the name of a relocatable segment. In the use of segments, ASM51 is more complex than conventional assemblers, which generally support only "code" and "data" segment types. However, ASM51 defines additional segment types to accommodate the diverse memory spaces in the 8051. The following are the defined 8051 segment types (memory spaces):

```
CODE (the code segment)
XDATA (the external data space)
DATA (the internal data space accessible by direct addressing, 00H–07H)
IDATA (the entire internal data space accessible by indirect addressing, 00H–07H)
BIT (the bit space; overlapping byte locations 20H–2FH of the internal data space)
```

For example, the statement

```
EPROM          SEGMENT      CODE
```

declares the symbol EPROM to be a SEGMENT of type CODE. Note that this statement simply declares what EPROM is. To actually begin using this segment, the RSEG directive is used (see below).

EQU (Equate) The format for the EQU directive is

```
Symbol          EQU          expression
```

The EQU directive assigns a numeric value to a specified symbol name. The symbol must be a valid symbol name, and the expression must conform to the rules described earlier.

The following are examples of the EQU directive:

```
N27            EQU    27          ;SET N27 TO THE VALUE 27
HERE           EQU    $          ;SET "HERE" TO THE VALUE OF
                                ;THE LOCATION COUNTER
CR             EQU    0DH         ;SET CR (CARRIAGE RETURN) TO 0DH
MESSAGE:       DB    'This is a message'
LENGTH        EQU    $ - MESSAGE ;"LENGTH" EQUALS LENGTH OF "MESSAGE"
```

Other Symbol Definition Directives The SET directive is similar to the EQU directive except the symbol may be redefined later, using another SET directive.

The DATA, IDATA, XDATA, BIT, and CODE directives assign addresses of the corresponding segment type to a symbol. These directives are not essential. A similar effect can be achieved using the EQU directive; if used, however, they evoke powerful type-checking by ASM51. Consider the following two directives and four instructions:

```

FLAG1      EQU    05H
FLAG2      BIT    05H
           SETB   FLAG1
           SETB   FLAG2
           MOV    FLAG1, #0
           MOV    FLAG2, #0

```

The use of FLAG2 in the last instruction in this sequence will generate a "data segment address expected" error message from ASM51. Since FLAG2 is defined as a bit address (using the BIT directive), it can be used in a set bit instruction, but it cannot be used in a move byte instruction. Hence, the error. Even though FLAG1 represents the same value (05H), it was defined using EQU and does not have an associated address space. This is not an advantage of EQU, but rather, a disadvantage. By properly defining address symbols for use in a specific memory space (using the directives BIT, DATA, XDATA, etc.), the programmer takes advantage of ASM51's powerful type-checking and avoids bugs from the misuse of symbols.

Storage Initialization/Reservation

The storage initialization and reservation directives initialize and reserve space in either word, byte, or bit units. The space reserved starts at the location indicated by the current value of the location counter in the currently active segment. These directives may be preceded by a label. The storage initialization/reservation directives are described below.

DS (Define Storage) The format for the DS (define storage) directive is

```

[label:]    DS      expression

```

The DS directive reserves space in byte units. It can be used in any segment type except BIT. The expression must be a valid assemble-time expression with no forward references and no relocatable or external references. When a DS statement is encountered in a program, the location counter of the current segment is incremented by the value of the expression. The sum of the location counter and the specified expression should not exceed the limitations of the current address space.

The following statement create a 40-byte buffer in the internal data segment:

```

          DSEG    AT      30H      ;PUT IN DATA SEGMENT (ABSOLUTE, INTERNAL)
LENGTH    EQU    40
BUFFER:    DS      LENGRH          ;40 BYTES RESERVED

```

The label BUFFER represents the address of the first location of reserved memory. For this example, the buffer begins at address 30H because "AT 30H" is specified with DSEG. The buffer could be cleared using the following instruction sequence:

```

          MOV     R7,    #LENGTH
          MOV     R0,    #BUFFER
LOOP:     MOV     @R0,   #0
          DJNZ    R7,    LOOP
          (continue)

```

To create a 1000-byte buffer in external RAM starting at 4000H, the following directives could be used:

```
XSTART      EQU    4000H
XLENGTH     EQU    1000
             XSEG    AT    XSTART
XBUFFER:    DS    XLENGTH
```

This buffer could be cleared with the following instruction sequence:

```
          MOV    DPTR, #XBUFFER
LOOP:     CLR    A
          MOVX   @DPTR, A
          INC    DPTR
          MOV    A,    DPL
          CJNE   A,    #LOW (XBUFFER + XLENGTH + 1), LOOP
          MOV    A,    DPH
          CJNE   A,    #HIGH (XBUFFER + XLENGTH + 1), LOOP
          (continue)
```

This is an excellent example of a powerful use of ASM51's operators and assemble-time expressions. Since an instruction does not exist to compare the data pointer with an immediate value, the operation must be fabricated from available instructions. Two compares are required, one each for the high- and low-bytes of the DPTR. Furthermore, the compare-and-jump-if-not-equal instruction works only with the accumulator or a register, so the data pointer bytes must be moved into the accumulator before the CJNE instruction. The loop terminates only when the data pointer has reached $XBUFFER + LENGTH + 1$. (The "+1" is needed because the data pointer is incremented after the last MOVX instruction.)

DBIT The format for the DBIT (define bit) directive is,

```
[label:]            DBIT    expression
```

The DBIT directive reserves space in bit units. It can be used only in a BIT segment. The expression must be a valid assemble-time expression with no forward references. When the DBIT statement is encountered in a program, the location counter of the current (BIT) segment is incremented by the value of the expression. Note that in a BIT segment, the basic unit of the location counter is bits rather than bytes. The following directives create three flags in a absolute bit segment:

```
          BSEG           ;BIT SEGMENT (ABSOLUTE)
KEFLAG:   DBIT    1      ;KEYBOARD STATUS
PRFLAG:   DBIT    1      ;PRINTER STATUS
DKFLAG:   DBIT    1      ;DISK STATUS
```

Since an address is not specified with BSEG in the example above, the address of the flags defined by DBIT could be determined (if one wishes to do so) by examining the symbol table in the .LST or .M51 files. If the definitions above were the first use of BSEG, then KBFLAG would be at bit address 00H (bit 0 of byte address 20H). If other bits were defined previously using BSEG, then the definitions above would follow the last bit defined.

DB (Define Byte) The format for the DB (define byte) directive is,

```
[label:]            DB        expression [, expression] [...]
```

The DB directive initializes code memory with byte values. Since it is used to actually place data constants in code memory, a CODE segment must be active. The expression list is a series of one or more byte values (each of which may be an expression) separated by commas.

The DB directive permits character strings (enclosed in single quotes) longer than two characters as long as they are not part of an expression. Each character in the string is converted to the corresponding ASCII code. If a label is used, it is assigned the address of the first byte. For example, the following statements

```

                CSEG  AT      0100H
SQUARES:      DB    0, 1, 4, 9, 16, 25          ;SQUARES OF NUMBERS 0-5
MESSAGE:      DB    'Login:', 0                ;NULL-TERMINATED CHARACTER STRING

```

When assembled, result in the following hexadecimal memory assignments for external code memory:

Address	Contents
0100	00
0101	01
0102	04
0103	09
0104	10
0105	19
0106	4C
0107	6F
0108	67
0109	69
010A	6E
010B	3A
010C	00

DW (Define Word) The format for the DW (define word) directive is

```
[label:]      DW    expression      [, expression] [...]
```

The DW directive is the same as the DB directive except two memory locations (16 bits) are assigned for each data item. For example, the statements

```

CSEG  AT      200H
DW    $, 'A', 1234H, 2, 'BC'

```

result in the following hexadecimal memory assignments:

Address	Contents
0200	02
0201	00
0202	00
0203	41
0204	12
0205	34
0206	00
0207	02
0208	42
0209	43

Program Linkage

Program linkage directives allow the separately assembled modules (files) to communicate by permitting inter-module references and the naming of modules. In the following discussion, a "module" can be considered a "file." (In fact, a module may encompass more than one file.)

Public The format for the PUBLIC (public symbol) directive is

PUBLIC symbol [, symbol] [...]

The PUBLIC directive allows the list of specified symbols to known and used outside the currently assembled module. A symbol declared PUBLIC must be defined in the current module. Declaring it PUBLIC allows it to be referenced in another module. For example,

PUBLIC INCHAR, OUTCHR, INLINE, OUTSTR

Extrn The format for the EXTRN (external symbol) directive is

EXTRN segment_type (symbol [, symbol] [...], ...)

The EXTRN directive lists symbols to be referenced in the current module that are defined in other modules. The list of external symbols must have a segment type associated with each symbol in the list. (The segment types are CODE, XDATA, DATA, IDATA, BIT, and NUMBER. NUMBER is a type-less symbol defined by EQU.) The segment type indicates the way a symbol may be used. The information is important at link-time to ensure symbols are used properly in different modules.

The PUBLIC and EXTRN directives work together. Consider the two files, MAIN.SRC and MESSAGES.SRC. The subroutines HELLO and GOOD_BYE are defined in the module MESSAGES but are made available to other modules using the PUBLIC directive. The subroutines are called in the module MAIN even though they are not defined there. The EXTRN directive declares that these symbols are defined in another module.

MAIN.SRC:

```
EXTRN           CODE (HELLO, GOOD_BYE)
...
CALL           HELLO
...
CALL           GOOD_BYE
...
END
```

MESSAGES.SRC:

```
          PUBLIC       HELLO, GOOD_BYE
...
HELLO:       (begin subroutine)
...
          RET
GOOD_BYE:   (begin subroutine)
...
          RET
...
          END
```

Neither MAIN.SRC nor MESSAGES.SRC is a complete program; they must be assembled separately and linked together to form an executable program. During linking, the external references are resolved with correct addresses inserted as the destination for the CALL instructions.

Name The format for the NAME directive is

NAME module_name

All the usual rules for symbol names apply to module names. If a name is not provided, the module takes on the file name (without a drive or subdirectory specifier and without an extension). In the absence of any use of the NAME directive, a program will contain one module for each file. The concept of "modules," therefore, is somewhat cumbersome, at least for relatively small programming problems. Even programs of moderate size (encompassing, for example, several files complete with relocatable segments) needn't use the NAME directive and needn't pay any special attention to the concept of "modules." For this reason, it was mentioned in the definition that a module may be considered a "file," to simplify learning ASM51. However, for very large programs (several thousand lines of code, or more), it makes sense to partition the problem into modules, where, for example, each module may encompass several files containing routines having a common purpose.

