طراحی و ساخت مداری

جهت کنترل دما

مقدمه

امروزه مردم جهان در فکر این هستند که چگونه در مصرف انرژی صرفه جویی کند . در نتیجه به فکر ساخت وسایلی کردند که در این زمینه کاربرد داشتند. که یکی از این وسایل دما سنج کنترلی است.

که این دستگاه بیشتر در سیستم های سرمازا وگرما زا استفاده می شود .که روش کار این دستگاه این چنین است . اگر ما در فصلی باشیم که هوا گرم باشد این دستگاه را طوری تنظیم می کنیم که سیستم سرمازا ما دمایی که ما در دستگاه مشخص کردیم (به فرض مثال اگر دما ۳۰ درجه سانتی گراد در دما سنج کنترلی تنظیم کرده باشیم و دما محیط به همان اندازه باشد) سیستم سرمازا ما روشن میشود و دمایی علاوه براین در دستگاه تعریف کردیم که اگر دما محیط کاهش پیدا کرد (به فرض مثال اگر دما ۲۰ درجه سانتی گراد در دما سنج کنترلی تنظیم کرده باشیم و دما محیط به همان اندازه باشد) سیستم سرمازا ما خاموش میشود.

پس همین طور که گفته شده است ما علاوه بر این که دما محیط راکاهش می دهیم در مصرف ا نرژی صرفه جویی می کنیم.

امروزه کشورهای پیشرفته از این دستگاه دراماکن های عمومی وسالن ها و... استفاده می کنند.

فصل اول

آشنایی با مدار

مشخصات مدار

شرح کار مدار

مشخصات مدار

مشخصات این دماسنج کنترلی بصورت زیر است

۱- قابلیت اندازه گیری دما تا ۱۰۰ درجه سانتی گراد

۲- قابلیت تنظیم هشدار دهنده ، دمای بیش از حد

۳- قابل استفاده در دو حالت winner , summer

۴-دارای نمایشگر *LCD*

این مدار شامل یک آی سی از خانواده میکروکنترلر (۸۰۵۱) که این آی سی *AT89C51* می باشد و با برنامه میکروکنترلر ۸۰۵۱ پروگرم می شود و داری یک مبدل آنالوگ به دیجتال (*ADC0804*) که دمایی که *LM 35* اندازه گیری می کند را تبدیل به ولت می کند و به میکروکنترلر می دهد که میکروکنترلر آن را برای نمایش دادن به *LCD* می دهد.

این مدار طوری طراحی شده است که می توان دما برای آن تعریف کرد که با رسیدن دما به اندازه تعریف شده رله وصل یا قطع می شود.

LM35 یکی از محصولات National که در این پروژه استفاده شده یک سنسور دقیق بر حسب سا نتی گراد است . رنج این سنسور بین۵۵ - تا ۱۵۰+ با ضریب خطای 0.5c +/- و خروجی ولتاژ این سنسور توسط مبدل A/D یک میکرو کنترلر ۸۰۵۱ تبدیل می شود .این نمونه یک دماسنج با دقت 2 درجه سانتیگراد است.

در این پروژه همچنین برای تنظیمات از ۴×۴ *Keypad* استفاده شده است و زیر روال آن توسط وقفه صورت می گیرد حسن این کار در این است که وقت میکروکنترلر صرف اسکن *Keypad* نمی شود و می تواند به کنترل دما مشغول باشد هرچند آی سی

هایی مانند *MC74C922* برای اسکن صفحه کلید وجود دارند اما باید به فکر کم کردن سخت افزا جانبی نیز بود.

شرح کار مدار

ابتدا دما بر روی نمایشگر ظاهر می شود و برای تنظیمات باید دکمه *Meno* از صفحه کلید را فشار دهیم تا وارد بخش تنظیمات شود حال عدد مورد نظر را با صفحه کلید وارد کرده و با دکمه های *Up* و *Down* حالت فعال شدن (*winner , summer*) را تنظیم می کنیم و دکمه *Set* را فشار می دهیم تا کلمه *ok* بر روی نمایشگر ظاهر شود حال تنظیمات شما انجام گرفته است اگر دما بیش از حد کم یا زیاد شود علاوه بر عکس ا لعمل رله خروجی یک عدد *LED* به عنوان خطا روشن و خاموش میشود و بر روی نمایشگر جمله *error high temp* یا *error cold temp* ظاهر می شود.

بطور مثال : می خواهیم دما بیش از ۲۸ درجه سانتی گراد به بالا کولر روشن شود و زیر دمای ۲۳ درجه سانتی گراد کولر خاموش شود.

ابتدا با زدن دکمه *Meno* وارد بخش تنظیمات شده و دما را با صفحه کلید بر روی ۲۸ و با دکمه *Down* نوع فعال شدن خروجی را بر روی *Summer* می گذاریم. به این ترتیب وقتی که از دما ۲۸ درجه به بالا رود کولر روشن می شود و سبب پایین آمدن درجه حرارت محیط می شود تا اینکه دما به زیر ۲۳ درجه می رسد و کولر خاموش می شود.

در این پروژه همچنین می توان حالت خروجی را تعریف کرد به این صورت که اگر برای دستگاه های داغ مانند : شوفاژ ، هیتر و ... استفاده شود وقتی از دما تعیین شده بیشتر باشد رله خروجی غیرفعال می شود و برای دستگاه هایی که سرد هستند مانند : خنک کننده ها، کولر و ... استفاده شود پس از رسیدن به دما مشخص شده رله خروجی فعال می شود.

