INTERFACING TO ADC AND SENSORS

ADC Devices

- ADCs (analog-to-digital converters) are among the most widely used devices for data acquisition
  - A physical quantity, like temperature, pressure, humidity, and velocity, etc., is converted to electrical (voltage, current) signals using a device called a *transducer*, or *sensor*
- We need an analog-to-digital converter to translate the analog signals to digital numbers, so microcontroller can read them

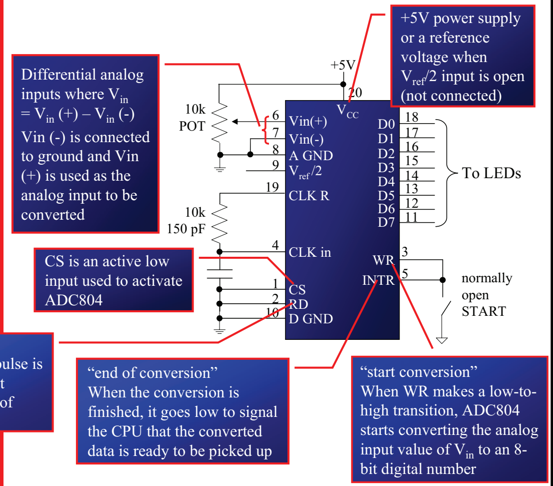
INTERFACING TO ADC AND SENSORS

ADC804 Chip

- ADC804 IC is an analog-to-digital converter
  - It works with +5 volts and has a resolution of 8 bits
  - *Conversion time* is another major factor in judging an ADC
    - Conversion time is defined as the time it takes the ADC to convert the analog input to a digital (binary) number
    - In ADC804 conversion time varies depending on the clocking signals applied to CLK R and CLK IN pins, but it cannot be faster than 110 μs

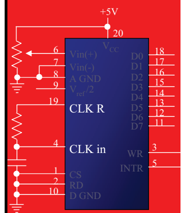
INTERFACING TO ADC AND SENSORS

ADC804 Chip (cont')



INTERFACING TO ADC AND SENSORS

ADC804 Chip (cont')



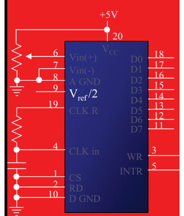
- CLK IN and CLK R
  - CLK IN is an input pin connected to an external clock source
  - To use the internal clock generator (also called self-clocking), CLK IN and CLK R pins are connected to a capacitor and a resistor, and the clock frequency is determined by

$$f = \frac{1}{1.1\,RC}$$

    - Typical values are R = 10K ohms and C = 150 pF
    - We get f = 606 kHz and the conversion time is 110 μs

INTERFACING TO ADC AND SENSORS

ADC804 Chip (cont')



- $V_{ref}/2$
  - It is used for the reference voltage
    - If this pin is open (not connected), the analog input voltage is in the range of 0 to 5 volts (the same as the Vcc pin)
    - If the analog input range needs to be 0 to 4 volts, $V_{ref}/2$ is connected to 2 volts

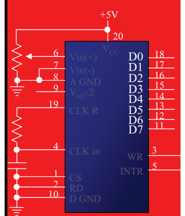
$V_{ref}/2$ Relation to V_{in} Range

$V_{ref}/2$(V)	V_{in}(V)	Step Size (mV)
Not connected*	0 to 5	5/256=19.53
2.0	0 to 4	4/255=15.62
1.5	0 to 3	3/256=11.71
1.28	0 to 2.56	2.56/256=10
1.0	0 to 2	2/256=7.81
0.5	0 to 1	1/256=3.90

Step size is the smallest change can be discerned by an ADC

INTERFACING TO ADC AND SENSORS

ADC804 Chip (cont')



- D0-D7
  - The digital data output pins
  - These are tri-state buffered
    - The converted data is accessed only when CS = 0 and RD is forced low
  - To calculate the output voltage, use the following formula

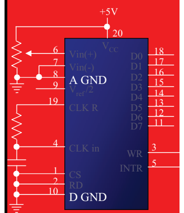
$$D_{out} = \frac{V_{in}}{step\ size}$$

    - *Dout* = digital data output (in decimal),
    - *Vin* = analog voltage, and
    - *step size* (resolution) is the smallest change

INTERFACING TO ADC AND SENSORS

ADC804 Chip (cont')

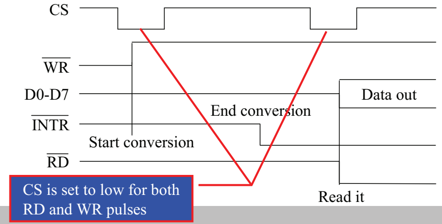
- Analog ground and digital ground
  - Analog ground is connected to the ground of the analog V_{in}
  - Digital ground is connected to the ground of the V_{cc} pin
- To isolate the analog V_{in} signal from transient voltages caused by digital switching of the output D0 – D7
  - This contributes to the accuracy of the digital data output