Segment Selection Directives

When the assembler encounters a segment selection directive, it diverts the following code or data into the selected segment until another segment is selected by a segment selection directive. The directive may select a previously defined relocatable segment or optionally create and select absolute segments.

RSEG (Relocatable Segment) The format for the RSEG (relocatable segment) directive is

```
RSEG      segment_name
```

Where "segment_name" is the name of a relocatable segment previously defined with the SEGMENT directive. RSEG is a "segment selection" directive that diverts subsequent code or data into the named segment until another segment selection directive is encountered.

Selecting Absolute Segments RSEG selects a relocatable segment. An "absolute" segment, on the other hand, is selected using one of the directives:

```
CSEG      (AT address)
DSEG      (AT address)
ISEG      (AT address)
BSEG      (AT address)
XSEG      (AT address)
```

These directives select an absolute segment within the code, internal data, indirect internal data, bit, or external data address spaces, respectively. If an absolute address is provided (by indicating "AT address"), the assembler terminates the last absolute address segment, if any, of the specified segment type and creates a new absolute segment starting at that address. If an absolute address is not specified, the last absolute segment of the specified type is continued. If no absolute segment of this type was previously selected and the absolute address is omitted, a new segment is created starting at location 0. Forward references are not allowed and start addresses must be absolute.

Each segment has its own location counter, which is always set to 0 initially. The default segment is an absolute code segment; therefore, the initial state of the assembler is location 0000H in the absolute code segment. When another segment is chosen for the first time, the location counter of the former segment retains the last active value. When that former segment is reselected, the location counter picks up at the last active value. The ORG directive may be used to change the location counter within the currently selected segment.

ASSEMBLER CONTROLS

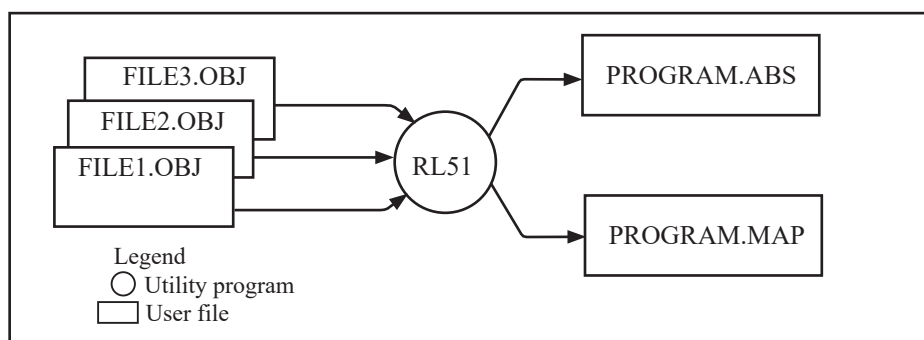
Assembler controls establish the format of the listing and object files by regulating the actions of ASM51. For the most part, assembler controls affect the look of the listing file, without having any affect on the program itself. They can be entered on the invocation line when a program is assembled, or they can be placed in the source file. Assembler controls appearing in the source file must be preceded with a dollar sign and must begin in column 1.

There are two categories of assembler controls: primary and general. Primary controls can be placed in the invocation line or at the beginning of the source program. Only other primary controls may precede a primary control. General controls may be placed anywhere in the source program.

LINKER OPERATION

In developing large application programs, it is common to divide tasks into subprograms or modules containing sections of code (usually subroutines) that can be written separately from the overall program. The term "modular programming" refers to this programming strategy. Generally, modules are relocatable, meaning they are not intended for a specific address in the code or data space. A linking and locating program is needed to combine the modules into one absolute object module that can be executed.

Intel's RL51 is a typical linker/locator. It processes a series of relocatable object modules as input and creates an executable machine language program (PROGRAM, perhaps) and a listing file containing a memory map and symbol table (PROGRAM.M51). This is illustrated in following figure.



Linker operation

As relocatable modules are combined, all values for external symbols are resolved with values inserted into the output file. The linker is invoked from the system prompt by

```
RL51  input_list  [T0 output_file]  [location_controls]
```

The `input_list` is a list of relocatable object modules (files) separated by commas. The `output_list` is the name of the output absolute object module. If none is supplied, it defaults to the name of the first input file without any suffix. The `location_controls` set start addresses for the named segments.

For example, suppose three modules or files (MAIN.OBJ, MESSAGES.OBJ, and SUBROUTINES.OBJ) are to be combined into an executable program (EXAMPLE), and that these modules each contain two relocatable segments, one called EPROM of type CODE, and the other called ONCHIP of type DATA. Suppose further that the code segment is to be executable at address 4000H and the data segment is to reside starting at address 30H (in internal RAM). The following linker invocation could be used:

```
RS51  MAIN.OBJ, MESSAGES.OBJ, SUBROUTINES.OBJ TO EXAMPLE & CODE
      (EPROM (4000H) DATA (ONCHIP (30H))
```

Note that the ampersand character "&" is used as the line continuation character.

If the program begins at the label START, and this is the first instruction in the MAIN module, then execution begins at address 4000H. If the MAIN module was not linked first, or if the label START is not at the beginning of MAIN, then the program's entry point can be determined by examining the symbol table in the listing file EXAMPLE.M51 created by RL51. By default, EXAMPLE.M51 will contain only the link map. If a symbol table is desired, then each source program must have used the SDEBUG control. The following table shows the assembler controls supported by ASM51.

Assembler controls supported by ASM51				
NAME	PRIMARY/ GENERAL	DEFAULT	ABBREV.	MEANING
DATE (date)	P	DATE()	DA	Place string in header (9 char. max.)
DEBUG	P	NODEBUG	DB	Outputs debug symbol information to object file
EJECT	G	not applicable	EJ	Continue listing on next page
ERRORPRINT (file)	P	NOERRORPRINT	EP	Designates a file to receive error messages in addition to the listing file (defaults to console)
NOERRORPRINT	P	NOERRORPRINT	NOEP	Designates that error messages will be printed in listing file only
GEN	G	GENONLY	GO	List only the fully expanded source as if all lines generated by a macro call were already in the source file
GENONLY	G	GENONLY	NOGE	List only the original source text in the listing file
INCLUDED(file)	G	not applicable	IC	Designates a file to be included as part of the program
LIST	G	LIST	LI	Print subsequent lines of source code in listing file
NOLIST	G	LIST	NOLI	Do not print subsequent lines of source code in listing file
MACRO (mem_percent)	P	MACRO(50)	MR	Evaluate and expand all macro calls. Allocate percentage of free memory for macro processing
NOMACRO	P	MACRO(50)	NOMR	Do not evaluate macro calls
MOD51	P	MOD51	MO	Recognize the 8051-specific predefined special function registers
NOMOD51	P	MOD51	NOMO	Do not recognize the 8051-specific predefined special function registers
OBJECT(file)	P	OBJECT(source.OBJ)	OJ	Designates file to receive object code
NOOBJECT	P	OBJECT(source.OBJ)	NOOJ	Designates that no object file will be created
PAGING	P	PAGING	PI	Designates that listing file be broken into pages and each will have a header
NOPAGING	P	PAGING	NOPI	Designates that listing file will contain no page breaks
PAGELNGTH (N)	P	PAGELNGT(60)	PL	Sets maximum number of lines in each page of listing file (range=10 to 65536)
PAGE WIDTH (N)	P	PAGEWIDTH(120)	PW	Set maximum number of characters in each line of listing file (range = 72 to 132)
PRINT(file)	P	PRINT(source.LST)	PR	Designates file to receive source listing
NOPRINT	P	PRINT(source.LST)	NOPR	Designates that no listing file will be created
SAVE	G	not applicable	SA	Stores current control settings from SAVE stack
RESTORE	G	not applicable	RS	Restores control settings from SAVE stack
REGISTERBANK (rb,...)	P	REGISTERBANK(0)	RB	Indicates one or more banks used in program module
NOREGISTER- BANK	P	REGISTERBANK(0)	NORB	Indicates that no register banks are used
SYMBOLS	P	SYMBOLS	SB	Creates a formatted table of all symbols used in program
NOSYMBOLS	P	SYMBOLS	NOSB	Designates that no symbol table is created
TITLE(string)	G	TITLE()	TT	Places a string in all subsequent page headers (max.60 characters)
WORKFILES (path)	P	same as source	WF	Designates alternate path for temporary workfiles
XREF	P	NOXREF	XR	Creates a cross reference listing of all symbols used in program
NOXREF	P	NOXREF	NOXR	Designates that no cross reference list is created

MACROS

The macro processing facility (MPL) of ASM51 is a "string replacement" facility. Macros allow frequently used sections of code be defined once using a simple mnemonic and used anywhere in the program by inserting the mnemonic. Programming using macros is a powerful extension of the techniques described thus far. Macros can be defined anywhere in a source program and subsequently used like any other instruction. The syntax for macro definition is

```
%*DEFINE      (call_pattern)      (macro_body)
```

Once defined, the call pattern is like a mnemonic; it may be used like any assembly language instruction by placing it in the mnemonic field of a program. Macros are made distinct from "real" instructions by preceding them with a percent sign, "%". When the source program is assembled, everything within the macro-body, on a character-by-character basis, is substituted for the call-pattern. The mystique of macros is largely unfounded. They provide a simple means for replacing cumbersome instruction patterns with primitive, easy-to-remember mnemonics. The substitution, we reiterate, is on a character-by-character basis—nothing more, nothing less.

For example, if the following macro definition appears at the beginning of a source file,

```
%*DEFINE      (PUSH_DPTR)
                (PUSH   DPH
                 PUSH   DPL
                 )
```

then the statement

```
%PUSH_DPTR
```

will appear in the .LST file as

```
PUSH   DPH
PUSH   DPL
```

The example above is a typical macro. Since the 8051 stack instructions operate only on direct addresses, pushing the data pointer requires two PUSH instructions. A similar macro can be created to POP the data pointer.

There are several distinct advantages in using macros:

A source program using macros is more readable, since the macro mnemonic is generally more indicative of the intended operation than the equivalent assembler instructions.

The source program is shorter and requires less typing.

Using macros reduces bugs

Using macros frees the programmer from dealing with low-level details.