فصل دوم

تشریح مدار

شماتیک

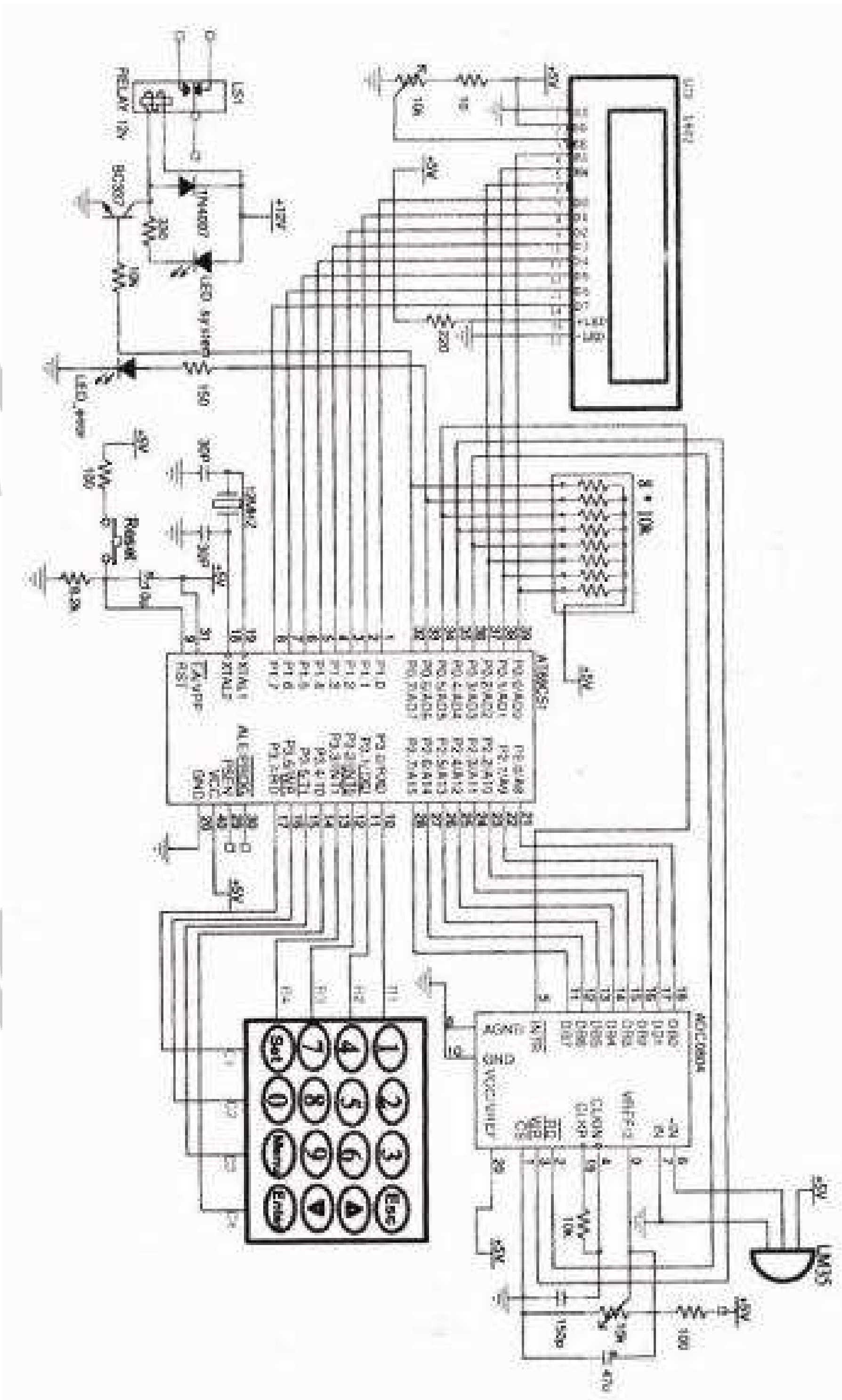
پشت فیبر

قطعات مورد نیاز

برنامه نرم افزاری

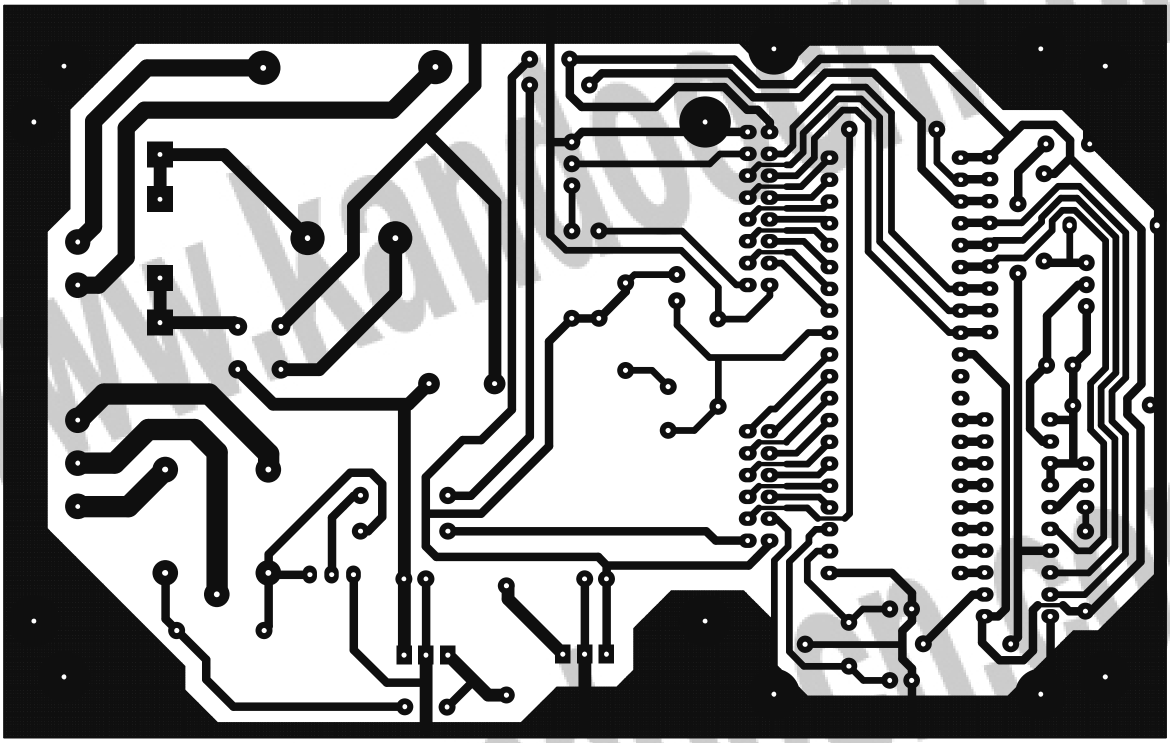
شماتیک

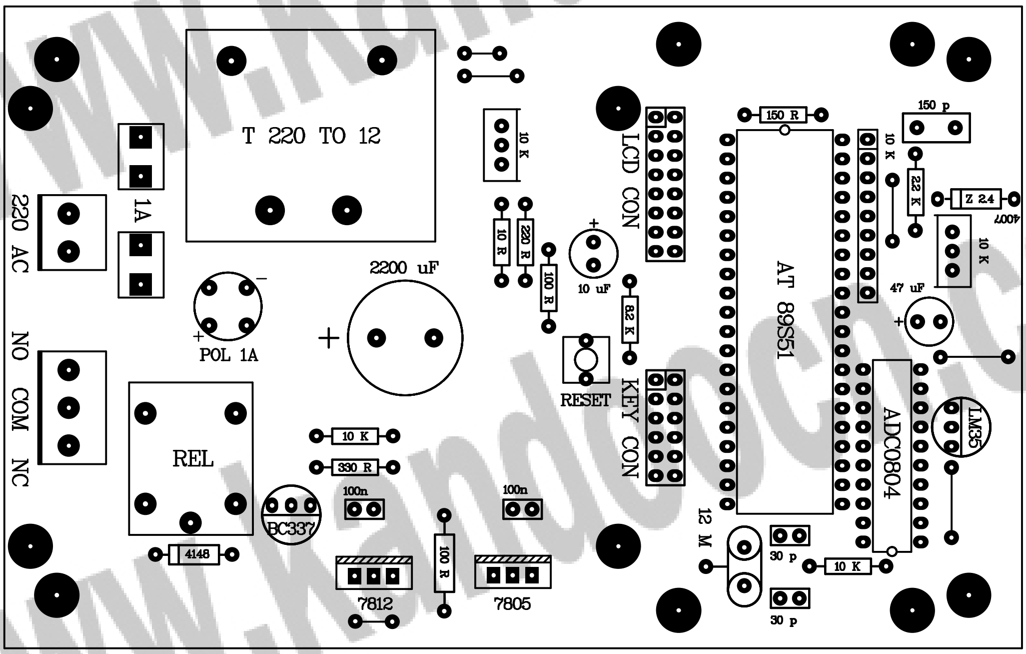
شماتیک این مدار به صورت زیر ا ست



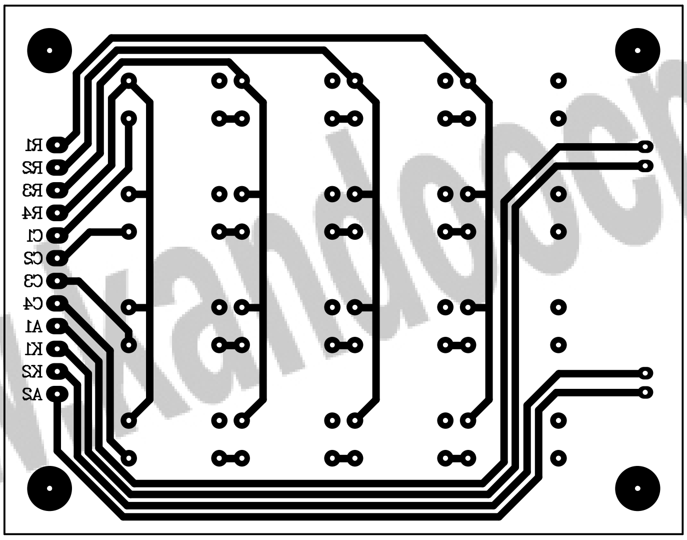
پشت فیبر

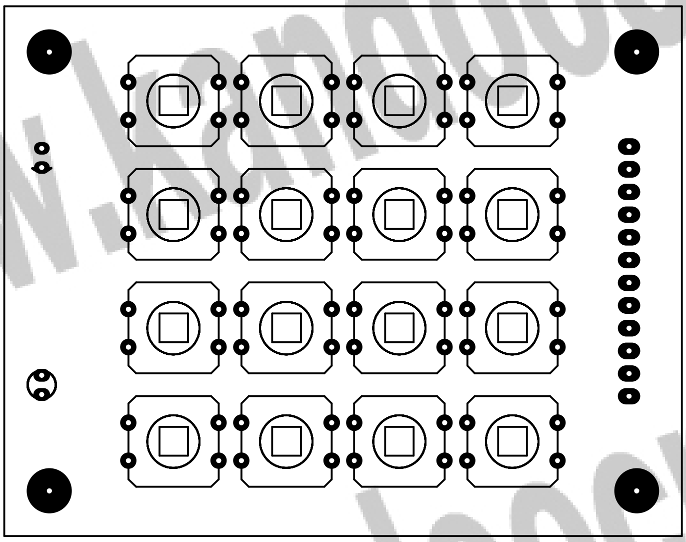
پشت فیبراین مدار به صورت زیر است





نقشه پشت فیبر ***Keypad*** این مدار به صورت زیر است





قطعات مورد نیاز

نام قطعه	تعداد
میکروکنترلر AT89C51	۱
سنسور حراتی LM35	۱
LCD1602	۱
آنالوگ به دیجتال ADC0804	۱
آی سی رگولاتور 7805-7812	۱
رله 12V/1A	۱
کا نکتور۲ و ۳ پایه	۱
دیود 1N4007	۱
LED	۲
ترانزیستور BC337	۱
ترا نسفورما تور(220V به 9V)	۱
میکرو سوئیچ	۱۷
کریستال 12MHZ	۱
خازن 30PF	۲
خازن 47µF	۱
خازن 2200µF	۱
خازن 10µF	۱
خازن 150PF	۱
خازن 100NF	۱

مقاومت (ARY) 10K	۱
مقاومت 10Ω	۱
مقاومت 100Ω	۲
مقاومت 330Ω	۱
مقاومت 150Ω	۱
مقاومت 220Ω	۱
مقاومت 8.2KΩ	۲
مقاومت 10KΩ	۲

برنامه نرم افزاری

برنامه نرم افزاری آن به صورت زیر است

```
$mod51
;=====================================================

LED_ERROR      EQU P0.0
LED_SYSTEM     EQU P0.1
READ           EQU P0.2
WRITE          EQU P0.3
INTR      EQU P0.4
RS        EQU P0.5
RW        EQU P0.6
E         EQU P0.7
HEX       DATA      40H
REFRENCE1      DATA      41H
REFRENCE2      DATA      42H
HELP           DATA      43H
DIFERENT            DATA      44H
CONTRL         BIT  25H.0
S         BIT  25H.1
BC        BIT  25H.2
ZERO           BIT  25H.3

;=====================================================

          ORG 00H
          LJMP      MAIN_A

;=====================================================

          ORG 13H
          MOVREFRENCE1,#0FFH
          MOVREFRENCE2,#0FFH
          MOVDIFERENT,#0FFH
          SETB      ZERO
          LJMP      UP
EXIT_I:        MOVIE,#84H
          RETI

;=====================================================
```

```
            ORG 30H
MAIN_A:         MOVDPTR,#DRIVER
LOOP_Y:         CLR  A
            MOVC      A,@A+DPTR
            JZ    EXIT_Y
            INC   DPTR
            MOVP1,A
            LCALL     INSTRUCTION
            SJMPLOOP_Y
EXIT_Y:         MOV25H,#0BH
            MOVREFRENCE2,#00H
            MOVDIFERENT,#03H
            MOVREFRENCE1,#25H
            CLR  BC
            MOVIE,#84H
            MOVP3,#7FH
            CLR  READ
            SETB       WRITE
            MOVP2,#0FFH

            MOVDPTR,#TEMP
LOOP_Q:         CLR  A
            MOVC      A,@A+DPTR
            JZ    MAIN
            INC   DPTR
            MOVP1,A
            LCALL     DISPLAY
            SJMPLOOP_Q

MAIN:           CLR  WRITE
            LCALL     DELAY
            SETB      WRITE
FLASH:          JB    INTR,FLASH
            CLR  READ
            LCALL     DELAY
            MOVA,P2
            MOVHELP,A
            SETB      READ
            MOVB,#10
            DIV   AB
```

```
        SWAP      A
        ORL  A,B
HOT:    CLR  C
        CJNEA,REFRENCE1,CARY
        SJMPCON
CARY:       JC     CON
        LJMP      ERROR
CON:    JNB  BC,FG
        MOVREFRENCE1,R7
        CLR  BC
FG:     MOVA,HELP
        CLR  LED_ERROR
        MOVC,S
        CPL  C
        MOVLED_SYSTEM,C
        MOVB,#10
        DIV  AB
        MOVHEX,B
        MOVR4,B
        MOVP1,#87H
        LCALL     INSTRUCTION
        LCALL     ASCII
        MOVB,#10
        DIV  AB
        MOVP1,#86H
        LCALL     INSTRUCTION
        MOVHEX,B
        MOVR6,B
        LCALL     ASCII
        MOVP1,#85H
        LCALL     INSTRUCTION
        MOVHEX,A
        LCALL     ASCII
        MOVP1,#88H
        LCALL     INSTRUCTION
        MOVP1,#"C"
        LCALL     DISPLAY
        MOVR3,#40
BACK:       LCALL     DELAY
        DJNZ      R3,BACK
```

```
                LJMP        MAIN

ASCII:                ANL  HEX,#0FH
                ORL  HEX,#30H
                MOVP1,HEX
                LCALL       DISPLAY
                RET

ERROR:                CPL  LED_ERROR
                JB     BC,HOT_HIGH
                MOVC,S
                MOVLED_SYSTEM,C
                CLR  C
                MOVA,REFRENCE1
                MOVR7,A
                SUBB        A,DIFERENT
                MOVHELP,A
                ANL  A,#0FH
                CLR  C
                CJNEA,#09H,TEST_CY
                SJMPG01
TEST_CY:  JC     G01
                MOVA,DIFERENT
                ADD A,#06H
                MOVDIFERENT,A
                MOVA,REFRENCE1
                SUBB        A,DIFERENT
                SJMPG02
G01:          MOVA,HELP
G02:          MOVREFRENCE1,A
                SETB        BC
HOT_HIGH:        MOVDPTR,#SEND
AGAIN:                MOVP1,#0C0H
                LCALL       INSTRUCTION
LOOP:                 CLR  A
                MOVC        A,@A+DPTR
                JZ     EXIT
                INC  DPTR
                MOVP1,A
                LCALL       DISPLAY
```

```
            SJMPLOOP
EXIT:           MOVR3,#40
BB:         LCALL       DELAY
            DJNZ        R3,BB
            JNB  CONTRL,EXIT2
            MOVDPTR,#CLEAR
            CLR  CONTRL
            SJMPAGAIN
EXIT2:          SETB        CONTRL
            LJMP        MAIN

;==============================================

DISPLAY:        LCALL       DELAY
            SETB        RS
            CLR  RW
            SETB        E
            CLR  E
            RET

;==============================================

INSTRUCTION: LCALL      DELAY
            CLR  RS
            CLR  RW
            SETB        E
            CLR  E
            RET

;==============================================

DELAY:          MOVR0,#50
LOOP2:          MOVR1,#250
LOOP1:          DJNZ        R1,LOOP1
            DJNZ        R0,LOOP2
            RET

;==============================================

UP:         MOVIE,#00H
```

```
        MOVB,#4
        MOVDPTR,#ROW
START:      CLR  A
        MOVC      A,@A+DPTR
        MOVP3,A
        INC   DPTR
        JNB   P3.4,C1
        JNB   P3.5,C2
        JNB   P3.6,C3
        JNB   P3.7,C4
        DJNZ      B,START
        LJMP      UP
C1:     MOVR5,#3
        LJMP      TABLE
C2:     MOVR5,#2
        LJMP      TABLE
C3:     MOVR5,#1
        LJMP      TABLE
C4:     MOVR5,#0
        LJMP      TABLE
TABLE:      MOVDPTR,#KEYCODE
        MOVA,#4
        DEC  B
        MUL AB
        ADD A,R5
        MOVC      A,@A+DPTR

        CJNEA,#"*",QW1
        LJMP      ENTER
QW1:        CJNEA,#"U",QW2
        LJMP      UPER
QW2:        CJNEA,#"D",ZXC1
        LJMP      DOWN
ZXC1:       MOVHELP,A
        MOVA,0FFH
        CJNEA,REFRENCE2,ZXC2
        MOVA,HELP
        ANL  A,#0FH
        SWAP      A
        MOVREFRENCE2,A
```

```
            MOVA,HELP
            SJMPZXC4
ZXC2:       CJNEA,REFRENCE1,ZXC3
            MOVA,HELP
            ANL  A,#0FH
            MOVREFRENCE1,A
            ORL  A,REFRENCE2
            MOVREFRENCE1,A
            MOVA,HELP
            SJMPZXC4
ZXC3:       CJNEA,DIFERENT,ZXC4
            CLR  ZERO
            MOVP1,#89H
            LCALL     INSTRUCTION
            MOVA,HELP
            ANL  A,#0FH
            MOVDIFERENT,A
            MOVA,HELP
            MOVP1,A
            LCALL     DISPLAY
ZXC4:       MOVA,HELP
            CJNEA,#"S",CM
            MOVP3,#7FH
            MOVP1,#8EH
            LCALL     INSTRUCTION
            MOVP1,#"O"
            LCALL     DISPLAY
            MOVP1,#"K"
            LCALL     DISPLAY
            MOVR3,#40
            MOVP1,#01H
            LCALL     INSTRUCTION
            MOVDPTR,#TEMP
LOOP_T:     CLR  A
            MOVC      A,@A+DPTR
            JZ   EXIT_T
            INC  DPTR
            MOVP1,A
            LCALL     DISPLAY
            SJMPLOOP_T
```

```
CM:         MOVP1,A
            JNB  ZERO,BACK_A
            LCALL     DISPLAY

BACK_A:          JNB  P3.4,BACK_A
            JNB  P3.5,BACK_A
            JNB  P3.6,BACK_A
            JNB  P3.7,BACK_A
            LCALL     DELAY
            LJMP      UP

ENTER:           MOVP1,#01H
            LCALL     INSTRUCTION
            MOVDPTR,#FIRST
LOOP_E:          CLR  A
            MOVC      A,@A+DPTR
            JZ   EXIT_E
            INC  DPTR
            MOVP1,A
            LCALL     DISPLAY
            SJMPLOOP_E
EXIT_E:          MOVP1,#0C0H
            LCALL     INSTRUCTION
            MOVDPTR,#TYPE
LOOP_TT: CLR  A
            MOVC      A,@A+DPTR
            JZ   EXIT_TT
            INC  DPTR
            MOVP1,A
            LCALL     DISPLAY
            SJMPLOOP_TT
EXIT_TT:         MOVP1,#88H
            LCALL     INSTRUCTION
            MOVP1,#"%"
            LCALL     DISPLAY
            MOVP1,#86H
            LCALL     INSTRUCTION
            LJMP      UP
UPER:            MOVDPTR,#U
```

```
            CLR  S
            LJMP        COM_UD
DOWN:              MOVDPTR,#D
            SETB        S
COM_UD:            MOVP1,#0C5H
            LCALL       INSTRUCTION
LOOP_UD:           CLR  A
            MOVC        A,@A+DPTR
            JZ    EXIT_UD
            INC   DPTR
            MOVP1,A
            LCALL       DISPLAY
            SJMPLOOP_UD
EXIT_UD:           LJMP        UP

;==================================================

ROW:               DB   0FEH,0FDH,0FBH,0F7H

KEYCODE:           DB   "*","M","0","S","D","9","8","7"
            DB    "U","6","5","4","E","3","2","1"

SEND:              DB   "error high temp",0

CLEAR:             DB   "              ",0

FIRST:             DB   "ENTER=",0

TEMP:              DB   "TEMP=",0

U:          DB    "HOT ",0

D:          DB    "COLD",0

TYPE:              DB   "TYPE=",0

DRIVER:            DB   38H,38H,01H,0CH,06H,80H,0

;==================================================
            END
```

نتیجه گیری

دماسنج با قابلیت کنترل امروزه استفاده زیادی دارد. زیر این دماسنج قادر به این است که دو دما را می توان برای آن تعریف کرد که یکی از دماهای تعریف شده برای روشن کردن سیستمی (به فرض مثال سیستم گرمازا) می باشد ودیگری برای خاموش کردن آن سیستم تعریف شده است.

پس استفاده از این دماسنج در اماکن های عمومی وسالن ها بیشتر مورد استفاده می شود زیا بااستفاده از این دماسنج در مصرف انرژی صرفه جویی می شود.همچنین این دماسنج علاوه بر صرفه جویی دارای دقت بالایی است و همچنین تا محدوده ۱۰۰ درجه سانتی گراد قابل استفاده می باشد .

این دماسنج از نظر ساخت ونصب آسان می باشد. همچین هزینه آن هم کم می باشد . هدف این دما سنج در کل برای صرفه جویی انرژی می باشد.

ضمائم

ضمیمه الف

intersil

ADC0803, ADC0804

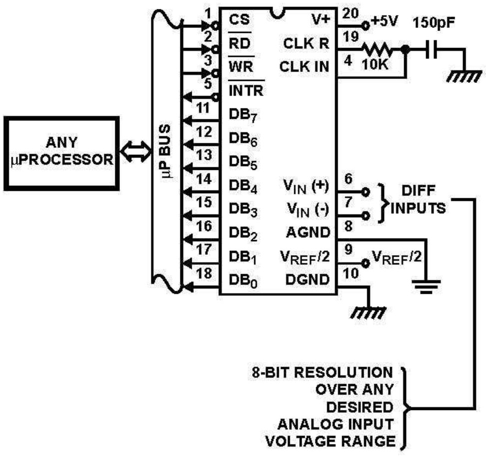
Data Sheet August 2002 FN3094.4

8-Bit, Microprocessor-Compatible, A/D Converters

The ADC080X family are CMOS 8-Bit, successive-approximation A/D converters which use a modified potentiometric ladder and are designed to operate with the 8080A control bus via three-state outputs. These converters appear to the processor as memory locations or I/O ports, and hence no interfacing logic is required.