INTERFACING TO ADC AND SENSORS

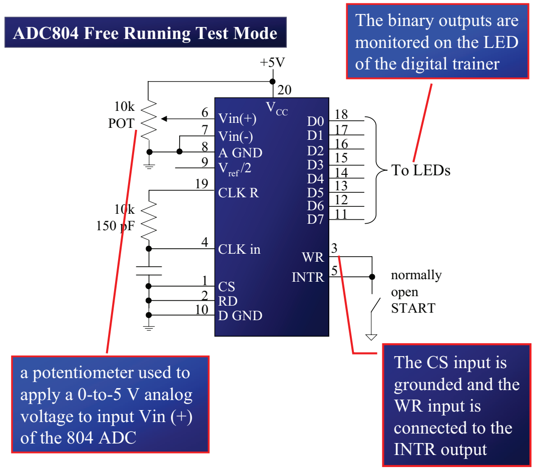
ADC804 Chip (cont')

- The following steps must be followed for data conversion by the ADC804 chip
  - Make CS = 0 and send a low-to-high pulse to pin WR to start conversion
  - Keep monitoring the INTR pin
    - If INTR is low, the conversion is finished
    - If the INTR is high, keep polling until it goes low
  - After the INTR has become low, we make CS = 0 and send a high-to-low pulse to the RD pin to get the data out of the ADC804



INTERFACING TO ADC AND SENSORS

Testing ADC804



INTERFACING TO ADC AND SENSORS

Testing ADC804 (cont')

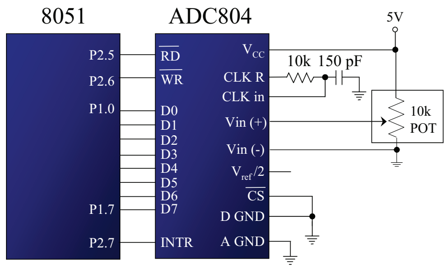
Examine the ADC804 connection to the 8051 in Figure 12-7. Write a program to monitor the INTR pin and bring an analog input into register A. Then call a hex-to ACSII conversion and data display subroutines. Do this continuously.

```
;p2.6=WR (start conversion needs to L-to-H pulse)
;p2.7 When low, end-of-conversion)
;p2.5=RD (a H-to-L will read the data from ADC chip)
;p1.0 – P1.7= D0 - D7 of the ADC804
;
      MOV   P1,#0FFH      ;make P1 = input
BACK: CLR   P2.6          ;WR = 0
      SETB  P2.6          ;WR = 1 L-to-H to start conversion
HERE: JB    P2.7,HERE     ;wait for end of conversion
      CLR   P2.5          ;conversion finished, enable RD
      MOV   A,P1          ;read the data
      ACALL CONVERSION    ;hex-to-ASCII conversion
      ACALL DATA_DISPLAY;display the data
      SETB  p2.5          ;make RD=1 for next round
      SJMP  BACK
```

INTERFACING TO ADC AND SENSORS

Testing ADC804 (cont')

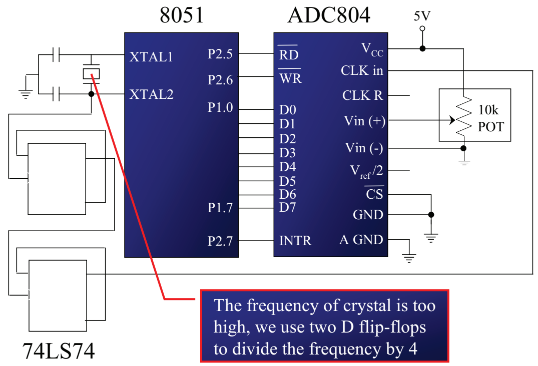
8051 Connection to ADC804 with Self-Clocking



INTERFACING TO ADC AND SENSORS

ADC804 Clock from 8051 XTAL2

8051 Connection to ADC804 with Clock from XTAL2 of 8051



INTERFACING TO ADC AND SENSORS

Interfacing Temperature Sensor

- A *thermistor* responds to temperature change by changing resistance, but its response is not linear
- The complexity associated with writing software for such nonlinear devices has led many manufacturers to market the linear temperature sensor