The last two points above are related. Once a macro is written and debugged, it is used freely without the worry of bugs. In the PUSH_DPTR example above, if PUSH and POP instructions are used rather than push and pop macros, the programmer may inadvertently reverse the order of the pushes or pops. (Was it the high-byte or low-byte that was pushed first?) This would create a bug. Using macros, however, the details are worked out once—when the macro is written—and the macro is used freely thereafter, without the worry of bugs.

Since the replacement is on a character-by-character basis, the macro definition should be carefully constructed with carriage returns, tabs, ect., to ensure proper alignment of the macro statements with the rest of the assembly language program. Some trial and error is required.

There are advanced features of ASM51's macro-processing facility that allow for parameter passing, local labels, repeat operations, assembly flow control, and so on. These are discussed below.

Parameter Passing

A macro with parameters passed from the main program has the following modified format:

```
%*DEFINE      (macro_name (parameter_list)) (macro_body)
```

For example, if the following macro is defined,

```
%*DEFINE      (CMPA# (VALUE))
              (CJNE  A, #VALUE, $ + 3
               )
```

then the macro call

```
%CMPA# (20H)
```

will expand to the following instruction in the .LST file:

```
CJNE  A, #20H, $ + 3
```

Although the 8051 does not have a "compare accumulator" instruction, one is easily created using the CJNE instruction with "\$+3" (the next instruction) as the destination for the conditional jump. The CMPA# mnemonic may be easier to remember for many programmers. Besides, use of the macro unburdens the programmer from remembering notational details, such as "\$+3."

Let's develop another example. It would be nice if the 8051 had instructions such as

```
JUMP  IF ACCUMULATOR GREATER THAN X
JUMP  IF ACCUMULATOR GREATER THAN OR EQUAL TO X
JUMP  IF ACCUMULATOR LESS THAN X
JUMP  IF ACCUMULATOR LESS THAN OR EQUAL TO X
```

but it does not. These operations can be created using CJNE followed by JC or JNC, but the details are tricky. Suppose, for example, it is desired to jump to the label GREATER_THAN if the accumulator contains an ASCII code greater than "Z" (5AH). The following instruction sequence would work:

```
CJNE  A, #5BH, $+3
JNC   GREATER_THAN
```

The CJNE instruction subtracts 5BH (i.e., "Z" + 1) from the content of A and sets or clears the carry flag accordingly. CJNE leaves C=1 for accumulator values 00H up to and including 5AH. (Note: 5AH-5BH<0, therefore C=1; but 5BH-5BH=0, therefore C=0.) Jumping to GREATER_THAN on the condition "not carry" correctly jumps for accumulator values 5BH, 5CH, 5DH, and so on, up to FFH. Once details such as these are worked out, they can be simplified by inventing an appropriate mnemonic, defining a macro, and using the macro instead of the corresponding instruction sequence. Here's the definition for a "jump if greater than" macro:

```
%*DEFINE      (JGT (VALUE, LABEL))
              (CJNE  A, #VALUE+1, $+3    ;JGT
               JNC   %LABEL
               )
```

To test if the accumulator contains an ASCII code greater than "Z," as just discussed, the macro would be called as

```
%JGT  ('Z', GREATER_THAN)
```

ASM51 would expand this into

```
CJNE  A, #5BH, $+3    ;JGT
JNC   GREATER_THAN
```

The JGT macro is an excellent example of a relevant and powerful use of macros. By using macros, the programmer benefits by using a meaningful mnemonic and avoiding messy and potentially bug-ridden details.

Local Labels

Local labels may be used within a macro using the following format:

```
%*DEFINE      (macro_name [(parameter_list)])  
                [LOCAL list_of_local_labels] (macro_body)
```

For example, the following macro definition

```
%*DEFINE      (DEC_DPTR)  LOCAL SKIP  
                (DEC      DPL                      ;DECREMENT DATA POINTER  
                 MOV      A,      DPL  
                 CJNE     A,      #0FFH, %SKIP  
                 DEC      DPL  
%SKIP:         )
```

would be called as

```
%DEC_DPTR
```

and would be expanded by ASM51 into

```
                DEC      DPL                      ;DECREMENT DATA POINTER  
                MOV      A,      DPL  
                CJNE     A,      #0FFH, SKIP00  
                DEC      DPH  
SKIP00:
```

Note that a local label generally will not conflict with the same label used elsewhere in the source program, since ASM51 appends a numeric code to the local label when the macro is expanded. Furthermore, the next use of the same local label receives the next numeric code, and so on.

The macro above has a potential "side effect." The accumulator is used as a temporary holding place for DPL. If the macro is used within a section of code that uses A for another purpose, the value in A would be lost. This side effect probably represents a bug in the program. The macro definition could guard against this by saving A on the stack. Here's an alternate definition for the DEC_DPTR macro:

```
%*DEFINE      (DEC_DPTR)  LOCAL SKIP  
                (PUSHACC  
                 DEC      DPL                      ;DECREMENT DATA POINTER  
                 MOV      A,      DPL  
                 CJNE     A,      #0FFH, %SKIP  
                 DEC      DPH  
%SKIP:         POP      ACC  
                )
```

Repeat Operations

This is one of several built-in (predefined) macros. The format is

```
%REPEAT      (expression)      (text)
```

For example, to fill a block of memory with 100 NOP instructions,

```
%REPEAT      (100)  
(NOP  
)
```

Control Flow Operations

The conditional assembly of section of code is provided by ASM51's control flow macro definition. The format is

```
%IF (expression) THEN (balanced_text)
[ELSE (balanced_text)] FI
```

For example,

```
INTRENAL      EQU      1          ;1 = 8051 SERIAL I/O DRIVERS
                                   ;0 = 8251 SERIAL I/O DRIVERS
                                   .
                                   .
                                   %IF (INTERNAL) THEN
(INCHAR:      .                  ;8051 DRIVERS
                                   .
OUTCHR:      .
                                   .
                                   ) ELSE
(INCHAR:      .                  ;8251 DRIVERS
                                   .
OUTCHR:      .
                                   .
                                   )
```

In this example, the symbol INTERNAL is given the value 1 to select I/O subroutines for the 8051's serial port, or the value 0 to select I/O subroutines for an external UART, in this case the 8251. The IF macro causes ASM51 to assemble one set of drivers and skip over the other. Elsewhere in the program, the INCHAR and OUTCHR subroutines are used without consideration for the particular hardware configuration. As long as the program is assembled with the correct value for INTERNAL, the correct subroutine is executed.

附录B：C语言编程

ADVANTAGES AND DISADVANTAGES OF 8051 C

The advantages of programming the 8051 in C as compared to assembly are:

- Offers all the benefits of high-level, structured programming languages such as C, including the ease of writing subroutines
- Often relieves the programmer of the hardware details that the compiler handles on behalf of the programmer
- Easier to write, especially for large and complex programs
- Produces more readable program source codes

Nevertheless, 8051 C, being very similar to the conventional C language, also suffers from the following disadvantages:

- Processes the disadvantages of high-level, structured programming languages.
- Generally generates larger machine codes
- Programmer has less control and less ability to directly interact with hardware

To compare between 8051 C and assembly language, consider the solutions to the Example—Write a program using Timer 0 to create a 1KHz square wave on P1.0.

A solution written below in 8051 C language:

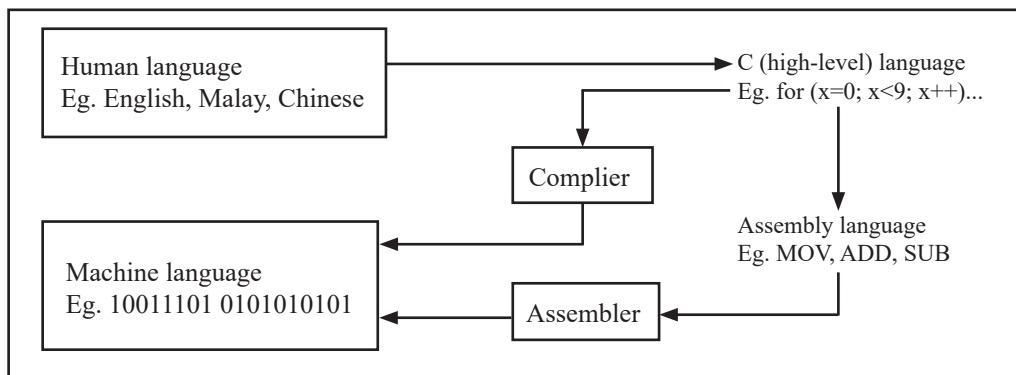
```
sbit portbit = P1^0;          /*Use variable portbit to refer to P1.0*/
main ()
{
    TMOD = 1;
    while (1)
    {
        TH0 = 0xFE;
        TL0 = 0xC;
        TR0 = 1;
        while (TF0 != 1);
        TR0 = 0;
        TF0 = 0;
        portbit = !(P1.^0);
    }
}
```

A solution written below in assembly language:

	ORG	8100H	
	MOV	TMOD, #01H	;16-bit timer mode
LOOP:	MOV	TH0, #0FEH	;500 (high byte)
	MOV	TL0, #0CH	;500 (low byte)
	SETB	TR0	;start timer
WAIT:	JNB	TF0, WAIT	;wait for overflow
	CLR	TR0	;stop timer
	CLR	TF0	;clear timer overflow flag
	CPL	P1.0	;toggle port bit
	SJMP	LOOP	;repeat
	END		

Notice that both the assembly and C language solutions for the above example require almost the same number of lines. However, the difference lies in the readability of these programs. The C version seems more human than assembly, and is hence more readable. This often helps facilitate the human programmer's efforts to write even very complex programs. The assembly language version is more closely related to the machine code, and though less readable, often results in more compact machine code. As with this example, the resultant machine code from the assembly version takes 83 bytes while that of the C version requires 149 bytes, an increase of 79.5%!

The human programmer's choice of either high-level C language or assembly language for talking to the 8051, whose language is machine language, presents an interesting picture, as shown in following figure.



Conversion between human, high-level, assembly, and machine language

8051 C COMPILERS

We saw in the above figure that a compiler is needed to convert programs written in 8051 C language into machine language, just as an assembler is needed in the case of programs written in assembly language. A compiler basically acts just like an assembler, except that it is more complex since the difference between C and machine language is far greater than that between assembly and machine language. Hence the compiler faces a greater task to bridge that difference.