The differential analog voltage input has good common-mode-rejection and permits offsetting the analog zero-input-voltage value. In addition, the voltage reference input can be adjusted to allow encoding any smaller analog voltage span to the full 8 bits of resolution.

Typical Application Schematic

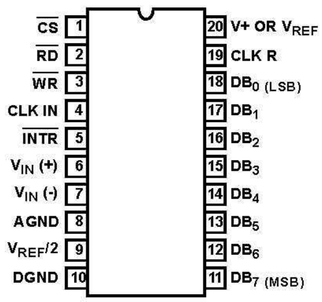


Features

- 80C48 and 80C80/85 Bus Compatible - No Interfacing Logic Required
- Conversion Time . . . . <100µs
- Easy Interface to Most Microprocessors
- Will Operate in a “Stand Alone” Mode
- Differential Analog Voltage Inputs
- Works with Bandgap Voltage References
- TTL Compatible Inputs and Outputs
- On-Chip Clock Generator
- Analog Voltage Input Range (Single + 5V Supply) . . . . 0V to 5V
- No Zero-Adjust Required
- 80C48 and 80C80/85 Bus Compatible - No Interfacing Logic Required

Pinout

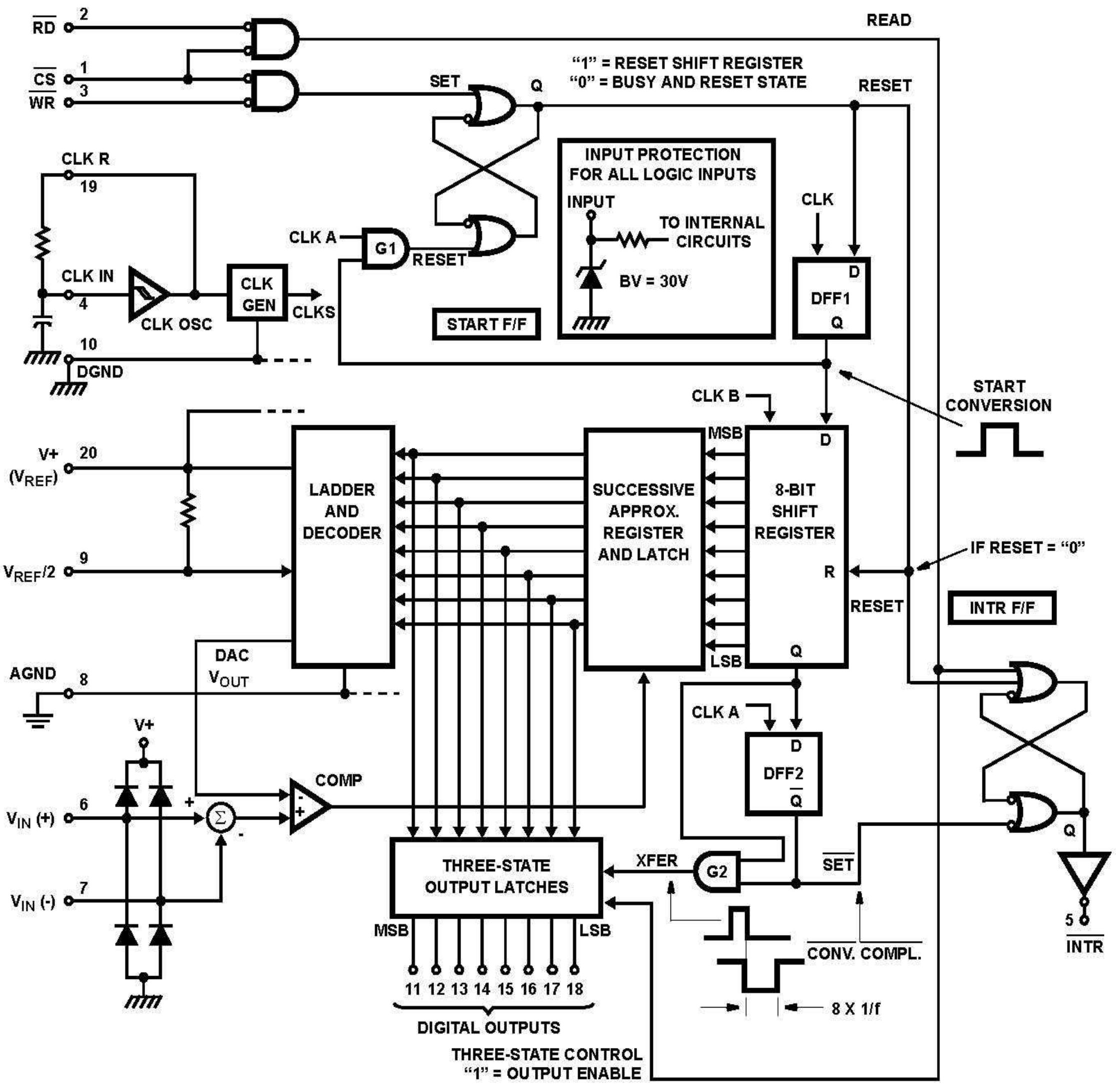
ADC0803, ADC0804
(PDIP)
TOP VIEW



Ordering Information

PART NUMBER	ERROR	EXTERNAL CONDITIONS	TEMP. RANGE (^oC)	PACKAGE	PKG. NO
ADC0803LCN	$\pm^1/_2$ LSB	$V_{REF}/2$ Adjusted for Correct Full Scale Reading	0 to 70	20 Ld PDIP	E20.3
ADC0804LCN	±1 LSB	$V_{REF}/2 = 2.500V_{DC}$ (No Adjustments)	0 to 70	20 Ld PDIP	E20.3

Functional Diagram



Absolute Maximum Ratings

Supply Voltage 6.5V
Voltage at Any Input. . . . . -0.3V to (V^+ +0.3V)

Operating Conditions

Temperature Range . . . . 0^oC to 70^oC

Thermal Information

Thermal Resistance (Typical, Note 1) θ_{JA} ($^oC/W$)
PDIP Package 80
Maximum Junction Temperature
Plastic Package . . . .150^oC
Maximum Storage Temperature Range. . . . . -65^oC to 150^oC
Maximum Lead Temperature (Soldering, 10s). . . . . .300^oC

CAUTION: Stresses above those listed in "Absolute Maximum Ratings" may cause permanent damage to the device. This is a stress only rating and operation of the device at these or any other conditions above those indicated in the operational sections of this specification is not implied.

NOTE:

1. θ_{JA} is measured with the component mounted on a low effective thermal conductivity test board in free air. See Tech Brief TB379 for details.

Electrical Specifications (Notes 2, 8)

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
CONVERTER SPECIFICATIONS V+ = 5V, T_A = 25^oC and f_{CLK} = 640kHz, Unless Otherwise Specified					
Total Unadjusted Error					
ADC0803	V_{REF}/2 Adjusted for Correct Full Scale Reading	-	-	$\pm^1/_2$	LSB
ADC0804	V_{REF}/2 = 2.500V	-	-	±1	LSB
V_{REF}/2 Input Resistance	Input Resistance at Pin 9	1.0	1.3	-	kΩ
Analog Input Voltage Range	(Note 3)	GND-0.05	-	(V+) + 0.05	V
DC Common-Mode Rejection	Over Analog Input Voltage Range	-	$\pm^1/_{16}$	$\pm^1/_8$	LSB
Power Supply Sensitivity	V+ = 5V ±10% Over Allowed Input Voltage Range	-	$\pm^1/_{16}$	$\pm^1/_8$	LSB
CONVERTER SPECIFICATIONS V+ = 5V, 0^oC to 70^oC and f_{CLK} = 640kHz, Unless Otherwise Specified					
Total Unadjusted Error					
ADC0803	V_{REF}/2 Adjusted for Correct Full Scale Reading	-	-	$\pm^1/_2$	LSB
ADC0804	V_{REF}/2 = 2.500V	-	-	±1	LSB
V_{REF}/2 Input Resistance	Input Resistance at Pin 9	1.0	1.3	-	kΩ
Analog Input Voltage Range	(Note 3)	GND-0.05	-	(V+) + 0.05	V
DC Common-Mode Rejection	Over Analog Input Voltage Range	-	$\pm^1/_8$	$\pm^1/_4$	LSB
Power Supply Sensitivity	V+ = 5V ±10% Over Allowed Input Voltage Range	-	$\pm^1/_{16}$	$\pm^1/_8$	LSB
AC TIMING SPECIFICATIONS V+ = 5V, and T_A = 25^oC, Unless Otherwise Specified					
Clock Frequency, f_{CLK}	V+ = 6V (Note 4)	100	640	1280	kHz
	V+ = 5V	100	640	800	kHz
Clock Periods per Conversion (Note 5), t_{CONV}		62	-	73	Clocks/Conv
Conversion Rate In Free-Running Mode, CR	$\overline{INTR}$ tied to $\overline{WR}$ with $\overline{CS}$ = 0V, f_{CLK} = 640kHz	-	-	8888	Conv/s
Width of $\overline{WR}$ Input (Start Pulse Width), $t_{W(WR)I}$	$\overline{CS}$ = 0V (Note 6)	100	-	-	ns
Access Time (Delay from Falling Edge of $\overline{RD}$ to Output Data Valid), t_{ACC}	C_L = 100pF (Use Bus Driver IC for Larger C_L)	-	135	200	ns
Three-State Control (Delay from Rising Edge of $\overline{RD}$ to HI-Z State), t_{1H}, t_{0H}	C_L = 10pF, R_L= 10K (See Three-State Test Circuits)	-	125	250	ns
Delay from Falling Edge of $\overline{WR}$ to Reset of $\overline{INTR}$, t_{WI}, t_{RI}		-	300	450	ns
Input Capacitance of Logic Control Inputs, C_{IN}		-	5	-	pF
Three-State Output Capacitance (Data Buffers), C_{OUT}		-	5	-	pF

Electrical Specifications (Notes 2, 8) (Continued)

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
DC DIGITAL LEVELS AND DC SPECIFICATIONS V+ = 5V, and T_{MIN} to T_{MAX}, Unless Otherwise Specified					
CONTROL INPUTS (Note 7)					
Logic "1" Input Voltage (Except Pin 4 CLK IN), V_{INH}	V+ = 5.25V	2.0	-	V+	V
Logic "0" Input Voltage (Except Pin 4 CLK IN), V_{INL}	V+ = 4.75V	-	-	0.8	V
CLK IN (Pin 4) Positive Going Threshold Voltage, $V+_{CLK}$		2.7	3.1	3.5	V
CLK IN (Pin 4) Negative Going Threshold Voltage, $V-_{CLK}$		1.5	1.8	2.1	V
CLK IN (Pin 4) Hysteresis, V_H		0.6	1.3	2.0	V
Logic "1" Input Current (All Inputs), I_{INHI}	V_{IN} = 5V	-	0.005	1	µA
Logic "0" Input Current (All Inputs), I_{INLO}	V_{IN} = 0V	-1	-0.005	-	µA
Supply Current (Includes Ladder Current), I+	f_{CLK} = 640kHz, T_A = 25°C and $\overline{CS}$ = HI	-	1.3	2.5	mA
DATA OUTPUTS AND $\overline{INTR}$					
Logic "0" Output Voltage, V_{OL}	I_O = 1.6mA, V+ = 4.75V	-	-	0.4	V
Logic "1" Output Voltage, V_{OH}	I_O = -360µA, V+ = 4.75V	2.4	-	-	V
Three-State Disabled Output Leakage (All Data Buffers), I_{LO}	V_{OUT} = 0V	-3	-	-	µA
	V_{OUT} = 5V	-	-	3	µA
Output Short Circuit Current, I_{SOURCE}	V_{OUT} Short to GND, T_A = 25°C	4.5	6	-	mA
Output Short Circuit Current, I_{SINK}	V_{OUT} Short to V+, T_A = 25°C	9.0	16	-	mA

NOTES:

2. All voltages are measured with respect to GND, unless otherwise specified. The separate AGND point should always be wired to the DGND, being careful to avoid ground loops.
3. For $V_{IN(-)} \geq V_{IN(+)}$ the digital output code will be 0000 0000. Two on-chip diodes are tied to each analog input (see Block Diagram) which will forward conduct for analog input voltages one diode drop below ground or one diode drop greater than the V+ supply. Be careful, during testing at low V+ levels (4.5V), as high level analog inputs (5V) can cause this input diode to conduct - especially at elevated temperatures, and cause errors for analog inputs near full scale. As long as the analog V_{IN} does not exceed the supply voltage by more than 50mV, the output code will be correct. To achieve an absolute 0V to 5V input voltage range will therefore require a minimum supply voltage of 4.950V over temperature variations, initial tolerance and loading.
4. With V+ = 6V, the digital logic interfaces are no longer TTL compatible.
5. With an asynchronous start pulse, up to 8 clock periods may be required before the internal clock phases are proper to start the conversion process.
6. The $\overline{CS}$ input is assumed to bracket the $\overline{WR}$ strobe input so that timing is dependent on the $\overline{WR}$ pulse width. An arbitrarily wide pulse width will hold the converter in a reset mode and the start of conversion is initiated by the low to high transition of the $\overline{WR}$ pulse (see Timing Diagrams).
7. CLK IN (pin 4) is the input of a Schmitt trigger circuit and is therefore specified separately.
8. None of these A/Ds requires a zero-adjust. However, if an all zero code is desired for an analog input other than 0V, or if a narrow full scale span exists (for example: 0.5V to 4V full scale) the $V_{IN(-)}$ input can be adjusted to achieve this. See the Zero Error description in this data sheet.