Temperature (C)	Tf (K ohms)
0	29.490
25	10.000
50	3.893
75	1.700
100	0.817

From William Kleitz, digital Electronics

INTERFACING TO ADC AND SENSORS

LM34 and LM35 Temperature Sensors

- The sensors of the LM34/LM35 series are precision integrated-circuit temperature sensors whose output voltage is linearly proportional to the Fahrenheit/Celsius temperature
  - The LM34/LM35 requires no external calibration since it is inherently calibrated
  - It outputs 10 mV for each degree of Fahrenheit/Celsius temperature

INTERFACING TO ADC AND SENSORS

Signal Conditioning and Interfacing LM35

- *Signal conditioning* is a widely used term in the world of data acquisition
  - It is the conversion of the signals (voltage, current, charge, capacitance, and resistance) produced by transducers to voltage, which is sent to the input of an A-to-D converter
- Signal conditioning can be a current-to-voltage conversion or a signal amplification
  - The thermistor changes resistance with temperature, while the change of resistance must be translated into voltage in order to be of any use to an ADC

INTERFACING TO ADC AND SENSORS

Signal Conditioning and Interfacing LM35 (cont')

Getting Data From the Analog World

Analog world (temperature, pressure, etc.)
↓
Transducer
↓
Signal conditioning
↓
ADC
↓
Microcontroller

INTERFACING TO ADC AND SENSORS

Signal Conditioning and Interfacing LM35 (cont')

Example:

Look at the case of connecting an LM35 to an ADC804. Since the ADC804 has 8-bit resolution with a maximum of 256 steps and the LM35 (or LM34) produces 10 mV for every degree of temperature change, we can condition Vin of the ADC804 to produce a Vout of 2560 mV full-scale output. Therefore, in order to produce the full-scale Vout of 2.56 V for the ADC804, We need to set Vref/2 = 1.28. This makes Vout of the ADC804 correspond directly to the temperature as monitored by the LM35.

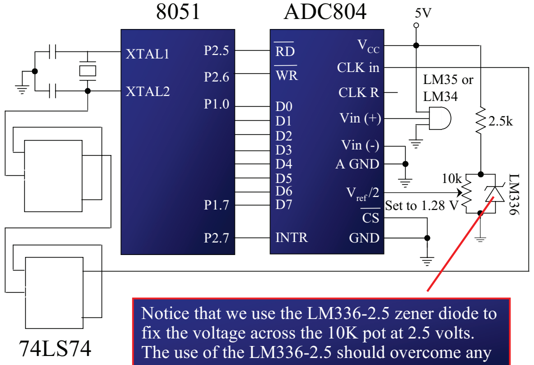
Temperature vs. Vout of the ADC804

Temp. (C)	Vin (mV)	Vout (D7 – D0)
0	0	0000 0000
1	10	0000 0001
2	20	0000 0010
3	30	0000 0011
10	100	0000 1010
30	300	0001 1110

INTERFACING TO ADC AND SENSORS

Signal Conditioning and Interfacing LM35 (cont')

8051 Connection to ADC804 and Temperature Sensor



Notice that we use the LM336-2.5 zener diode to fix the voltage across the 10K pot at 2.5 volts. The use of the LM336-2.5 should overcome any fluctuations in the power supply

INTERFACING TO ADC AND SENSORS

ADC808/809 Chip

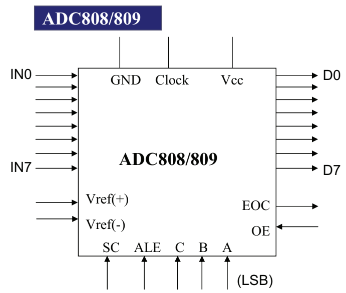
- ADC808 has 8 analog inputs
  - It allows us to monitor up to 8 different transducers using only a single chip
  - The chip has 8-bit data output just like the ADC804
  - The 8 analog input channels are multiplexed and selected according to table below using three address pins, A, B, and C

ADC808 Analog Channel Selection

Selected Analog Channel	C	B	A
IN0	0	0	0
IN1	0	0	1
IN2	0	1	0
IN3	0	1	1
IN4	1	0	0
IN5	1	0	1
IN6	1	1	0
IN7	1	1	1

INTERFACING TO ADC AND SENSORS

ADC808/809 Chip (cont')



INTERFACING TO ADC AND SENSORS

Steps to Program ADC808/809

1. Select an analog channel by providing bits to A, B, and C addresses
2. Activate the ALE pin
   - It needs an L-to-H pulse to latch in the address
3. Activate SC (start conversion) by an H-to-L pulse to initiate conversion
4. Monitor EOC (end of conversion) to see whether conversion is finished
5. Activate OE (output enable) to read data out of the ADC chip
   - An H-to-L pulse to the OE pin will bring digital data out of the chip