Currently, there exist various 8051 C compiler, which offer almost similar functions. All our examples and programs have been compiled and tested with Keil's μ Vision 2 IDE by Keil Software, an integrated 8051 program development environment that includes its C51 cross compiler for C. A cross compiler is a compiler that normally runs on a platform such as IBM compatible PCs but is meant to compile programs into codes to be run on other platforms such as the 8051.

DATA TYPES

8051 C is very much like the conventional C language, except that several extensions and adaptations have been made to make it suitable for the 8051 programming environment. The first concern for the 8051 C programmer is the data types. Recall that a data type is something we use to store data. Readers will be familiar with the basic C data types such as `int`, `char`, and `float`, which are used to create variables to store integers, characters, or floating-points. In 8051 C, all the basic C data types are supported, plus a few additional data types meant to be used specifically with the 8051.

The following table gives a list of the common data types used in 8051 C. The ones in bold are the specific 8051 extensions. The data type **`bit`** can be used to declare variables that reside in the 8051's bit-addressable locations (namely byte locations 20H to 2FH or bit locations 00H to 7FH). Obviously, these bit variables can only store bit values of either 0 or 1. As an example, the following C statement:

```
bit flag = 0;
```

declares a bit variable called `flag` and initializes it to 0.

Data types used in 8051 C language

Data Type	Bits	Bytes	Value Range
bit	1		0 to 1
signed char	8	1	-128 to +127
unsigned char	8	1	0 to 255
enum	16	2	-32768 to +32767
signed short	16	2	-32768 to +32767
unsigned short	16	2	0 to 65535
signed int	16	2	-32768 to +32767
unsigned int	16	2	0 to 65535
signed long	32	4	-2,147,483,648 to +2,147,483,647
unsigned long	32	4	0 to 4,294,967,295
float	32	4	$\pm 1.175494\text{E-}38$ to $\pm 3.402823\text{E+}38$
sbit	1		0 to 1
sfr	8	1	0 to 255
sfr16	16	2	0 to 65535

The data type **sbit** is somewhat similar to the bit data type, except that it is normally used to declare 1-bit variables that reside in special function registers (SFRs). For example:

```
sbit    P = 0xD0;
```

declares the **sbit** variable P and specifies that it refers to bit address D0H, which is really the LSB of the PSW SFR. Notice the difference here in the usage of the assignment ("=") operator. In the context of **sbit** declarations, it indicates what address the **sbit** variable resides in, while in **bit** declarations, it is used to specify the initial value of the **bit** variable.

Besides directly assigning a bit address to an **sbit** variable, we could also use a previously defined **sfr** variable as the base address and assign our **sbit** variable to refer to a certain bit within that **sfr**. For example:

```
sfr     PSW = 0xD0;
sbit    P = PSW^0;
```

This declares an **sfr** variable called PSW that refers to the byte address D0H and then uses it as the base address to refer to its LSB (bit 0). This is then assigned to an **sbit** variable, P. For this purpose, the caret symbol (^) is used to specify bit position 0 of the PSW.

A third alternative uses a constant byte address as the base address within which a certain bit is referred. As an illustration, the previous two statements can be replaced with the following:

```
sbit    P = 0xD0 ^ 0;
```

Meanwhile, the **sfr** data type is used to declare byte (8-bit) variables that are associated with SFRs. The statement:

```
sfr     IE = 0xA8;
```

declares an **sfr** variable IE that resides at byte address A8H. Recall that this address is where the Interrupt Enable (IE) SFR is located; therefore, the **sfr** data type is just a means to enable us to assign names for SFRs so that it is easier to remember.

The **sfr16** data type is very similar to **sfr** but, while the **sfr** data type is used for 8-bit SFRs, **sfr16** is used for 16-bit SFRs. For example, the following statement:

```
sfr16   DPTR = 0x82;
```

declares a 16-bit variable DPTR whose lower-byte address is at 82H. Checking through the 8051 architecture, we find that this is the address of the DPL SFR, so again, the **sfr16** data type makes it easier for us to refer to the SFRs by name rather than address. There's just one thing left to mention. When declaring **sbit**, **sfr**, or **sfr16** variables, remember to do so outside main, otherwise you will get an error.

In actual fact though, all the SFRs in the 8051, including the individual flag, status, and control bits in the bit-addressable SFRs have already been declared in an include file, called reg51.h, which comes packaged with most 8051 C compilers. By using reg51.h, we can refer for instance to the interrupt enable register as simply IE rather than having to specify the address A8H, and to the data pointer as DPTR rather than 82H. All this makes 8051 C programs more human-readable and manageable. The contents of reg51.h are listed below.

```
/*-----
REG51.H
Header file for generic 8051 microcontroller.
-----*/

/* BYTE Register */
sfr    P0      = 0x80;
sfr    P1      = 0x90;
sfr    P2      = 0xA0;
sfr    P3      = 0xB0;
sfr    PSW     = 0xD0;
sfr    ACC     = 0xE0;
sfr    B       = 0xF0;
sfr    SP      = 0x81;
sfr    DPL     = 0x82;
sfr    DPH     = 0x83;
sfr    PCON    = 0x87;
sfr    TCON    = 0x88;
sfr    TMOD    = 0x89;
sfr    TL0     = 0x8A;
sfr    TL1     = 0x8B;
sfr    TH0     = 0x8C;
sfr    TH1     = 0x8D;
sfr    IE      = 0xA8;
sfr    IP      = 0xB8;
sfr    SCON    = 0x98;
sfr    SBUF    = 0x99;
/* BIT Register */
/* PSW */
sbit    CY      = 0xD7;
sbit    AC      = 0xD6;
sbit    F0      = 0xD5;
sbit    RS1     = 0xD4;
sbit    RS0     = 0xD3;
sbit    OV      = 0xD2;
sbit    P       = 0xD0;
/* TCON */
sbit    TF1     = 0x8F;
sbit    TR1     = 0x8E;
sbit    TF0     = 0x8D;
sbit    TR0     = 0x8C;

sbit    IE1     = 0xA8;
sbit    IT1     = 0xA8;
sbit    IE0     = 0xA9;
sbit    IT0     = 0xA8;
/* IE */
sbit    EA      = 0xAF;
sbit    ES      = 0xAC;
sbit    ET1     = 0xAB;
sbit    EX1     = 0xAA;
sbit    ET0     = 0xA9;
sbit    EX0     = 0xA8;
/* IP */
sbit    PS      = 0xBC;
sbit    PT1     = 0xBB;
sbit    PX1     = 0xBA;
sbit    PT0     = 0xB9;
sbit    PX0     = 0xB8;
/* P3 */
sbit    RD      = 0xB7;
sbit    WR      = 0xB6;
sbit    T1      = 0xB5;
sbit    T0      = 0xB4;
sbit    INT1    = 0xB3;
sbit    INT0    = 0xB2;
sbit    TXD     = 0xB1;
sbit    RXD     = 0xB0;
/* SCON */
sbit    SM0     = 0x9F;
sbit    SM1     = 0x9E;
sbit    SM2     = 0x9D;
sbit    REN     = 0x9C;
sbit    TB8     = 0x9B;
sbit    RB8     = 0x9A;
sbit    TI      = 0x99;
sbit    RI      = 0x98;
```

MEMORY TYPES AND MODELS

The 8051 has various types of memory space, including internal and external code and data memory. When declaring variables, it is hence reasonable to wonder in which type of memory those variables would reside. For this purpose, several memory type specifiers are available for use, as shown in following table.

Memory types used in 8051 C language	
Memory Type	Description (Size)
code	Code memory (64 Kbytes)
data	Directly addressable internal data memory (128 bytes)
idata	Indirectly addressable internal data memory (256 bytes)
bdata	Bit-addressable internal data memory (16 bytes)
xdata	External data memory (64 Kbytes)
pdata	Paged external data memory (256 bytes)

The first memory type specifier given in above table is **code**. This is used to specify that a variable is to reside in code memory, which has a range of up to 64 Kbytes. For example:

```
char    code    errmsg[ ] = "An error occurred" ;
```

declares a char array called errmsg that resides in code memory.

If you want to put a variable into data memory, then use either of the remaining five data memory specifiers in above table. Though the choice rests on you, bear in mind that each type of data memory affect the speed of access and the size of available data memory. For instance, consider the following declarations:

```
signed int  data  num1;
bit bdata  numbit;
unsigned int  xdata  num2;
```

The first statement creates a signed int variable num1 that resides in internal **data** memory (00H to 7FH). The next line declares a bit variable numbit that is to reside in the bit-addressable memory locations (byte addresses 20H to 2FH), also known as **bdata**. Finally, the last line declares an unsigned int variable called num2 that resides in external data memory, **xdata**. Having a variable located in the directly addressable internal data memory speeds up access considerably; hence, for programs that are time-critical, the variables should be of type **data**. For other variants such as 8052 with internal data memory up to 256 bytes, the **idata** specifier may be used. Note however that this is slower than data since it must use indirect addressing. Meanwhile, if you would rather have your variables reside in external memory, you have the choice of declaring them as **pdata** or **xdata**. A variable declared to be in **pdata** resides in the first 256 bytes (a page) of external memory, while if more storage is required, **xdata** should be used, which allows for accessing up to 64 Kbytes of external data memory.

What if when declaring a variable you forget to explicitly specify what type of memory it should reside in, or you wish that all variables are assigned a default memory type without having to specify them one by one? In this case, we make use of **memory models**. The following table lists the various memory models that you can use.

Memory models used in 8051 C language	
Memory Model	Description
Small	Variables default to the internal data memory (data)
Compact	Variables default to the first 256 bytes of external data memory (pdata)
Large	Variables default to external data memory (xdata)

A program is explicitly selected to be in a certain memory model by using the C directive, `#pragma`. Otherwise, the default memory model is **small**. It is recommended that programs use the small memory model as it allows for the fastest possible access by defaulting all variables to reside in internal data memory.

The **compact** memory model causes all variables to default to the first page of external data memory while the **large** memory model causes all variables to default to the full external data memory range of up to 64 Kbytes.

ARRAYS

Often, a group of variables used to store data of the same type need to be grouped together for better readability. For example, the ASCII table for decimal digits would be as shown below.

ASCII table for decimal digits	
Decimal Digit	ASCII Code In Hex
0	30H
1	31H
2	32H
3	33H
4	34H
5	35H
6	36H
7	37H
8	38H
9	39H

To store such a table in an 8051 C program, an array could be used. An array is a group of variables of the same data type, all of which could be accessed by using the name of the array along with an appropriate index.