Timing Waveforms

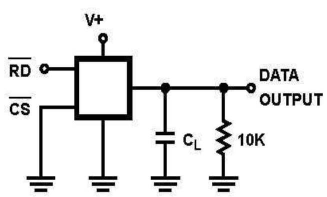


FIGURE 1A. t_{1H}

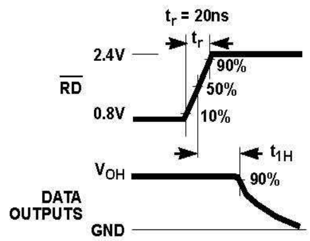


FIGURE 1B. t_{1H}, C_L = 10pF

Timing Waveforms (Continued)

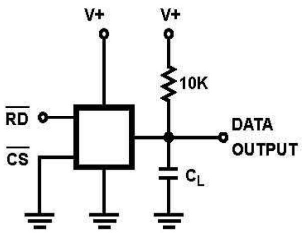


FIGURE 1C. t_{0H}

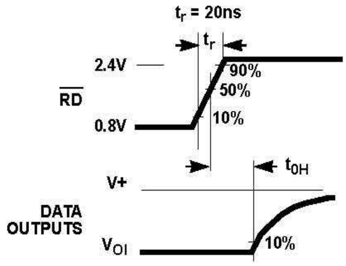


FIGURE 1D. t_{0H}, C_L = 10pF

FIGURE 1. THREE-STATE CIRCUITS AND WAVEFORMS

Typical Performance Curves

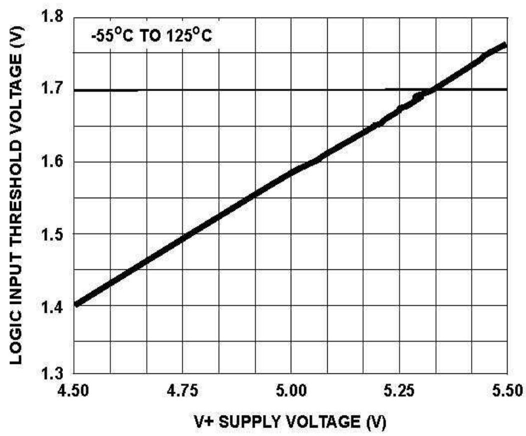


FIGURE 2. LOGIC INPUT THRESHOLD VOLTAGE vs SUPPLY VOLTAGE

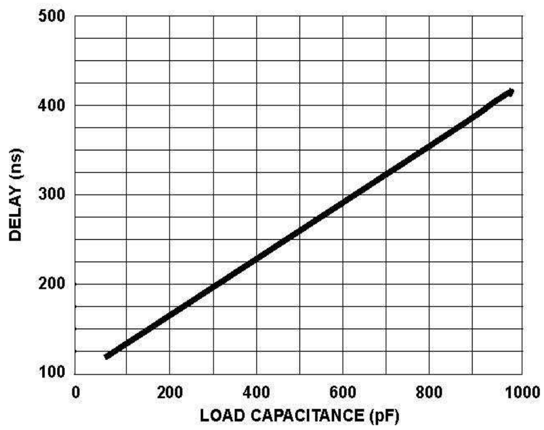


FIGURE 3. DELAY FROM FALLING EDGE OF $\overline{RD}$ TO OUTPUT DATA VALID vs LOAD CAPACITANCE

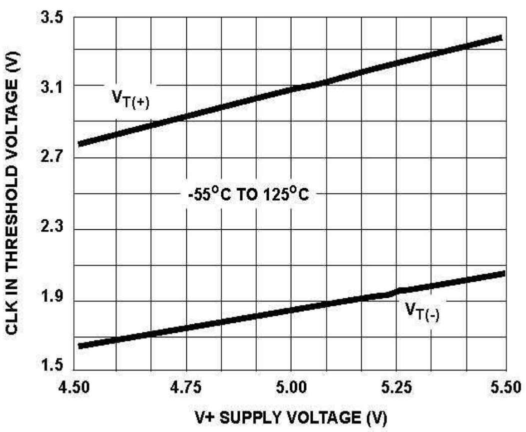


FIGURE 4. CLK IN SCHMITT TRIP LEVELS vs SUPPLY VOLTAGE

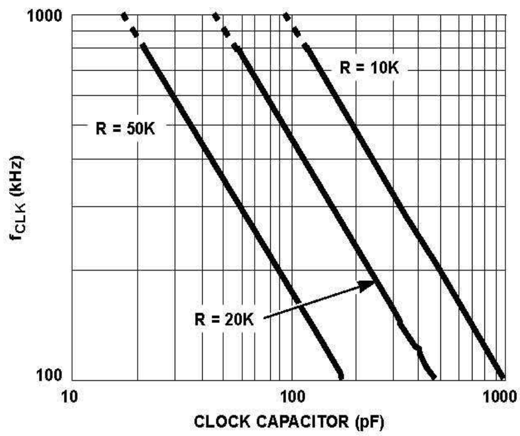


FIGURE 5. f_{CLK} vs CLOCK CAPACITOR

Typical Performance Curves (Continued)

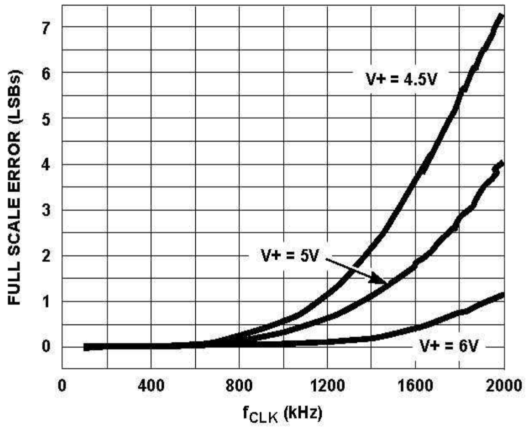


FIGURE 6. FULL SCALE ERROR vs f_{CLK}

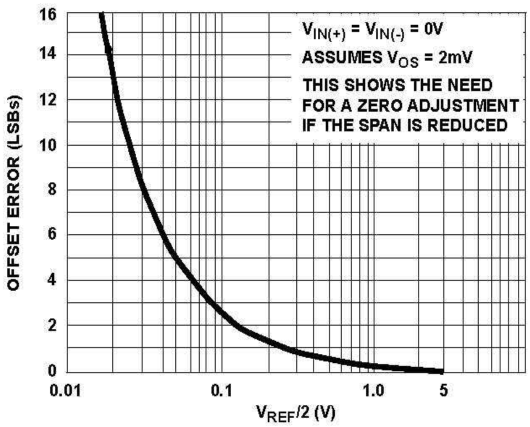


FIGURE 7. EFFECT OF UNADJUSTED OFFSET ERROR

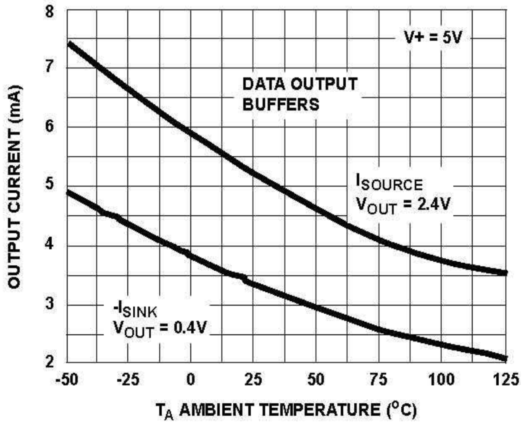


FIGURE 8. OUTPUT CURRENT vs TEMPERATURE

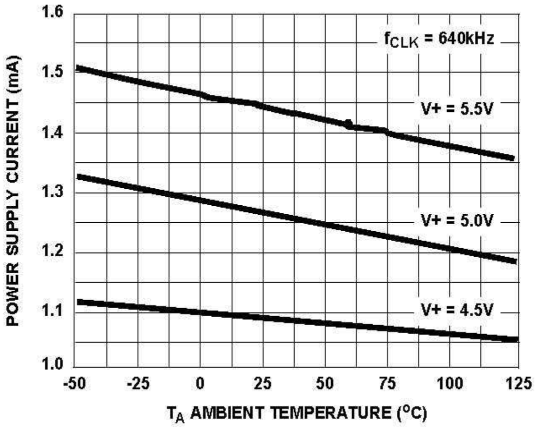


FIGURE 9. POWER SUPPLY CURRENT vs TEMPERATURE

Timing Diagrams

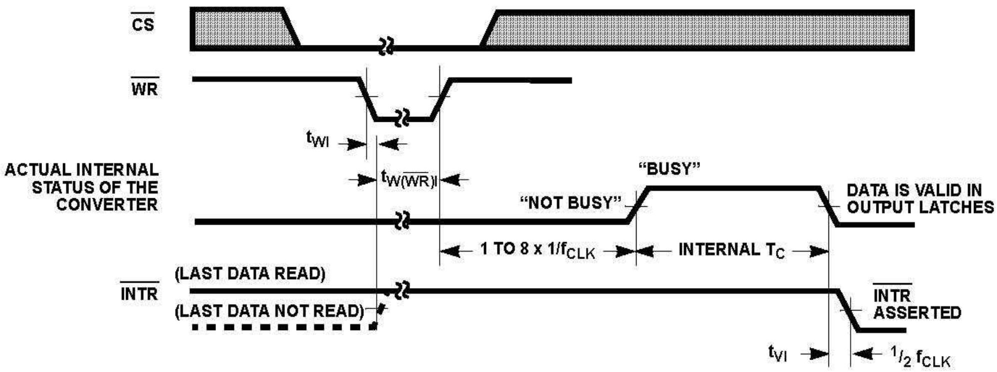


FIGURE 10A. START CONVERSION

Timing Diagrams (Continued)

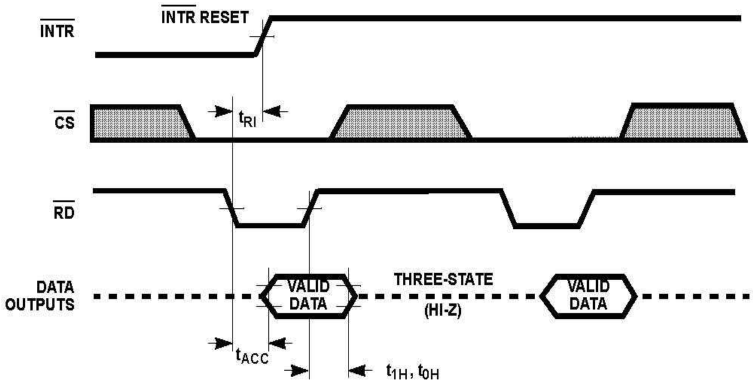
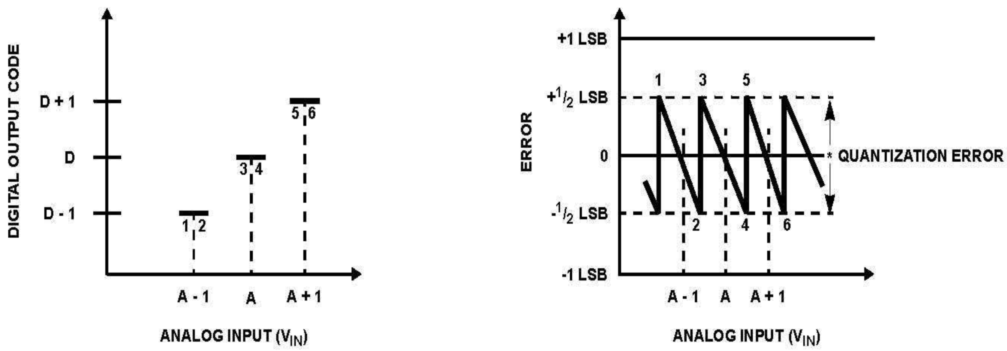


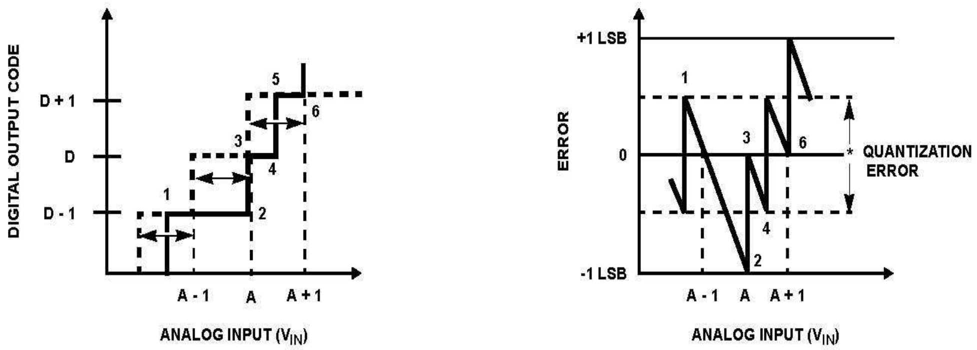
FIGURE 10B. OUTPUT ENABLE AND RESET INTR



TRANSFER FUNCTION

ERROR PLOT

FIGURE 11A. ACCURACY = ±0 LSB; PERFECT A/D



TRANSFER FUNCTION

ERROR PLOT

FIGURE 11B. ACCURACY = ±1/2 LSB

FIGURE 11. CLARIFYING THE ERROR SPECS OF AN A/D CONVERTER

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National Semiconductor

November 2000

LM35
Precision Centigrade Temperature Sensors

General Description

The LM35 series are precision integrated-circuit temperature sensors, whose output voltage is linearly proportional to the Celsius (Centigrade) temperature. The LM35 thus has an advantage over linear temperature sensors calibrated in ° Kelvin, as the user is not required to subtract a large constant voltage from its output to obtain convenient Centigrade scaling. The LM35 does not require any external calibration or trimming to provide typical accuracies of ±¼°C at room temperature and ±¾°C over a full −55 to +150°C temperature range. Low cost is assured by trimming and calibration at the wafer level. The LM35's low output impedance, linear output, and precise inherent calibration make interfacing to readout or control circuitry especially easy. It can be used with single power supplies, or with plus and minus supplies. As it draws only 60 µA from its supply, it has very low self-heating, less than 0.1°C in still air. The LM35 is rated to operate over a −55° to +150°C temperature range, while the LM35C is rated for a −40° to +110°C range (−10° with improved accuracy). The LM35 series is available packaged in hermetic TO-46 transistor packages, while the LM35C, LM35CA, and LM35D are also available in the plastic TO-92 transistor package. The LM35D is also available in an 8-lead surface mount small outline package and a plastic TO-220 package.

Features

- Calibrated directly in ° Celsius (Centigrade)
- Linear + 10.0 mV/°C scale factor
- 0.5°C accuracy guaranteeable (at +25°C)
- Rated for full −55° to +150°C range
- Suitable for remote applications
- Low cost due to wafer-level trimming
- Operates from 4 to 30 volts
- Less than 60 µA current drain
- Low self-heating, 0.08°C in still air
- Nonlinearity only ±¼°C typical
- Low impedance output, 0.1 Ω for 1 mA load

Typical Applications

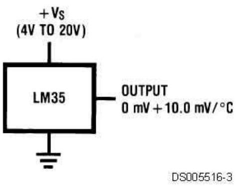
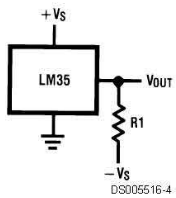


FIGURE 1. Basic Centigrade Temperature Sensor (+2°C to +150°C)



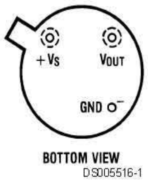
Choose $R_1 = -V_S/50\ \mu A$
V_{OUT} = +1,500 mV at +150°C
= +250 mV at +25°C
= −550 mV at −55°C

FIGURE 2. Full-Range Centigrade Temperature Sensor

 DS005516 www.national.com

Connection Diagrams

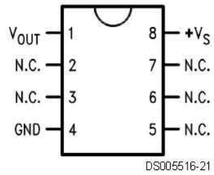
TO-46
Metal Can Package*



*Case is connected to negative pin (GND)

Order Number LM35H, LM35AH, LM35CH, LM35CAH or LM35DH
See NS Package Number H03H

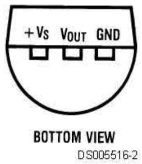
SO-8
Small Outline Molded Package



N.C. = No Connection

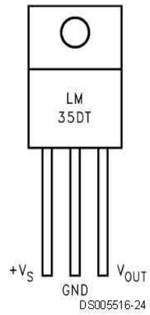
Top View
Order Number LM35DM
See NS Package Number M08A

TO-92
Plastic Package



Order Number LM35CZ, LM35CAZ or LM35DZ
See NS Package Number Z03A

TO-220
Plastic Package*



*Tab is connected to the negative pin (GND).
Note: The LM35DT pinout is different than the discontinued LM35DP.