The array to store the decimal ASCII table is:

```
int    table[10] =
    {0x30, 0x31, 0x32, 0x33, 0x34, 0x35, 0x36, 0x37, 0x38, 0x39};
```

Notice that all the elements of an array are separated by commas. To access an individual element, an index starting from 0 is used. For instance, `table[0]` refers to the first element while `table[9]` refers to the last element in this ASCII table.

STRUCTURES

Sometime it is also desired that variables of different data types but which are related to each other in some way be grouped together. For example, the name, age, and date of birth of a person would be stored in different types of variables, but all refer to the person's personal details. In such a case, a structure can be declared. A structure is a group of related variables that could be of different data types. Such a structure is declared by:

```
struct    person {
            char name;
            int age;
            long DOB;
        };
```

Once such a structure has been declared, it can be used like a data type specifier to create structure variables that have the member's name, age, and DOB. For example:

```
struct    person    grace = {"Grace", 22, 01311980};
```

would create a structure variable `grace` to store the name, age, and data of birth of a person called Grace. Then in order to access the specific members within the person structure variable, use the variable name followed by the dot operator (`.`) and the member name. Therefore, `grace.name`, `grace.age`, `grace.DOB` would refer to Grace's name, age, and data of birth, respectively.

POINTERS

When programming the 8051 in assembly, sometimes register such as `R0`, `R1`, and `DPTR` are used to store the addresses of some data in a certain memory location. When data is accessed via these registers, indirect addressing is used. In this case, we say that `R0`, `R1`, or `DPTR` are used to point to the data, so they are essentially pointers.

Correspondingly in C, indirect access of data can be done through specially defined pointer variables. Pointers are simply just special types of variables, but whereas normal variables are used to directly store data, pointer variables are used to store the addresses of the data. Just bear in mind that whether you use normal variables or pointer variables, you still get to access the data in the end. It is just whether you go directly to where it is stored and get the data, as in the case of normal variables, or first consult a directory to check the location of that data before going there to get it, as in the case of pointer variables.

Declaring a pointer follows the format:

```
data_type    *pointer_name;
```

where

<code>data_type</code>	refers to which type of data that the pointer is pointing to
<code>*</code>	denotes that this is a pointer variable
<code>pointer_name</code>	is the name of the pointer

As an example, the following declarations:

```
int  * numPtr
int  num;
numPtr = &num;
```

first declares a pointer variable called `numPtr` that will be used to point to data of type `int`. The second declaration declares a normal variable and is put there for comparison. The third line assigns the address of the `num` variable to the `numPtr` pointer. The address of any variable can be obtained by using the address operator, `&`, as is used in this example. Bear in mind that once assigned, the `numPtr` pointer contains the address of the `num` variable, not the value of its data.

The above example could also be rewritten such that the pointer is straightaway initialized with an address when it is first declared:

```
int  num;
int  * numPtr = &num;
```

In order to further illustrate the difference between normal variables and pointer variables, consider the following, which is not a full C program but simply a fragment to illustrate our point:

```
int  num = 7;
int  * numPtr = &num;
printf ("%d\n", num);
printf ("%d\n", numPtr);
printf ("%d\n", &num);
printf ("%d\n", *numPtr);
```

The first line declare a normal variable, num, which is initialized to contain the data 7. Next, a pointer variable, numPtr, is declared, which is initialized to point to the address of num. The next four lines use the printf() function, which causes some data to be printed to some display terminal connected to the serial port. The first such line displays the contents of the num variable, which is in this case the value 7. The next displays the contents of the numPtr pointer, which is really some weird-looking number that is the address of the num variable. The third such line also displays the address of the num variable because the address operator is used to obtain num's address. The last line displays the actual data to which the numPtr pointer is pointing, which is 7. The * symbol is called the indirection operator, and when used with a pointer, indirectly obtains the data whose address is pointed to by the pointer. Therefore, the output display on the terminal would show:

```
7
13452 (or some other weird-looking number)
13452 (or some other weird-looking number)
7
```

A Pointer's Memory Type

Recall that pointers are also variables, so the question arises where they should be stored. When declaring pointers, we can specify different types of memory areas that these pointers should be in, for example:

```
int    *xdata numPtr = &num;
```

This is the same as our previous pointer examples. We declare a pointer numPtr, which points to data of type int stored in the num variable. The difference here is the use of the memory type specifier **xdata** after the *. This specifies that pointer numPtr should reside in external data memory (**xdata**), and we say that the pointer's memory type is **xdata**.

Typed Pointers

We can go even further when declaring pointers. Consider the example:

```
int    data *xdata numPtr = &num;
```

The above statement declares the same pointer numPtr to reside in external data memory (**xdata**), and this pointer points to data of type int that is itself stored in the variable num in internal data memory (**data**). The memory type specifier, **data**, before the * specifies the *data memory type* while the memory type specifier, **xdata**, after the * specifies the pointer memory type.

Pointer declarations where the data memory types are explicitly specified are called typed pointers. Typed pointers have the property that you specify in your code where the data pointed by pointers should reside. The size of typed pointers depends on the data memory type and could be one or two bytes.

Untyped Pointers

When we do not explicitly state the data memory type when declaring pointers, we get untyped pointers, which are generic pointers that can point to data residing in any type of memory. Untyped pointers have the advantage that they can be used to point to any data independent of the type of memory in which the data is stored. All untyped pointers consist of 3 bytes, and are hence larger than typed pointers. Untyped pointers are also generally slower because the data memory type is not determined or known until the compiled program is run at runtime. The first byte of untyped pointers refers to the data memory type, which is simply a number according to the following table. The second and third bytes are, respectively, the higher-order and lower-order bytes of the address being pointed to.

An untyped pointer is declared just like normal C, where:

```
int    *xdata numPtr = &num;
```

does not explicitly specify the memory type of the data pointed to by the pointer. In this case, we are using untyped pointers.

Data memory type values stored in first byte of untyped pointers	
Value	Data Memory Type
1	idata
2	xdata
3	pdata
4	data/bdata
5	code

FUNCTIONS

In programming the 8051 in assembly, we learnt the advantages of using subroutines to group together common and frequently used instructions. The same concept appears in 8051 C, but instead of calling them subroutines, we call them **functions**. As in conventional C, a function must be declared and defined. A function definition includes a list of the number and types of inputs, and the type of the output (return type), plus a description of the internal contents, or what is to be done within that function.

The format of a typical function definition is as follows:

```
return_type  function_name (arguments)  [memory] [reentrant] [interrupt] [using]
{
    ...
}
```

where

return_type	refers to the data type of the return (output) value
function_name	is any name that you wish to call the function as
arguments	is the list of the type and number of input (argument) values
memory	refers to an explicit memory model (small, compact or large)
reentrant	refers to whether the function is reentrant (recursive)
interrupt	indicates that the function is actually an ISR
using	explicitly specifies which register bank to use

Consider a typical example, a function to calculate the sum of two numbers:

```
int sum (int a, int b)
{
    return a + b;
}
```

This function is called sum and takes in two arguments, both of type int. The return type is also int, meaning that the output (return value) would be an int. Within the body of the function, delimited by braces, we see that the return value is basically the sum of the two arguments. In our example above, we omitted explicitly specifying the options: memory, reentrant, interrupt, and using. This means that the arguments passed to the function would be using the default small memory model, meaning that they would be stored in internal data memory. This function is also by default non-recursive and a normal function, not an ISR. Meanwhile, the default register bank is bank 0.

Parameter Passing

In 8051 C, parameters are passed to and from functions and used as function arguments (inputs). Nevertheless, the technical details of where and how these parameters are stored are transparent to the programmer, who does not need to worry about these technicalities. In 8051 C, parameters are passed through the register or through memory. Passing parameters through registers is faster and is the default way in which things are done. The registers used and their purpose are described in more detail below.

Registers used in parameter passing				
Number of Argument	Char / 1-Byte Pointer	INT / 2-Byte Pointer	Long/Float	Generic Pointer
1	R7	R6 & R7	R4–R7	R1–R3
2	R5	R4 & R5	R4–R7	
3	R3	R2 & R3		

Since there are only eight registers in the 8051, there may be situations where we do not have enough registers for parameter passing. When this happens, the remaining parameters can be passed through fixed memory locations. To specify that all parameters will be passed via memory, the NOREGPARMs control directive is used. To specify the reverse, use the REGPARMs control directive.

Return Values

Unlike parameters, which can be passed by using either registers or memory locations, output values must be returned from functions via registers. The following table shows the registers used in returning different types of values from functions.

Registers used in returning values from functions		
Return Type	Register	Description
bit	Carry Flag (C)	
char/unsigned char/1-byte pointer	R7	
int/unsigned int/2-byte pointer	R6 & R7	MSB in R6, LSB in R7
long/unsigned long	R4–R7	MSB in R4, LSB in R7
float	R4–R7	32-bit IEEE format
generic pointer	R1–R3	Memory type in R3, MSB in R2, LSB in R1

附录C：STC89C51RC/RD+系列单片机电气特性

Absolute Maximum Ratings

Parameter	Symbol	Min	Max	Unit
Storage temperature	TST	-55	+125	°C
Operating temperature (I)	TA	-40	+85	°C
Operating temperature (C)	TA	0	+70	°C
DC power supply (5V)	VDD - VSS	-0.3	+6.0	V
DC power supply (3V)	VDD - VSS	-0.3	+4.0	V
Voltage on any pin	-	-0.5	+ 5.5	V

DC Specification (5V MCU)

Sym	Parameter	Specification				Test Condition
		Min.	Typ	Max.	Unit	
V _{DD}	Operating Voltage	3.8	5.0	5.5	V	
I _{PD}	Power Down Current	-	< 0.1	-	uA	5V
I _{IDL}	Idle Current	-	2.0	-	mA	5V
I _{CC}	Operating Current	-	4	20	mA	5V
V _{IL1}	Input Low (P0,P1,P2,P3, P4)	-	-	0.8	V	5V
V _{IL2}	Input Low voltage (RESET, XTAL1)	-	-	1.5	V	5V
V _{IH1}	Input High (P0,P1,P2,P3, P4, /EA)	2.0	-	-	V	5V
V _{IH2}	Input High (RESET)	3.0	-	-	V	5V
I _{OL1}	Sinking Current for output low (P1,P2,P3,P4)	4	6	-	mA	5V
I _{OL2}	Sinking Current for output low(P0,ALE,PSSEN)	8	12	-	mA	5V
I _{OH1}	Sourcing Current for output high (P1,P2,P3,P4)	150	220	-	uA	5V
I _{OH2}	Sourcing Current for output high (ALE,PSSEN)	14	20	-	mA	5V
I _{IL}	Logic 0 input current (P1,P2,P3,P4)	-	18	50	uA	V _{pin} =0V
I _{TL}	Logic 1 to 0 transition current (P1,P2,P3,P4)	-	270	600	uA	V _{pin} =2.0V

DC Specification (3V MCU)

Sym	Parameter	Specification				Test Condition
		Min.	Typ	Max.	Unit	
V _{DD}	Operating Voltage	2.4	3.3	3.8	V	
I _{PD}	Power Down Current	-	<0.1	-	uA	3.3V
I _{IDL}	Idle Current	-	2.0	-	mA	3.3V
I _{CC}	Operating Current	-	4	15	mA	3.3V
V _{IL1}	Input Low (P0,P1,P2,P3,P4)	-	-	0.8	V	3.3V
V _{IL2}	Input Low (RESET, XTAL1)	-	-	1.5	V	3.3V
V _{IH1}	Input High (P0,P1,P2,P3)	2.0	-	-	V	3.3V
V _{IH2}	Input High (RESET)	3.0	-	-	V	3.3V
I _{OL1}	Sink Current for output low (P1,P2,P3,P4)	2.5	4	-	mA	3.3V
I _{OL2}	Sink Current for output low (P0,ALE,PSEN)	5	8	-	mA	3.3V
I _{OH1}	Sourcing Current for output high (P1,P2,P3,P4)	40	70	-	uA	3.3V
I _{OH2}	Sourcing Current for output high (ALE,PSEN)	8	13	-	mA	3.3V
I _{IL}	Logic 0 input current (P1,P2,P3,P4)	-	8	50	uA	V _{pin} =0V
I _{TL}	Logic 1 to 0 transition current (P1,P2,P3,P4)	-	110	600	uA	V _{pin} =2.0V

附录D：内部常规256字节RAM间接寻址测试程序

```
;/* --- STC International Limited ----- */
;/* --- 宏晶科技 姚永平 2006/1/6 V1.0 ----- */
;/* --- STC89C51RC/RD+ 系列单片机 内部常规RAM间接寻址测试程序----- */
;/* --- 本演示程序在STC-ISP Ver 3.0A.PCB的下载编程工具上测试通过 ----- */
;/* --- 如果要在程序中使用该程序,请在程序中注明使用了宏晶科技的资料及程序 --- */
;/* --- 如果要在文章中引用该程序,请在文章中注明使用了宏晶科技的资料及程序 --- */

TEST_CONST EQU 5AH
;TEST_RAM EQU 03H
    ORG 0000H
    LJMP INITIAL

    ORG 0050H
INITIAL:
    MOV R0, #253

    MOV R1, #3H
TEST_ALL_RAM:
    MOV R2, #0FFH
TEST_ONE_RAM:
    MOV A, R2
    MOV @R1, A
    CLR A
    MOV A, @R1

    CJNE A, 2H, ERROR_DISPLAY
    DJNZ R2, TEST_ONE_RAM
    INC R1
    DJNZ R0, TEST_ALL_RAM
```

OK_DISPLAY:

MOV P1, #11111110B

Wait1:

SJMP Wait1

ERROR_DISPLAY:

MOV A, R1

MOV P1, A

Wait2:

SJMP Wait2

END

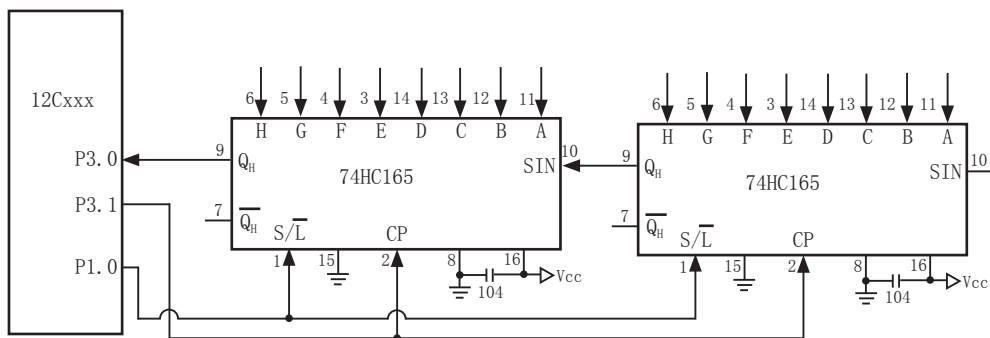
附录E：用串口扩展I/O接口

STC89C51RC/RD+系列单片机串行口的方式0可用于I/O扩展。如果在应用系统中，串行口未被占用，那么将它用来扩展并行I/O口是一种经济、实用的方法。

在操作方式0时，串行口作同步移位寄存器，其波特率是固定的，为 $\text{SYSclk}/12$ （ SYSclk 为系统时钟频率）。数据由RXD端（P3.0）出入，同步移位时钟由TXD端（P3.1）输出。发送、接收的是8位数据，低位在先。

一、用74HC165扩展并行输入口

下图是利用两片74HC165扩展二个8位并行输入口的接口电路图。



74HC165是8位并行置入移位寄存器。当移位/置入端(S/L)由高到低跳变时，并行输入端的数据置入寄存器；当 $S/L=1$ ，且时钟禁止端（第15脚）为低电平时，允许时钟输入，这时在时钟脉冲的作用下，数据将由 Q_A 到 Q_H 方向移位。

上图中，TXD(P3.1)作为移位脉冲输出端与所有74HC165的移位脉冲输入端CP相连；RXD(P3.0)作为串行输入端与74HC165的串行输出端 Q_H 相连；P1.0用来控制74HC165的移位与置入而同S/L相连；74HC165的时钟禁止端（15脚）接地，表示允许时钟输入。当扩展多个8位输入口时，两芯片的首尾（ Q_H 与 S_{IN} ）相连。

下面的程序是从16位扩展口读入5组数据（每组二个字节），并把它们转存到内部RAM 20H开始的单元中。

MOV R7, #05H; 设置读入组数

MOV RO, #20H; 设置内部RAM数据区首址

START: CLR P1.0; 并行置入数据, S/L=0

SETB P1.0; 允许串行移位S/L=1

MOV R1, #02H; 设置每组字节数, 即外扩74LS165的个数

RXDATA: MOV SCON, #00010000B; 设串行方式0, 允许接收, 启动接收过程

WAIT: JNB RI, WAIT; 未接收完一帧, 循环等待

CLR RI; 清RI标志, 准备下次接收

MOV A, SBUF; 读入数据

MOV @RO, A; 送至RAM缓冲区

INC RO; 指向下一个地址

DJNZ R1, RXDATA; 为读完一组数据, 继续

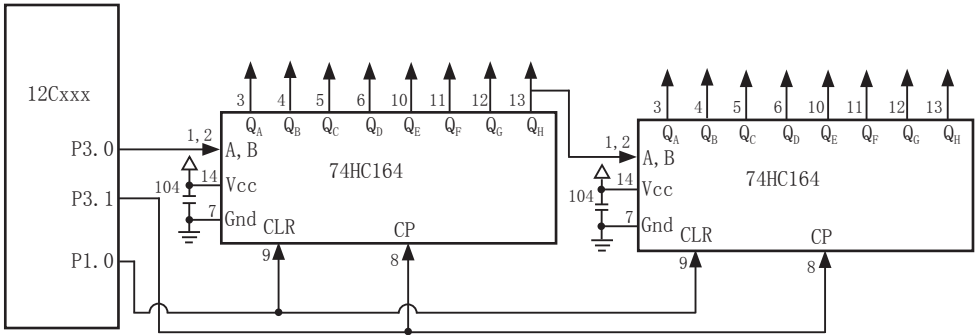
DJNZ R7, START; 5组数据未读完重新并行置入

.....; 对数据进行处理

上面的程序对串行接收过程采用的是查询等待的控制方式，如有必要，也可改用中断方式。从理论上讲，按上图方法扩展的输入口几乎是无限的，但扩展的越多，口的操作速度也就越慢。

二、用74HC164扩展并行输出口

74HC164是8位串入并出移位寄存器。下图是利用74HC164扩展二个8位输出口的接口电路。

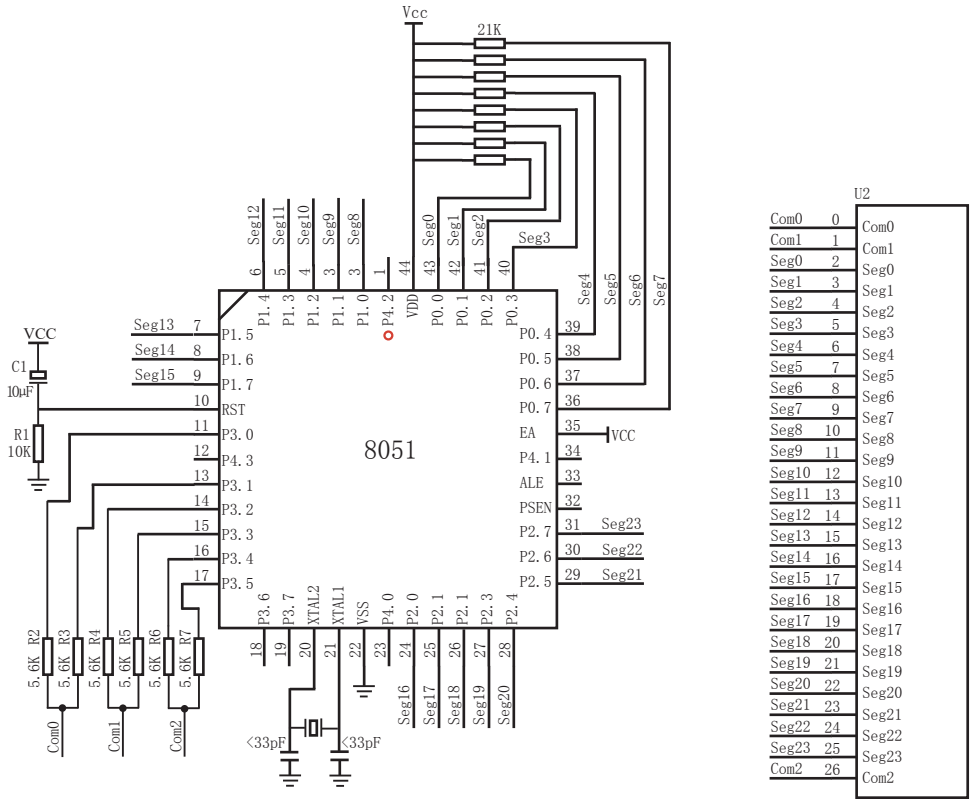


当单片机串行口工作在方式0的发送状态时，串行数据由P3.0（RXD）送出，移位时钟由P3.1（TXD）送出。在移位时钟的作用下，串行口发送缓冲器的数据一位一位地移入74HC164中。需要指出的是，由于74HC164无并行输出控制端，因而在串行输入过程中，其输出端的状态会不断变化，故在某些应用场合，在74HC164的输出端应加接输出三态门控制，以便保证串行输入结束后再输出数据。