Order Number LM35DT
See NS Package Number TA03F

Absolute Maximum Ratings (Note 10)

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/ Distributors for availability and specifications.

Supply Voltage	+35V to −0.2V
Output Voltage	+6V to −1.0V
Output Current	10 mA
Storage Temp.;	
TO-46 Package,	−60°C to +180°C
TO-92 Package,	−60°C to +150°C
SO-8 Package,	−65°C to +150°C
TO-220 Package,	−65°C to +150°C
Lead Temp.:	
TO-46 Package, (Soldering, 10 seconds)	300°C
TO-92 and TO-220 Package, (Soldering, 10 seconds)	260°C
SO Package (Note 12)	
Vapor Phase (60 seconds)	215°C
Infrared (15 seconds)	220°C
ESD Susceptibility (Note 11)	2500V
Specified Operating Temperature Range: T_{MIN} to T_{MAX} (Note 2)	
LM35, LM35A	−55°C to +150°C
LM35C, LM35CA	−40°C to +110°C
LM35D	0°C to +100°C

Electrical Characteristics

(Notes 1, 6)

Parameter	Conditions	LM35A			LM35CA			Units
		Typical	Tested Limit (Note 4)	Design Limit (Note 5)	Typical	Tested Limit (Note 4)	Design Limit (Note 5)	(Max.)
Accuracy (Note 7)	T_A=+25°C	±0.2	±0.5		±0.2	±0.5		°C
	T_A=−10°C	±0.3			±0.3		±1.0	°C
	$T_A=T_{MAX}$	±0.4	±1.0		±0.4	±1.0		°C
	$T_A=T_{MIN}$	±0.4	±1.0		±0.4		±1.5	°C
Nonlinearity (Note 8)	$T_{MIN} \le T_A \le T_{MAX}$	**±0.18**		**±0.35**	**±0.15**		**±0.3**	°C
Sensor Gain (Average Slope)	$T_{MIN} \le T_A \le T_{MAX}$	**+10.0**	**+9.9, +10.1**		**+10.0**		**+9.9, +10.1**	mV/°C
Load Regulation (Note 3) $0 \le I_L \le 1$ mA	T_A=+25°C	±0.4	±1.0		±0.4	±1.0		mV/mA
	$T_{MIN} \le T_A \le T_{MAX}$	**±0.5**		**±3.0**	**±0.5**		**±3.0**	mV/mA
Line Regulation (Note 3)	T_A=+25°C	±0.01	±0.05		±0.01	±0.05		mV/V
	$4V \le V_S \le 30V$	**±0.02**		**±0.1**	**±0.02**		**±0.1**	mV/V
Quiescent Current (Note 9)	V_S=+5V, +25°C	56	67		56	67		μA
	V_S=+5V	**105**		**131**	**91**		**114**	μA
	V_S=+30V, +25°C	56.2	68		56.2	68		μA
	V_S=+30V	**105.5**		**133**	**91.5**		**116**	μA
Change of Quiescent Current (Note 3)	$4V \le V_S \le 30V$, +25°C	0.2	1.0		0.2	1.0		μA
	$4V \le V_S \le 30V$	**0.5**		**2.0**	**0.5**		**2.0**	μA
Temperature Coefficient of Quiescent Current		**+0.39**		**+0.5**	**+0.39**		**+0.5**	μA/°C
Minimum Temperature for Rated Accuracy	In circuit of *Figure 1*, I_L=0	+1.5		+2.0	+1.5		+2.0	°C
Long Term Stability	$T_J=T_{MAX}$, for 1000 hours	±0.08			±0.08			°C

Electrical Characteristics

(Notes 1, 6)

Parameter	Conditions	LM35 Typical	LM35 Tested Limit (Note 4)	LM35 Design Limit (Note 5)	LM35C, LM35D Typical	LM35C, LM35D Tested Limit (Note 4)	LM35C, LM35D Design Limit (Note 5)	Units (Max.)
Accuracy, LM35, LM35C (Note 7)	T_A=+25°C	±0.4	±1.0		±0.4	±1.0		°C
	T_A=−10°C	±0.5			±0.5		±1.5	°C
	$T_A=T_{MAX}$	±0.8	±1.5		±0.8		±1.5	°C
	$T_A=T_{MIN}$	±0.8		±1.5	±0.8		±2.0	°C
Accuracy, LM35D (Note 7)	T_A=+25°C				±0.6	±1.5		°C
	$T_A=T_{MAX}$				±0.9		±2.0	°C
	$T_A=T_{MIN}$				±0.9		±2.0	°C
Nonlinearity (Note 8)	$T_{MIN}\le T_A\le T_{MAX}$	**±0.3**		**±0.5**	**±0.2**		**±0.5**	°C
Sensor Gain (Average Slope)	$T_{MIN}\le T_A\le T_{MAX}$	**+10.0**	**+9.8, +10.2**		**+10.0**		**+9.8, +10.2**	mV/°C
Load Regulation (Note 3) $0\le I_L\le 1$ mA	T_A=+25°C	±0.4	±2.0		±0.4	±2.0		mV/mA
	$T_{MIN}\le T_A\le T_{MAX}$	**±0.5**		**±5.0**	**±0.5**		**±5.0**	mV/mA
Line Regulation (Note 3)	T_A=+25°C	±0.01	±0.1		±0.01	±0.1		mV/V
	$4V\le V_S\le 30V$	**±0.02**		**±0.2**	**±0.02**		**±0.2**	mV/V
Quiescent Current (Note 9)	V_S=+5V, +25°C	56	80		56	80		μA
	V_S=+5V	**105**		**158**	**91**		**138**	μA
	V_S=+30V, +25°C	56.2	82		56.2	82		μA
	V_S=+30V	**105.5**		**161**	**91.5**		**141**	μA
Change of Quiescent Current (Note 3)	$4V\le V_S\le 30V$, +25°C	0.2	2.0		0.2	2.0		μA
	$4V\le V_S\le 30V$	**0.5**		**3.0**	**0.5**		**3.0**	μA
Temperature Coefficient of Quiescent Current		**+0.39**		**+0.7**	**+0.39**		**+0.7**	μA/°C
Minimum Temperature for Rated Accuracy	In circuit of *Figure 1*, I_L=0	+1.5		+2.0	+1.5		+2.0	°C
Long Term Stability	$T_J=T_{MAX}$, for 1000 hours	±0.08			±0.08			°C

Note 1: Unless otherwise noted, these specifications apply: $-55°C\le T_J\le +150°C$ for the LM35 and LM35A; $-40°C\le T_J\le +110°C$ for the LM35C and LM35CA; and $0°C\le T_J\le +100°C$ for the LM35D. V_S=+5Vdc and I_{LOAD}=50 μA, in the circuit of *Figure 2*. These specifications also apply from +2°C to T_{MAX} in the circuit of *Figure 1*. Specifications in **boldface** apply over the full rated temperature range.

Note 2: Thermal resistance of the TO-46 package is 400°C/W, junction to ambient, and 24°C/W junction to case. Thermal resistance of the TO-92 package is 180°C/W junction to ambient. Thermal resistance of the small outline molded package is 220°C/W junction to ambient. Thermal resistance of the TO-220 package is 90°C/W junction to ambient. For additional thermal resistance information see table in the Applications section.

Note 3: Regulation is measured at constant junction temperature, using pulse testing with a low duty cycle. Changes in output due to heating effects can be computed by multiplying the internal dissipation by the thermal resistance.

Note 4: Tested Limits are guaranteed and 100% tested in production.

Note 5: Design Limits are guaranteed (but not 100% production tested) over the indicated temperature and supply voltage ranges. These limits are not used to calculate outgoing quality levels.

Note 6: Specifications in **boldface** apply over the full rated temperature range.

Note 7: Accuracy is defined as the error between the output voltage and 10mv/°C times the device's case temperature, at specified conditions of voltage, current, and temperature (expressed in °C).

Note 8: Nonlinearity is defined as the deviation of the output-voltage-versus-temperature curve from the best-fit straight line, over the device's rated temperature range.

Note 9: Quiescent current is defined in the circuit of *Figure 1*.

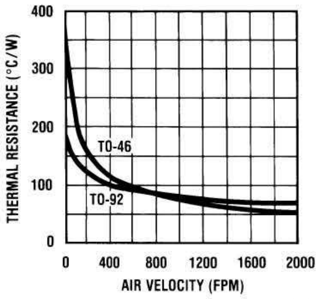
Note 10: Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. DC and AC electrical specifications do not apply when operating the device beyond its rated operating conditions. See Note 1.

Note 11: Human body model, 100 pF discharged through a 1.5 kΩ resistor.

Note 12: See AN-450 "Surface Mounting Methods and Their Effect on Product Reliability" or the section titled "Surface Mount" found in a current National Semiconductor Linear Data Book for other methods of soldering surface mount devices.

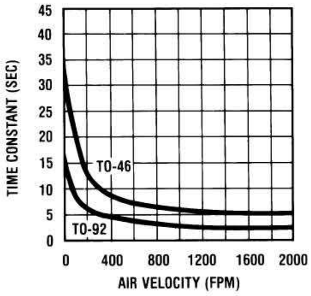
Typical Performance Characteristics

Thermal Resistance Junction to Air



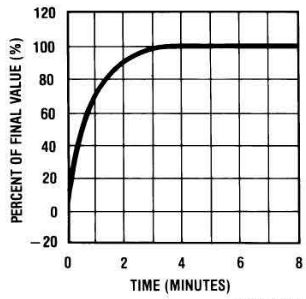
DS005516-25

Thermal Time Constant



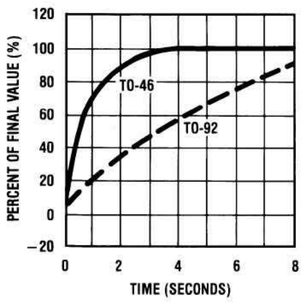
DS005516-26

Thermal Response in Still Air



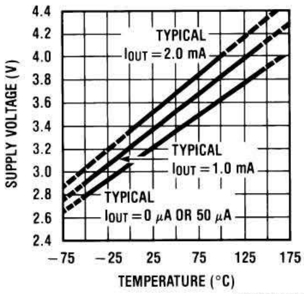
DS005516-27

Thermal Response in Stirred Oil Bath



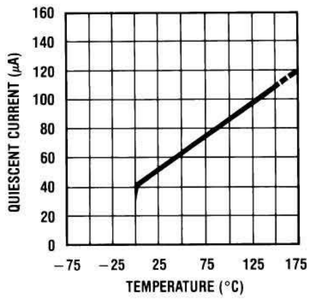
DS005516-28

Minimum Supply Voltage vs. Temperature



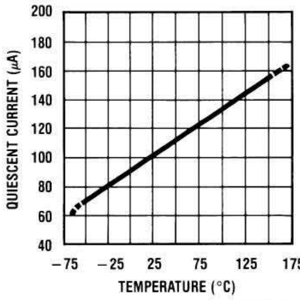
DS005516-29

Quiescent Current vs. Temperature (In Circuit of *Figure 1*.)



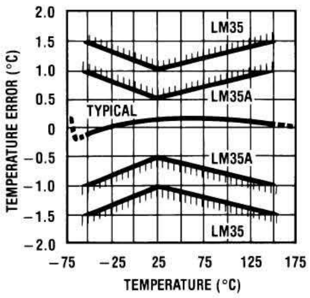
DS005516-30

Quiescent Current vs. Temperature (In Circuit of *Figure 2*.)



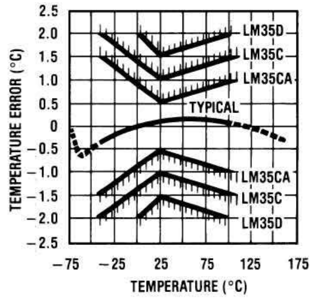
DS005516-31

Accuracy vs. Temperature (Guaranteed)



DS005516-32

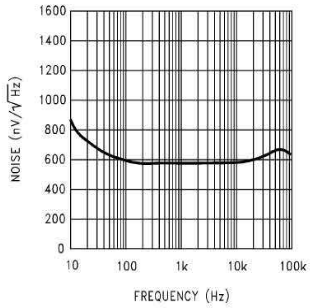
Accuracy vs. Temperature (Guaranteed)



DS005516-33

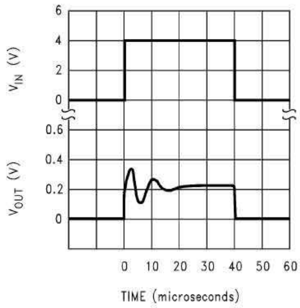
Typical Performance Characteristics (Continued)

Noise Voltage



DS005516-34

Start-Up Response



DS005516-35

Applications

The LM35 can be applied easily in the same way as other integrated-circuit temperature sensors. It can be glued or cemented to a surface and its temperature will be within about 0.01˚C of the surface temperature.

This presumes that the ambient air temperature is almost the same as the surface temperature; if the air temperature were much higher or lower than the surface temperature, the actual temperature of the LM35 die would be at an intermediate temperature between the surface temperature and the air temperature. This is expecially true for the TO-92 plastic package, where the copper leads are the principal thermal path to carry heat into the device, so its temperature might be closer to the air temperature than to the surface temperature.

To minimize this problem, be sure that the wiring to the LM35, as it leaves the device, is held at the same temperature as the surface of interest. The easiest way to do this is to cover up these wires with a bead of epoxy which will insure that the leads and wires are all at the same temperature as the surface, and that the LM35 die's temperature will not be affected by the air temperature.

The TO-46 metal package can also be soldered to a metal surface or pipe without damage. Of course, in that case the V− terminal of the circuit will be grounded to that metal. Alternatively, the LM35 can be mounted inside a sealed-end metal tube, and can then be dipped into a bath or screwed into a threaded hole in a tank. As with any IC, the LM35 and accompanying wiring and circuits must be kept insulated and dry, to avoid leakage and corrosion. This is especially true if the circuit may operate at cold temperatures where condensation can occur. Printed-circuit coatings and varnishes such as Humiseal and epoxy paints or dips are often used to insure that moisture cannot corrode the LM35 or its connections.

These devices are sometimes soldered to a small light-weight heat fin, to decrease the thermal time constant and speed up the response in slowly-moving air. On the other hand, a small thermal mass may be added to the sensor, to give the steadiest reading despite small deviations in the air temperature.

Temperature Rise of LM35 Due To Self-heating (Thermal Resistance, θ_{JA})

	TO-46, no heat sink	TO-46*, small heat fin	TO-92, no heat sink	TO-92**, small heat fin	SO-8 no heat sink	SO-8** small heat fin	TO-220 no heat sink
Still air	400˚C/W	100˚C/W	180˚C/W	140˚C/W	220˚C/W	110˚C/W	90˚C/W
Moving air	100˚C/W	40˚C/W	90˚C/W	70˚C/W	105˚C/W	90˚C/W	26˚C/W
Still oil	100˚C/W	40˚C/W	90˚C/W	70˚C/W			
Stirred oil	50˚C/W	30˚C/W	45˚C/W	40˚C/W			
(Clamped to metal, Infinite heat sink)		(24˚C/W)				(55˚C/W)	

*Wakefield type 201, or 1" disc of 0.020" sheet brass, soldered to case, or similar.
**TO-92 and SO-8 packages glued and leads soldered to 1" square of 1/16" printed circuit board with 2 oz. foil or similar.

Typical Applications

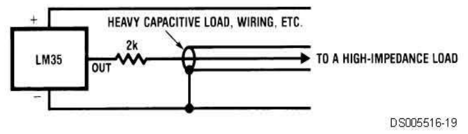


FIGURE 3. LM35 with Decoupling from Capacitive Load

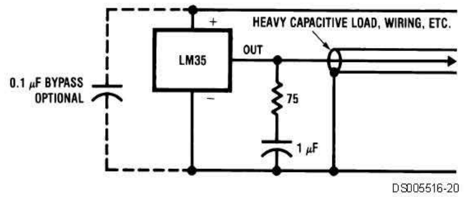


FIGURE 4. LM35 with R-C Damper

CAPACITIVE LOADS

Like most micropower circuits, the LM35 has a limited ability to drive heavy capacitive loads. The LM35 by itself is able to drive 50 pf without special precautions. If heavier loads are anticipated, it is easy to isolate or decouple the load with a resistor; see *Figure 3*. Or you can improve the tolerance of capacitance with a series R-C damper from output to ground; see *Figure 4*.

When the LM35 is applied with a 200Ω load resistor as shown in *Figure 5*, *Figure 6* or *Figure 8* it is relatively immune to wiring capacitance because the capacitance forms a bypass from ground to input, not on the output. However, as with any linear circuit connected to wires in a hostile environment, its performance can be affected adversely by intense electromagnetic sources such as relays, radio transmitters, motors with arcing brushes, SCR transients, etc, as its wiring can act as a receiving antenna and its internal junctions can act as rectifiers. For best results in such cases, a bypass capacitor from V_{IN} to ground and a series R-C damper such as 75Ω in series with 0.2 or 1 μF from output to ground are often useful. These are shown in *Figure 13*, *Figure 14*, and *Figure 16*.

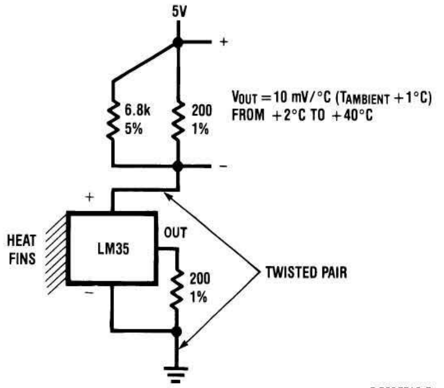


FIGURE 5. Two-Wire Remote Temperature Sensor (Grounded Sensor)

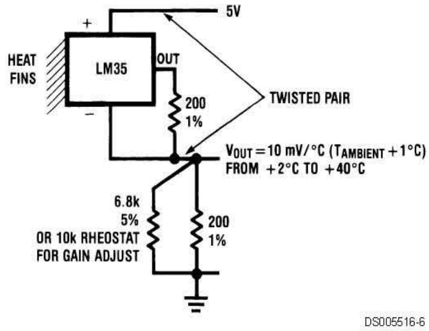


FIGURE 6. Two-Wire Remote Temperature Sensor (Output Referred to Ground)

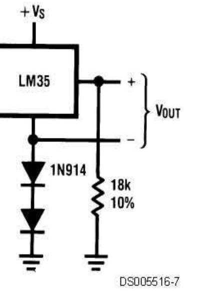


FIGURE 7. Temperature Sensor, Single Supply, −55˚ to +150˚C

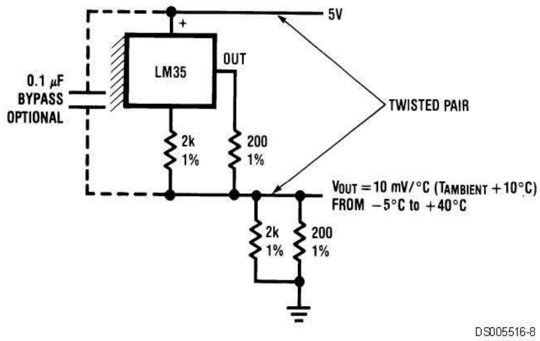


FIGURE 8. Two-Wire Remote Temperature Sensor (Output Referred to Ground)

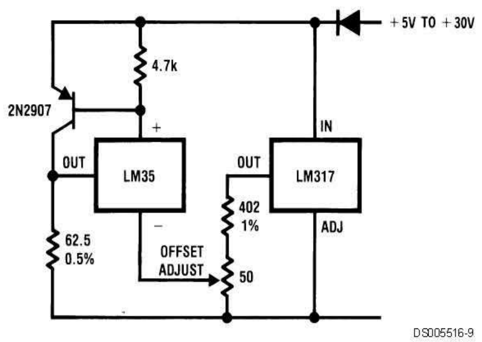


FIGURE 9. 4-To-20 mA Current Source (0˚C to +100˚C)

Typical Applications (Continued)

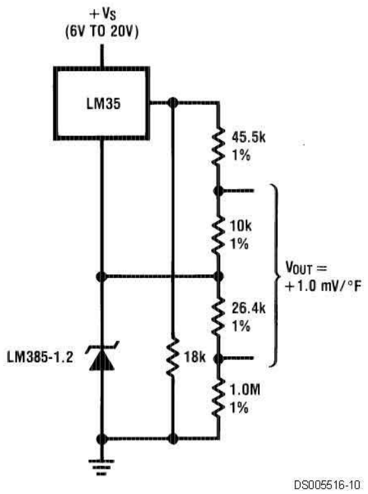


FIGURE 10. Fahrenheit Thermometer

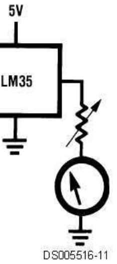


FIGURE 11. Centigrade Thermometer (Analog Meter)

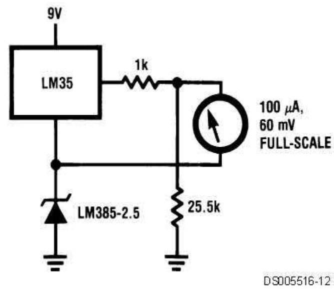


FIGURE 12. Fahrenheit ThermometerExpanded Scale Thermometer
(50° to 80° Fahrenheit, for Example Shown)

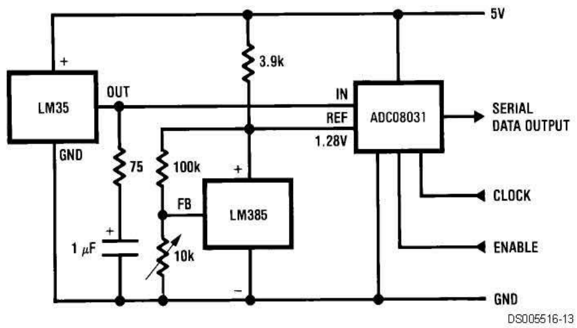


FIGURE 13. Temperature To Digital Converter (Serial Output) (+128°C Full Scale)

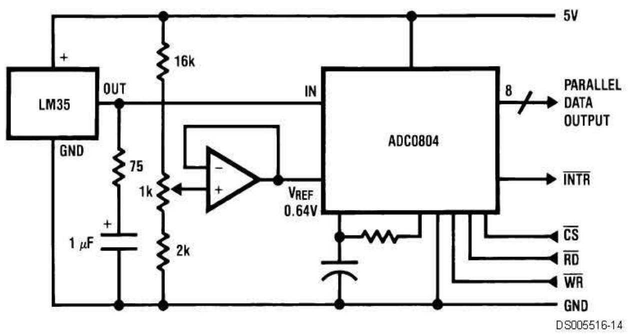


FIGURE 14. Temperature To Digital Converter (Parallel TRI-STATE™ Outputs for Standard Data Bus to μP Interface) (128°C Full Scale)

ضمیمه پ

Features

- Compatible with MCS-51™ Products
- 4 Kbytes of In-System Reprogrammable Flash Memory
  Endurance: 1,000 Write/Erase Cycles
- Fully Static Operation: 0 Hz to 24 MHz
- Three-Level Program Memory Lock
- 128 x 8-Bit Internal RAM
- 32 Programmable I/O Lines
- Two 16-Bit Timer/Counters
- Six Interrupt Sources
- Programmable Serial Channel
- Low Power Idle and Power Down Modes

8-Bit Microcontroller with 4 Kbytes Flash

AT89C51

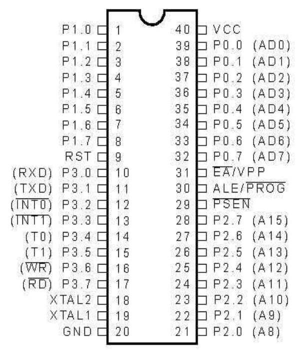
Description

The AT89C51 is a low-power, high-performance CMOS 8-bit microcomputer with 4 Kbytes of Flash Programmable and Erasable Read Only Memory (PEROM). The device is manufactured using Atmel's high density nonvolatile memory technology and is compatible with the industry standard MCS-51™ instruction set and pinout. The on-chip Flash allows the program memory to be reprogrammed in-system or by a conventional nonvolatile memory programmer. By combining a versatile 8-bit CPU with Flash on a monolithic chip, the Atmel AT89C51 is a powerful microcomputer which provides a highly flexible and cost effective solution to many embedded control applications.

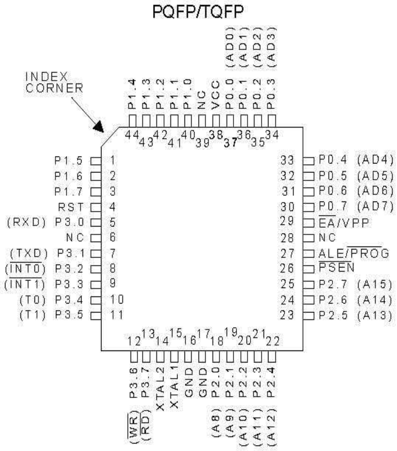
(continued)

Pin Configurations

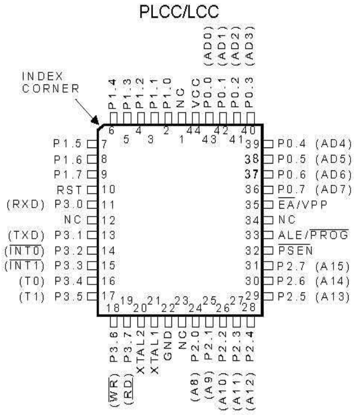
PDIP/Cerdip



PQFP/TQFP

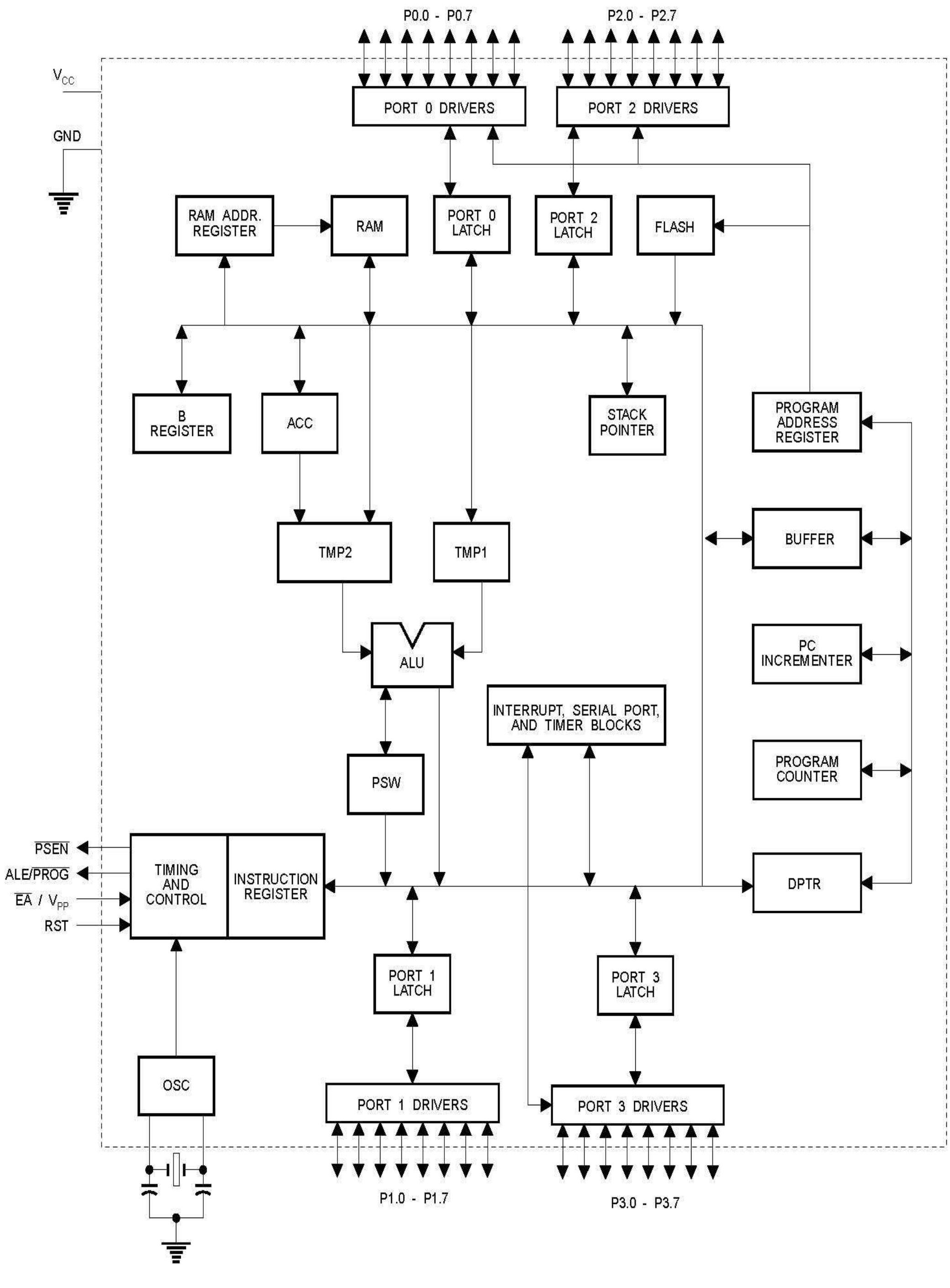


PLCC/LCC



0265E

Block Diagram



Pin Description (Continued)

When the AT89C51 is executing code from external program memory, $\overline{\text{PSEN}}$ is activated twice each machine cycle, except that two $\overline{\text{PSEN}}$ activations are skipped during each access to external data memory.

$\overline{\text{EA}}/V_{PP}$

External Access Enable. $\overline{\text{EA}}$ must be strapped to GND in order to enable the device to fetch code from external program memory locations starting at 0000H up to FFFFH. Note, however, that if lock bit 1 is programmed, $\overline{\text{EA}}$ will be internally latched on reset.

$\overline{\text{EA}}$ should be strapped to V_{CC} for internal program executions.

This pin also receives the 12-volt programming enable voltage (V_{PP}) during Flash programming, for parts that require 12-volt V_{PP}.