下面是将RAM缓冲区30H、31H的内容串行口由74HC164并行输出的子程序。

```
START: MOV          R7, #02H           ; 设置要发送的字节个数
        MOV          R0, #30H         ; 设置地址指针
        MOV          SCON, #00H       ; 设置串行口方式0
SEND:   MOV          A, @R0
        MOV          SBUF, A          ; 启动串行口发送过程
WAIT:   JNB          TI, WAIT         ; 一帧数据未发送完，循等待
        CLR          TI
        INC          R0               ; 取下一个数
        DJNZ         R7, SEND
        RET
```


附录F：利用STC单片机普通I/O驱动LCD显示



本资料不提供技术支持, 请自行消化吸收

NAME LcdDriver

#include<reg52.h>

```

,*****
;
;the LCD is 1/3 duty and 1/3 bias; 3Com*24Seg; 9 display RAM;
;
;
;          Bit7   Bit6   Bit5   Bit4   Bit3   Bit2   Bit1   Bit0
;Com0: Com0Data0: Seg7   Seg6   Seg5   Seg4   Seg3   Seg2   Seg1   Seg0
;          Com0Data1: Seg15  Seg14  Seg13  Seg12  Seg11  Seg10  Seg9   Seg8
;          Com0Data2: Seg23  Seg22  Seg21  Seg20  Seg19  Seg18  Seg17  Seg16
;Com1: Com1Data0: Seg7   Seg6   Seg5   Seg4   Seg3   Seg2   Seg1   Seg0
;          Com1Data1: Seg15  Seg14  Seg13  Seg12  Seg11  Seg10  Seg9   Seg8
;          Com1Data2: Seg23  Seg22  Seg21  Seg20  Seg19  Seg18  Seg17  Seg16
;Com2: Com2Data0: Seg7   Seg6   Seg5   Seg4   Seg3   Seg2   Seg1   Seg0
;          Com2Data1: Seg15  Seg14  Seg13  Seg12  Seg11  Seg10  Seg9   Seg8
;          Com2Data2: Seg23  Seg22  Seg21  Seg20  Seg19  Seg18  Seg17  Seg16
,*****
;Com0: P3^0,P3^1  when P3^0 = P3^1 = 1          then Com0=VCC(=5V);
;                  P3^0 = P3^1 = 0          then Com0=GND(=0V);
;                  P3^0 = 1, P3^1=0         then Com0=1/2 VCC;
;Com1: P3^2,P3^3  the same as the Com0
;Com2: P3^4,P3^5  the same as the Com0
;

sbit  SEG0  =P0^0
sbit  SEG1  =P0^1
sbit  SEG2  =P0^2
sbit  SEG3  =P0^3
sbit  SEG4  =P0^4
sbit  SEG5  =P0^5
sbit  SEG6  =P0^6
sbit  SEG7  =P0^7
sbit  SEG8  =P1^0
sbit  SEG9  =P1^1
sbit  SEG10 =P1^2

```

```

sbit    SEG11 =P1^3
sbit    SEG12 =P1^4
sbit    SEG13 =P1^5
sbit    SEG14 =P1^6
sbit    SEG15 =P1^7
sbit    SEG16 =P2^0
sbit    SEG17 =P2^1
sbit    SEG18 =P2^2
sbit    SEG19 =P2^3
sbit    SEG20 =P2^4
sbit    SEG21 =P2^5
sbit    SEG22 =P2^6
sbit    SEG23 =P2^7
,*****
;=====Interrupt=====
    CSEG      AT      0000H
    LJMP      start

    CSEG      AT      000BH
    LJMP      int_t0

;=====register=====
lccd_bit SEGMENT BIT
    RSEG lccd_bit
    OutFlag:   DBIT 1      ;the output display reverse flag
lccd_data SEGMENT DATA
    RSEG lccd_data
    Com0Data0: DS 1
    Com0Data1: DS 1
    Com0Data2: DS 1
    Com1Data0: DS 1
    Com1Data1: DS 1
    Com1Data2: DS 1
    Com2Data0: DS 1
    Com2Data1: DS 1
    Com2Data2: DS 1
    TimeS:     DS 1

```

```
;=====Interrupt Code=====
t0_int SEGMENT CODE
        RSEG t0_int
        USING 1
;*****
;Time0 interrupt
;ths system crystalloid is 22.1184MHz
;the time to get the Time0 interrups is 2.5mS
;the whole duty is 2.5mS*6=15mS, including reverse
;*****
int_t0:
        ORL    TL0,#00H
        MOV    TH0,#0EEH
        PUSH   ACC
        PUSH   PSW
        MOV    PSW,#08H
        ACALL  OutData
        POP    PSW
        POP    ACC
        RETI

;=====SUB CODE=====
uart_sub SEGMENT CODE
        RSEG  uart_sub
        USING 0
;*****
;initial the display RAM data
;if want to display other,then you may add other data to this RAM
;Com0:  Com0Data0,Com0Data1,Com0Data2
;Com1:  Com1Data0,Com1Data1,Com1Data2
;Com2:  Com2Data0,Com0Data1,Com0Data2
;*****
InitComData:          ;it will display "1111111"
        MOV    Com0Data0,    #24H
        MOV    Com0Data1,    #49H
        MOV    Com0Data2,    #92H
```

```

MOV    Com1Data0,    #92H
MOV    Com1Data1,    #24H
MOV    Com1Data2,    #49H
MOV    Com2Data0,    #00H
MOV    Com2Data1,    #00H
MOV    Com2Data2,    #00H
RET

,*****
;reverse the display data
,*****
RetComData:
    MOV    R0,    #Com0Data0    ;get the first data address
    MOV    R7,    #9
RetCom_0:
    MOV    A,    @R0
    CPL    A
    MOV    @R0,    A
    INC    R0
    DJNZ   R7,    RetCom_0
    RET

,*****
;get the display Data and send to Output register
,*****
OutData:
    INC    TimeS
    MOV    A,    TimeS
    MOV    P3,    #11010101B    ;clear display,all Com are 1/2VCC and invalidate
    CJNE   A,    #01H,    OutData_1    ;judge the duty
    MOV    P0,    Com0Data0
    MOV    P1,    Com0Data1
    MOV    P2,    Com0Data2
    JNB    OutFlag,OutData_00
    MOV    P3,    #11010111B    ;Com0 is work and is VCC
    RET

```

OutData_00:

```
    MOV    P3,    #11010100B    ;Com0 is work and is GND
    RET
```

OutData_1:

```
    CJNE   A,    #02H,OutData_2
    MOV    P0,    Com1Data0
    MOV    P1,    Com1Data1
    MOV    P2,    Com1Data2
    JNB    OutFlag,OutData_10
    MOV    P3,    #11011101B    ;Com1 is work and is VCC
    RET
```

OutData_10:

```
    MOV    P3,    #11010001B    ;Com1 is work and is GND
    RET
```

OutData_2:

```
    MOV    P0,    Com2Data0
    MOV    P1,    Com2Data1
    MOV    P2,    Com2Data2
    JNB    OutFlag,OutData_20
    MOV    P3,    #11110101B    ;Com2 is work and is VCC
    SJMP   OutData_21
```

OutData_20:

```
    MOV    P3,#11000101B    ;Com2 is work and is GND
```

OutData_21:

```
    MOV    TimeS, #00H
    ACALL  RetComData
    CPL    OutFlag
    RET
```

;=====Main Code=====

uart_main SEGMENT CODE

```
    RSEG   uart_main
    USING  0
```

start:

```
MOV    SP,#40H
CLR    OutFlag
MOV    TimeS,#00H
MOV    TL0,#00H
MOV    TH0,#0EEH
MOV    TMOD,#01H
MOV    IE,#82H
ACALL  InitComData
SETB   TR0
```

Main:

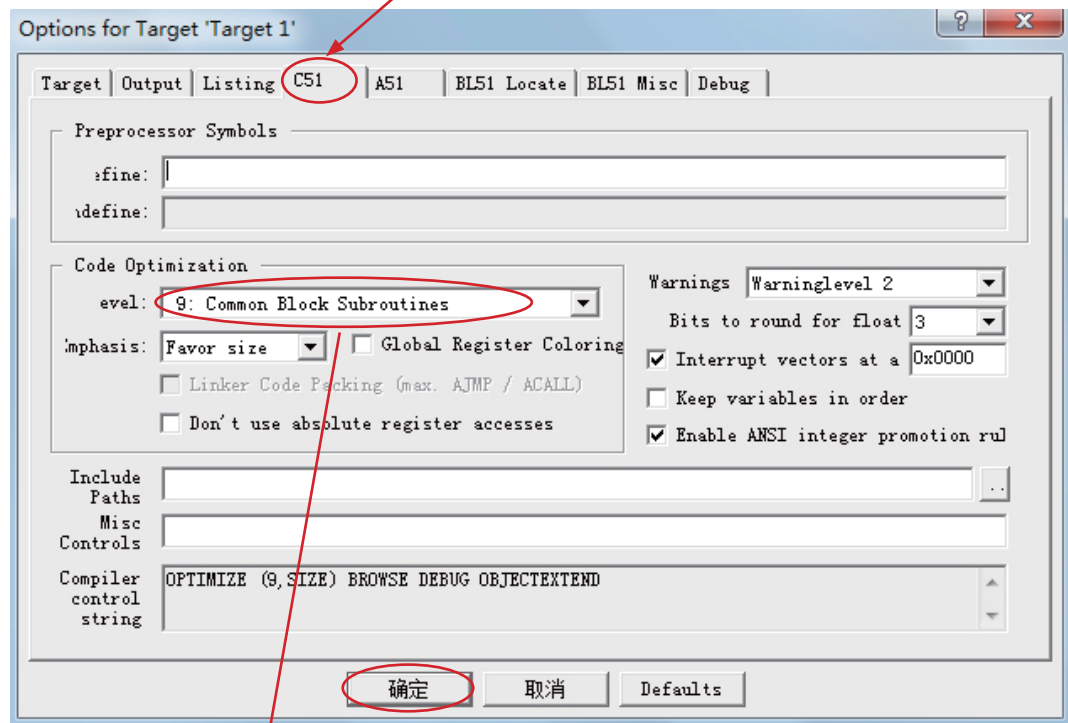
```
NOP
SJMP   Main

END
```

附录G：如何利用Keil C软件减少代码长度

在Keil C软件中选择作如下设置，能将原代码长度最大减少10K。

1. 在“Project”菜单中选择“Options for Target”
2. 在“Options for Target”中选择“C51”