XTAL1

Input to the inverting oscillator amplifier and input to the internal clock operating circuit.

XTAL2

Output from the inverting oscillator amplifier.

Oscillator Characteristics

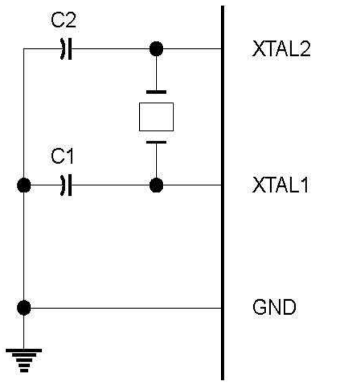
XTAL1 and XTAL2 are the input and output, respectively, of an inverting amplifier which can be configured for use as an on-chip oscillator, as shown in Figure 1. Either a quartz crystal or ceramic resonator may be used. To drive the device from an external clock source, XTAL2 should be left unconnected while XTAL1 is driven as shown in Figure 2. There are no requirements on the duty cycle of the external clock signal, since the input to the internal clocking circuitry is through a divide-by-two flip-flop, but minimum and maximum voltage high and low time specifications must be observed.

Idle Mode

In idle mode, the CPU puts itself to sleep while all the on-chip peripherals remain active. The mode is invoked by software. The content of the on-chip RAM and all the special functions registers remain unchanged during this mode. The idle mode can be terminated by any enabled interrupt or by a hardware reset.

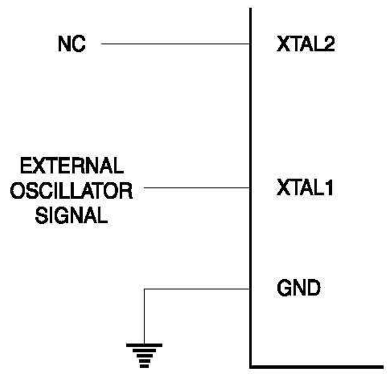
It should be noted that when idle is terminated by a hardware reset, the device normally resumes program execution, from where it left off, up to two machine cycles before the internal reset algorithm takes control. On-chip hard-

Figure 1. Oscillator Connections



Notes: C1, C2 = 30 pF ± 10 pF for Crystals
= 40 pF ± 10 pF for Ceramic Resonators

Figure 2. External Clock Drive Configuration



Status of External Pins During Idle and Power Down

Mode	Program Memory	ALE	$\overline{\text{PSEN}}$	PORT0	PORT1	PORT2	PORT3
Idle	Internal	1	1	Data	Data	Data	Data
Idle	External	1	1	Float	Data	Address	Data
Power Down	Internal	0	0	Data	Data	Data	Data
Power Down	External	0	0	Float	Data	Data	Data

Programming the Flash (Continued)

tempted read of the last byte written will result in the complement of the written datum on PO.7. Once the write cycle has been completed, true data are valid on all outputs, and the next cycle may begin. Data Polling may begin any time after a write cycle has been initiated.

Ready/Busy: The progress of byte programming can also be monitored by the RDY/BSY output signal. P3.4 is pulled low after ALE goes high during programming to indicate BUSY. P3.4 is pulled high again when programming is done to indicate READY.

Program Verify: If lock bits LB1 and LB2 have not been programmed, the programmed code data can be read back via the address and data lines for verification. The lock bits cannot be verified directly. Verification of the lock bits is achieved by observing that their features are enabled.

Chip Erase: The entire Flash array is erased electrically by using the proper combination of control signals and by holding ALE/PROG low for 10 ms. The code array is written with all "1"s. The chip erase operation must be executed before the code memory can be re-programmed.

Reading the Signature Bytes: The signature bytes are read by the same procedure as a normal verification of locations 030H,

031H, and 032H, except that P3.6 and P3.7 must be pulled to a logic low. The values returned are as follows.

(030H) = 1EH indicates manufactured by Atmel
(031H) = 51H indicates 89C51
(032H) = FFH indicates 12 V programming
(032H) = 05H indicates 5 V programming

Programming Interface

Every code byte in the Flash array can be written and the entire array can be erased by using the appropriate combination of control signals. The write operation cycle is self-timed and once initiated, will automatically time itself to completion.

All major programming vendors offer worldwide support for the Atmel microcontroller series. Please contact your local programming vendor for the appropriate software revision.

Flash Programming Modes

Mode		RST	PSEN	ALE/ PROG	EA/ VPP	P2.6	P2.7	P3.6	P3.7
Write Code Data		H	L	⌴	H/12V(1)	L	H	H	H
Read Code Data		H	L	H	H	L	L	H	H
Write Lock	Bit - 1	H	L	⌴	H/12V	H	H	H	H
	Bit - 2	H	L	⌴ (2)	H/12V	H	H	L	L
	Bit - 3	H	L	⌴	H/12V	H	L	H	L
Chip Erase		H	L	⌴	H/12V	H	L	L	L
Read Signature Byte		H	L	H	H	L	L	L	L

Notes: 1. The signature byte at location 032H designates whether V_{PP} = 12 V or V_{PP} = 5 V should be used to enable programming.
2. Chip Erase requires a 10 ms PROG pulse.

Figure 3. Programming the Flash

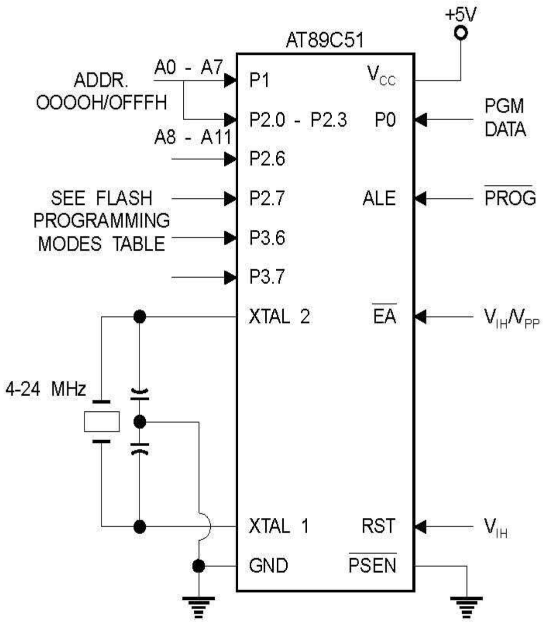
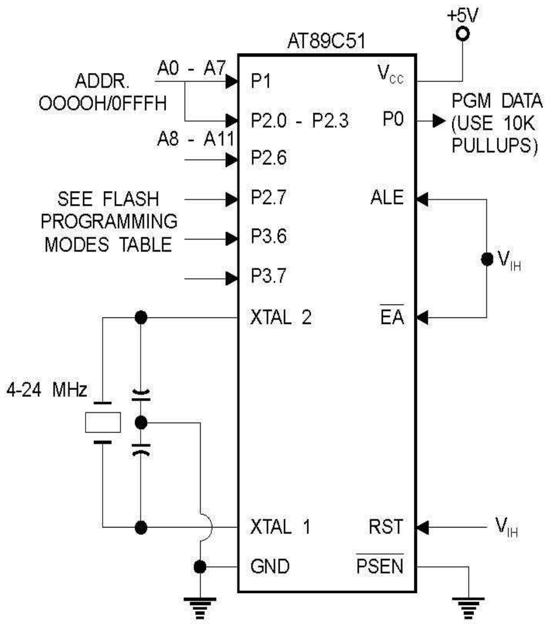


Figure 4. Verifying the Flash



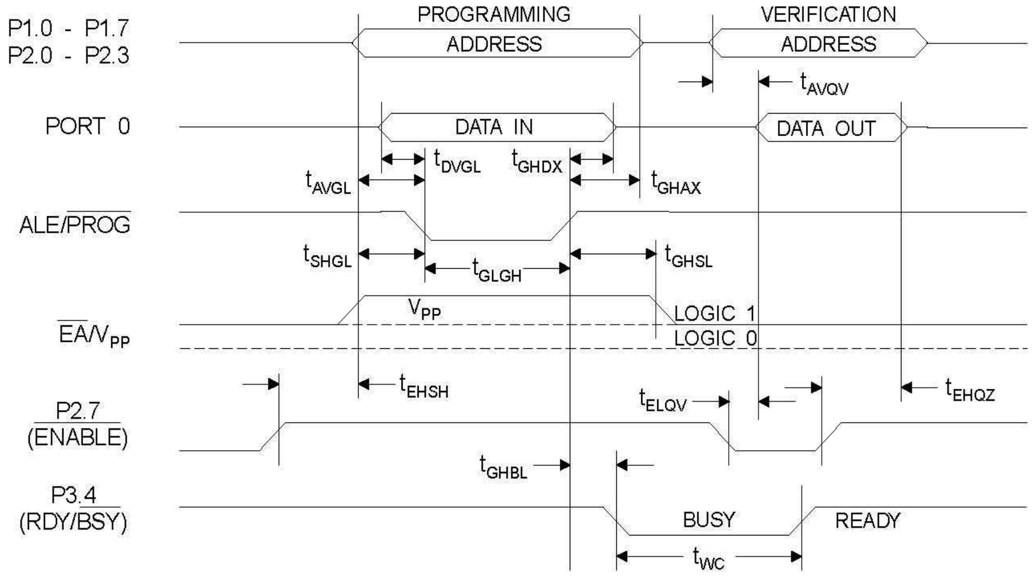
Flash Programming and Verification Characteristics

T_A = 21°C to 27°C, V_{CC} = 5.0 ± 10%

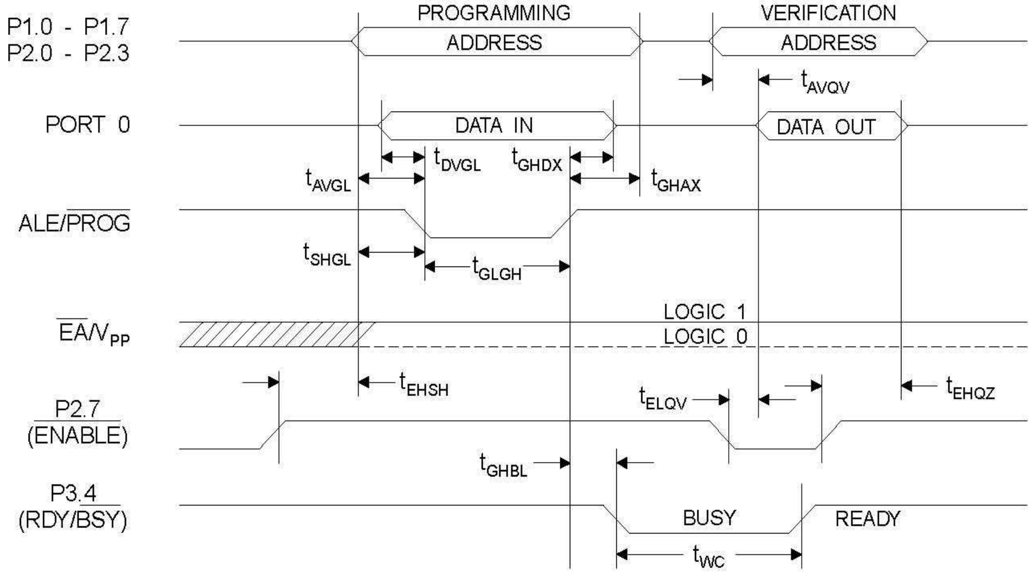
Symbol	Parameter	Min	Max	Units
V_{PP}(1)	Programming Enable Voltage	11.5	12.5	V
I_{PP}(1)	Programming Enable Current		1.0	mA
$1/t_{CLCL}$	Oscillator Frequency	4	24	MHz
t_{AVGL}	Address Setup to $\overline{PROG}$ Low	$48t_{CLCL}$		
t_{GHAX}	Address Hold After $\overline{PROG}$	$48t_{CLCL}$		
t_{DVGL}	Data Setup to $\overline{PROG}$ Low	$48t_{CLCL}$		
t_{GHDX}	Data Hold After $\overline{PROG}$	$48t_{CLCL}$		
t_{EHSH}	P2.7 (ENABLE) High to V_{PP}	48tCLCL		
t_{SHGL}	V_{PP} Setup to $\overline{PROG}$ Low	10		µs
t_{GHSL}(1)	V_{PP} Hold After $\overline{PROG}$	10		µs
t_{GLGH}	$\overline{PROG}$ Width	1	110	µs
t_{AVQV}	Address to Data Valid		48tCLCL	
t_{ELQV}	$\overline{ENABLE}$ Low to Data Valid		$48t_{CLCL}$	
t_{EHQV}	Data Float After $\overline{ENABLE}$	0	$48t_{CLCL}$	
t_{GHBL}	$\overline{PROG}$ High to $\overline{BUSY}$ Low		1.0	µs
t_{WC}	Byte Write Cycle Time		2.0	ms

Note: 1. Only used in 12-volt programming mode.

Flash Programming and Verification Waveforms - High Voltage Mode



Flash Programming and Verification Waveforms - Low Voltage Mode



Absolute Maximum Ratings*

Operating Temperature	-55°C to +125°C
Storage Temperature	-65°C to +150°C
Voltage on Any Pin with Respect to Ground	-1.0 V to +7.0 V
Maximum Operating Voltage	6.6 V
DC Output Current	15.0 mA

*NOTICE: Stresses beyond those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. This is a stress rating only and functional operation of the device at these or any other conditions beyond those indicated in the operational sections of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

D.C. Characteristics

T_A = -40°C to 85°C, V_{CC} = 5.0 V ± 20% (unless otherwise noted)

Symbol	Parameter	Condition	Min	Max	Units
V_{IL}	Input Low Voltage	(Except $\overline{EA}$)	-0.5	0.2 V_{CC}-0.1	V
V_{IL1}	Input Low Voltage ($\overline{EA}$)		-0.5	0.2 V_{CC}-0.3	V
V_{IH}	Input High Voltage	(Except XTAL1, RST)	0.2 V_{CC}+0.9	V_{CC}+0.5	V
V_{IH1}	Input High Voltage	(XTAL1, RST)	0.7 V_{CC}	V_{CC}+0.5	V
V_{OL}	Output Low Voltage(1) (Ports 1,2,3)	I_{OL} = 1.6 mA		0.45	V
V_{OL1}	Output Low Voltage(1) (Port 0, ALE, $\overline{PSEN}$)	I_{OL} = 3.2 mA		0.45	V
V_{OH}	Output High Voltage (Ports 1,2,3, ALE, $\overline{PSEN}$)	I_{OH} = -60 µA, V_{CC} = 5 V ± 10%	2.4		V
		I_{OH} = -25 µA	0.75 V_{CC}		V
		I_{OH} = -10 µA	0.9 V_{CC}		V
V_{OH1}	Output High Voltage (Port 0 in External Bus Mode)	I_{OH} = -800 µA, V_{CC} = 5 V ± 10%	2.4		V
		I_{OH} = -300 µA	0.75 V_{CC}		V
		I_{OH} = -80 µA	0.9 V_{CC}		V
I_{IL}	Logical 0 Input Current (Ports 1,2,3)	V_{IN} = 0.45 V		-50	µA
I_{TL}	Logical 1 to 0 Transition Current (Ports 1,2,3)	V_{IN} = 2 V		-650	µA
I_{LI}	Input Leakage Current (Port 0, $\overline{EA}$)	0.45 < V_{IN} < V_{CC}		±10	µA
RRST	Reset Pulldown Resistor		50	300	KΩ
C_{IO}	Pin Capacitance	Test Freq. = 1 MHz, T_A = 25°C		10	pF
I_{CC}	Power Supply Current	Active Mode, 12 MHz		20	mA
		Idle Mode, 12 MHz		5	mA
	Power Down Mode(2)	V_{CC} = 6 V		100	µA
		V_{CC} = 3 V		40	µA

Notes: 1. Under steady state (non-transient) conditions, I_{OL} must be externally limited as follows:
Maximum I_{OL} per port pin: 10 mA
Maximum I_{OL} per 8-bit port:
Port 0: 26 mA
Ports 1,2, 3: 15 mA
Maximum total IOL for all output pins: 71 mA
If IOL exceeds the test condition, VOL may exceed the related specification. Pins are not guaranteed to sink current greater than the listed test conditions.
2. Minimum VCC for Power Down is 2 V.

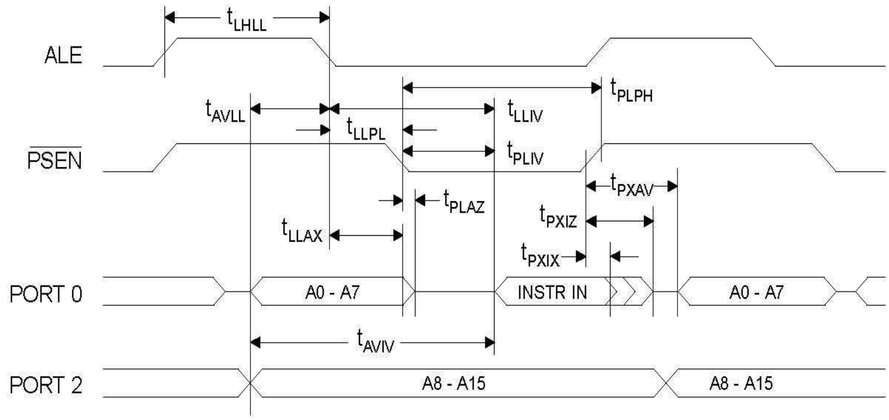
A.C. Characteristics

(Under Operating Conditions; Load Capacitance for Port 0, ALE/$\overline{PROG}$, and $\overline{PSEN}$ = 100 pF; Load Capacitance for all other outputs = 80 pF)

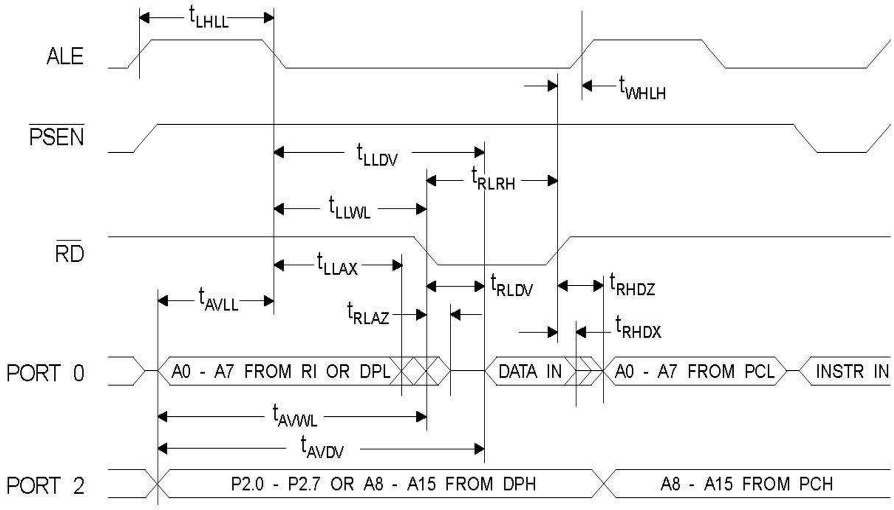
External Program and Data Memory Characteristics

Symbol	Parameter	12 MHz Oscillator Min	12 MHz Oscillator Max	16 to 24 MHz Oscillator Min	16 to 24 MHz Oscillator Max	Units
$1/t_{CLCL}$	Oscillator Frequency			0	24	MHz
t_{LHLL}	ALE Pulse Width	127		$2t_{CLCL}$-40		ns
t_{AVLL}	Address Valid to ALE Low	28		tCLCL-13		ns
t_{LLAX}	Address Hold After ALE Low	48		tCLCL-20		ns
t_{LLIV}	ALE Low to Valid Instruction In		233		4tCLCL-65	ns
t_{LLPL}	ALE Low to $\overline{PSEN}$ Low	43		t_{CLCL}-13		ns
t_{PLPH}	$\overline{PSEN}$ Pulse Width	205		$3t_{CLCL}$-20		ns
t_{PLIV}	$\overline{PSEN}$ Low to Valid Instruction In		145		$3t_{CLCL}$-45	ns
t_{PXIX}	Input Instruction Hold After $\overline{PSEN}$	0		0		ns
t_{PXIZ}	Input Instruction Float After $\overline{PSEN}$		59		t_{CLCL}-10	ns
t_{PXAV}	$\overline{PSEN}$ to Address Valid	75		t_{CLCL}-8		ns
t_{AVIV}	Address to Valid Instruction In		312		$5t_{CLCL}$-55	ns
t_{PLAZ}	$\overline{PSEN}$ Low to Address Float		10		10	ns
t_{RLRH}	$\overline{RD}$ Pulse Width	400		$6t_{CLCL}$-100		ns
t_{WLWH}	$\overline{WR}$ Pulse Width	400		$6t_{CLCL}$-100		ns
t_{RLDV}	$\overline{RD}$ Low to Valid Data In		252		$5t_{CLCL}$-90	ns
t_{RHDX}	Data Hold After $\overline{RD}$	0		0		ns
t_{RHDZ}	Data Float After $\overline{RD}$		97		$2t_{CLCL}$-28	ns
t_{LLDV}	ALE Low to Valid Data In		517		8tCLCL-150	ns
t_{AVDV}	Address to Valid Data In		585		9tCLCL-165	ns
t_{LLWL}	ALE Low to $\overline{RD}$ or $\overline{WR}$ Low	200	300	$3t_{CLCL}$-50	$3t_{CLCL}$+50	ns
t_{AVWL}	Address to $\overline{RD}$ or $\overline{WR}$ Low	203		$4t_{CLCL}$-75		ns
t_{QVWX}	Data Valid to $\overline{WR}$ Transition	23		t_{CLCL}-20		ns
t_{QVWH}	Data Valid to $\overline{WR}$ High	433		$7t_{CLCL}$-120		ns
t_{WHQX}	Data Hold After $\overline{WR}$	33		t_{CLCL}-20		ns
t_{RLAZ}	$\overline{RD}$ Low to Address Float		0		0	ns
t_{WHLH}	$\overline{RD}$ or $\overline{WR}$ High to ALE High	43	123	t_{CLCL}-20	t_{CLCL}+25	ns

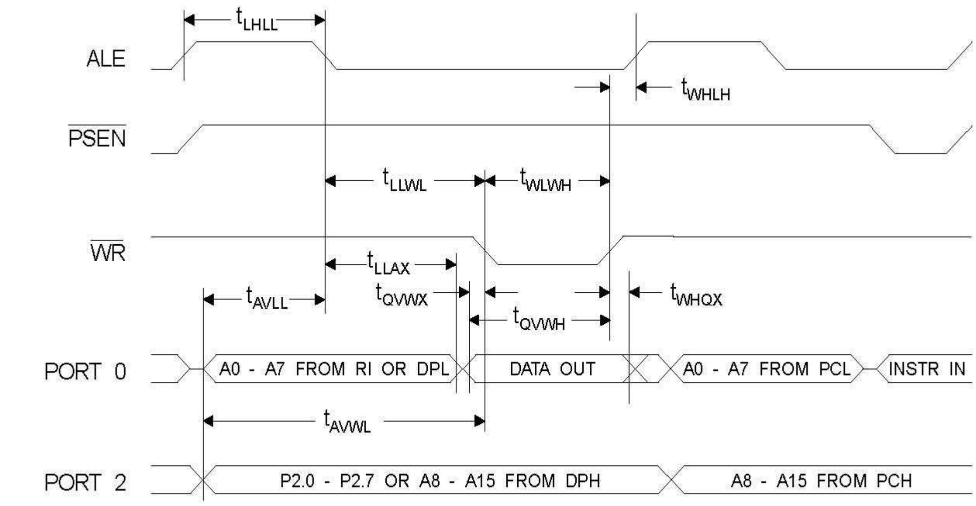
External Program Memory Read Cycle



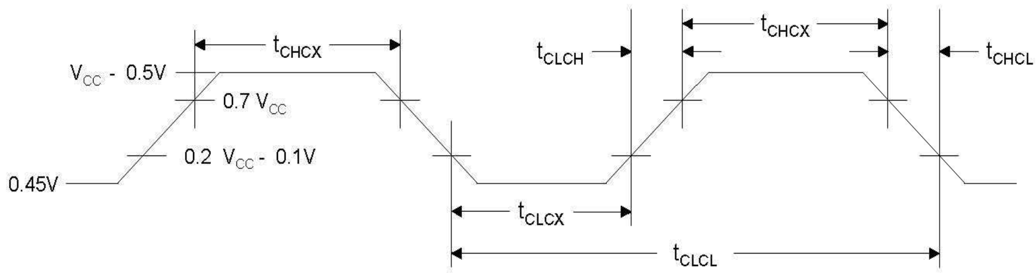
External Data Memory Read Cycle



External Data Memory Cycle



External Clock Drive Waveforms



External Clock Drive

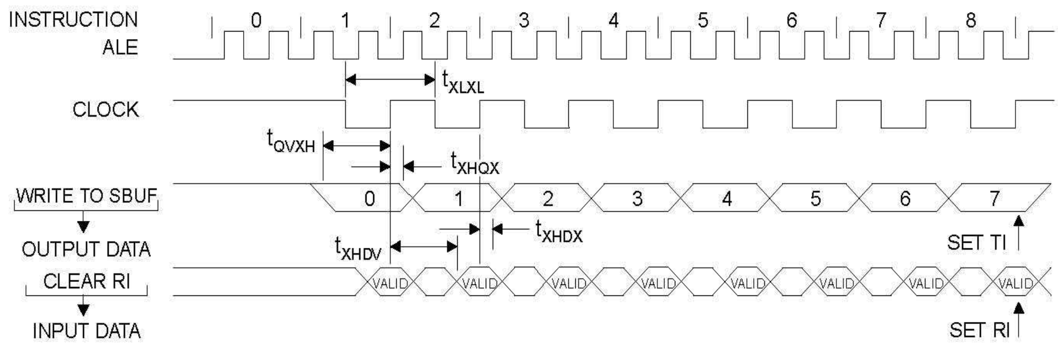
Symbol	Parameter	Min	Max	Units
$1/t_{CLCL}$	Oscillator Frequency	0	24	MHz
t_{CLCL}	Clock Period	41.6		ns
t_{CHCX}	High Time	15		ns
t_{CLCX}	Low Time	15		ns
t_{CLCH}	Rise Time		20	ns
t_{CHCL}	Fall Time		20	ns

Serial Port Timing: Shift Register Mode Test Conditions

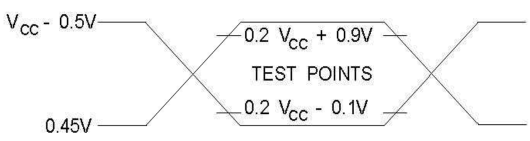
(V_{CC} = 5.0 V ± 20%; Load Capacitance = 80 pF)

Symbol	Parameter	12 MHz Osc Min	12 MHz Osc Max	Variable Oscillator Min	Variable Oscillator Max	Units
t_{XLXL}	Serial Port Clock Cycle Time	1.0		$12t_{CLCL}$		µs
t_{QVXH}	Output Data Setup to Clock Rising Edge	700		$10t_{CLCL}$-133		ns
t_{XHQX}	Output Data Hold After Clock Rising Edge	50		$2t_{CLCL}$-33		ns
t_{XHDX}	Input Data Hold After Clock Rising Edge	0		0		ns
t_{XHDV}	Clock Rising Edge to Input Data Valid		700		10tCLCL-133	ns

Shift Register Mode Timing Waveforms

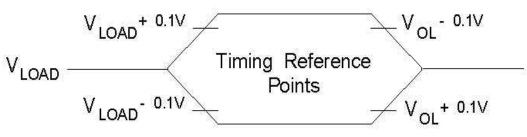


AC Testing Input/Output Waveforms [(1)]



Note: 1. AC Inputs during testing are driven at V_{CC} - 0.5 V for a logic 1 and 0.45 V for a logic 0. Timing measurements are made at V_{IH} min. for a logic 1 and V_{IL} max. for a logic 0.

Float Waveforms [(1)]



Note: 1. For timing purposes, a port pin is no longer floating when a 100 mV change from load voltage occurs. A port pin begins to float when a 100 mV change from the loaded V_{OH}/V_{OL} level occurs.

Ordering Information

Speed (MHz)	Power Supply	Ordering Code	Package	Operation Range
12	5 V ± 20%	AT89C51-12AC AT89C51-12JC AT89C51-12PC AT89C51-12QC	44A 44J 40P6 44Q	Commercial (0°C to 70°C)
		AT89C51-12AI AT89C51-12JI AT89C51-12PI AT89C51-12QI	44A 44J 40P6 44Q	Industrial (-40°C to 85°C)
		AT89C51-12AA AT89C51-12JA AT89C51-12PA AT89C51-12QA	44A 44J 40P6 44Q	Automotive (-40°C to 125°C)
	5 V ± 10%	AT89C51-12DM AT89C51-12LM	40D6 44L	Military (-55°C to 125°C)
		AT89C51-12DM/883 AT89C51-12LM/883	40D6 44L	Military/883C Class B, Fully Compliant (-55°C to 125°C)
16	5 V ± 20%	AT89C51-16AC AT89C51-16JC AT89C51-16PC AT89C51-16QC	44A 44J 40P6 44Q	Commercial (0°C to 70°C)
		AT89C51-16AI AT89C51-16JI AT89C51-16PI AT89C51-16QI	44A 44J 40P6 44Q	Industrial (-40°C to 85°C)
		AT89C51-16AA AT89C51-16JA AT89C51-16PA AT89C51-16QA	44A 44J 40P6 44Q	Automotive (-40°C to 125°C)
20	5 V ± 20%	AT89C51-20AC AT89C51-20JC AT89C51-20PC AT89C51-20QC	44A 44J 40P6 44Q	Commercial (0°C to 70°C)
		AT89C51-20AI AT89C51-20JI AT89C51-20PI AT89C51-20QI	44A 44J 40P6 44Q	Industrial (-40°C to 85°C)

۱- www.Atmel.Com

۲- www.Vaultbbs.Com

۳- www.electronic.Com

۴- www.Labcenter.Com

۵- www.fsinc.Com

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