3. 选择按空间大小，9级优化程序
4. 点击“确定”后，重新编译程序即可。

附录H：如何实现运行中自定义下载

——无仿真器时方便调试

——自定义下载演示程序(实现不停电下载)

自定义下载原理：STC-ISP.exe软件

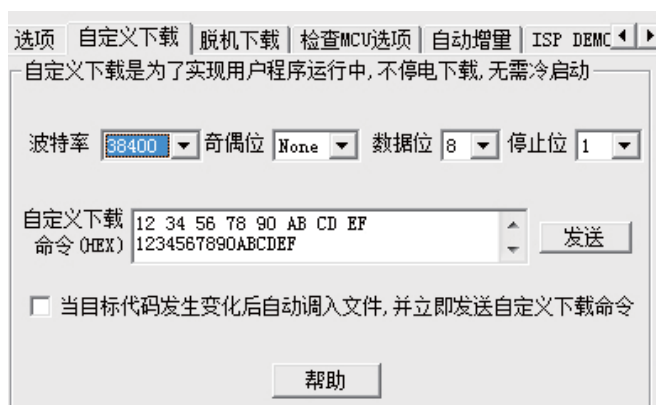
1. STC-ISP.exe软件,可由用户设置,按UART/RS-232的格式向用户程序发送命令

波特率：38400bps, 19200bps, 9600bps, 4800bps, 2400bps, 1200bps等

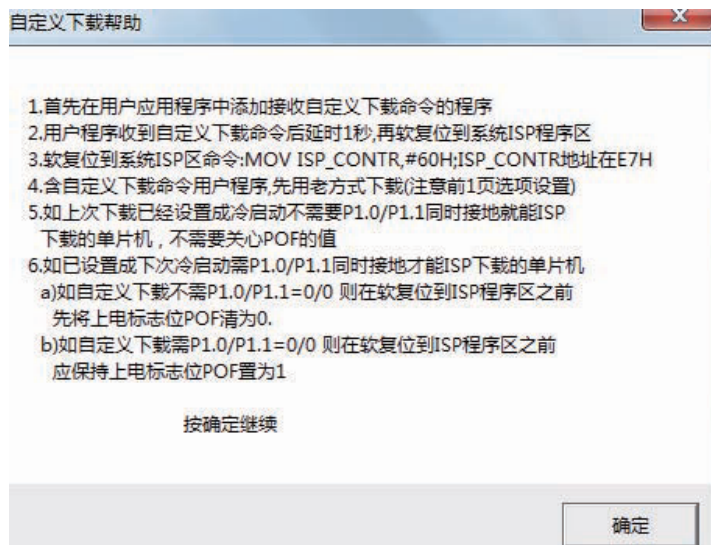
奇偶校验位：无, 偶校验, 奇校验

数据位几位：8位, 7位, 6位, 5位, 等

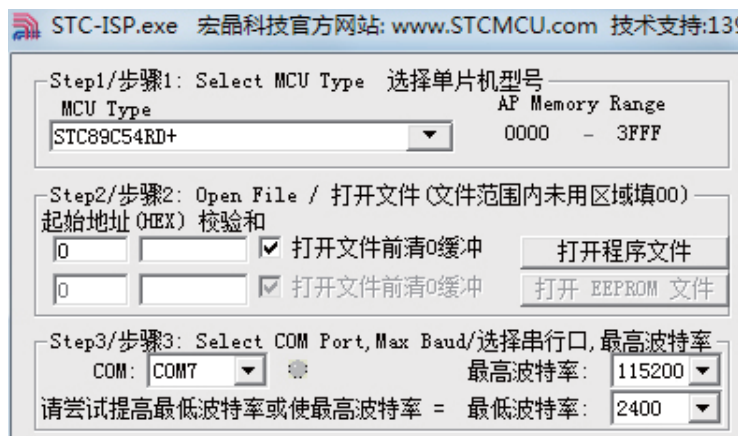
停止位几位：1位, 1.5位, 2位, 等



点击软件STC-ISP.EXE中的帮助按钮（如上图所示），可见详细的帮助说明，如下图所示

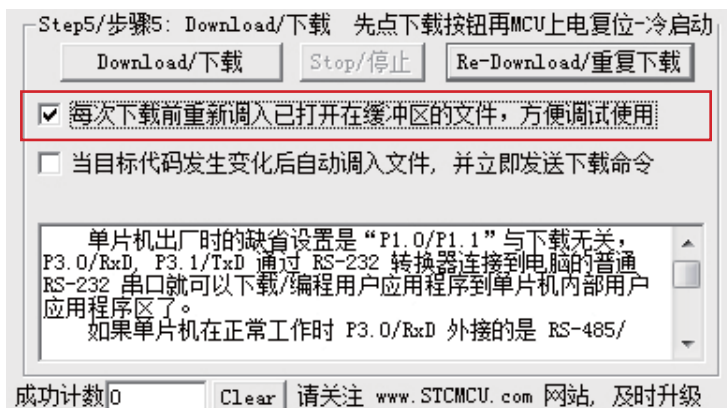


- 需向用户程序发送的命令用户可在上图自定义下载命令输入窗口中输入 (HEX) 命令之间建议加一个空格, 也可不加, STC-ISP.exe 会处理, 上例为发送自定义命令
12H, 34H, 56H, 78H, 0ABH, 0CDH, 0EFH, 12H, 34H, 56H, 78H, 0ABH, 0CDH, 0EFH
- 用户程序中应加入收到自定义下载命令, 延时一秒, 软复位到系统 ISP 程序区的程序
- 将以上含有接收自定义下载命令的用户程序先用老方法下载进 STC 单片机内部,
这样 STC89C51RC/RD+ 系列单片机就具有了“不停电/运行中/自定义下载功能”
- 以下选好型号, 打开文件..., 在自定义下载中设置相关选项, 选择“发送”即可,



STC-ISP.exe 在“发送”完用户自定义下载命令后, 就会转去调用老的那一套下载命令, 而不管用户单片机程序收到命令没有。不过这个转换有些电脑有时需要将近 1S 的时间, 所以用户应用程序要延时 1S, 否则系统 ISP 程序收不到下载命令, 又会回到用户应用程序。

- 调试程序时, 还可以在选项中选择“每次下载前自动重新调入文件”, 这样你每次修改原文件并重新编译/汇编后生成的 *.hex, *.bin 文件就不要再次手工调入了, 生产时不要用。



自定义下载演示程序(实现不停电下载)

```

/*-----*/
/* --- STC MCU International Limited -----*/
/* --- 演示STC 1T 系列单片机 利用软件实现自定义下载-----*/
/* 如果要在程序中使用或在文章中引用该程序， -----*/
/* 请在程序或文章中注明使用了宏晶科技的资料及程序 -----*/
/*-----*/
/*对STC89xx系列单片机，请适当地将等待时间缩短-----*/

#include <reg51.h>
#include <instrins.h>

sfr IAP_CONTR = 0xc7;
sbit MCU_Start_Led = P1^7;

#define Self_Define_ISP_Download_Command 0x22
#define RELOAD_COUNT 0xfb //18.432MHz,12T,SMOD=0,9600bps
//#define RELOAD_COUNT 0xf6 //18.432MHz,12T,SMOD=0,4800bps
//#define RELOAD_COUNT 0xec //18.432MHz,12T,SMOD=0,2400bps
//#define RELOAD_COUNT 0xd8 //18.432MHz,12T,SMOD=0,1200bps

void serial_port_initial(void);
void send_UART(unsigned char);
void UART_Interrupt_Receive(void);
void soft_reset_to_ISP_Monitor(void);
void delay(void);
void display_MCU_Start_Led(void);

void main(void)
{
    unsigned char i = 0;

    serial_port_initial(); //Initial UART
    display_MCU_Start_Led(); //Turn on the work LED
    send_UART(0x34); //Send UART test data
    send_UART(0xa7); // Send UART test data
    while (1);
}

```

```
void send_UART(unsigned char i)
```

```
{
    ES = 0;                //Disable serial interrupt
    TI = 0;                //Clear TI flag
    SBUF = i;              //send this data
    while (!TI);           //wait for the data is sent
    TI = 0;                //clear TI flag
    ES = 1;                //enable serial interrupt
}
```

```
void UART_Interrupt)Receive(void) interrupt 4 using 1
```

```
{
    unsigned char k = 0;
    if (RI)
    {
        RI = 0;
        k = SBUF;
        if (k == Self_Define_ISP_Command)    //check the serial data
        {
            delay();                        //delay 1s
            delay();                        //delay 1s
            soft_reset_to_ISP_Monitor();
        }
    }
    if (TI)
    {
        TI = 0;
    }
}
```

```
void soft_reset_to_ISP_Monitor(void)
```

```
{
    IAP_CONTR = 0x60;                //0110,0000 soft reset system to run ISP monitor
}
```

```
void delay(void)
```

```
{
    unsigned int j = 0;
    unsigned int g = 0;
```

```
    for (j=0; j<5; j++)
    {
        for (g=0; g<60000; g++)
        {
            _nop_();
            _nop_();
            _nop_();
            _nop_();
            _nop_();
        }
    }
}

void display_MCU_Start_Led(void)
{
    unsigned char i = 0;
    for (i=0; i<3; i++)
    {
        MCU_Start_Led = 0;    //Turn on work LED
        dejay();
        MCU_Start_Led = 1;    //Turn off work LED
        dejay();
        MCU_Start_Led = 0;    //Turn on work LED
    }
}
```