Contents

- **ADC**
- **DAC**

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

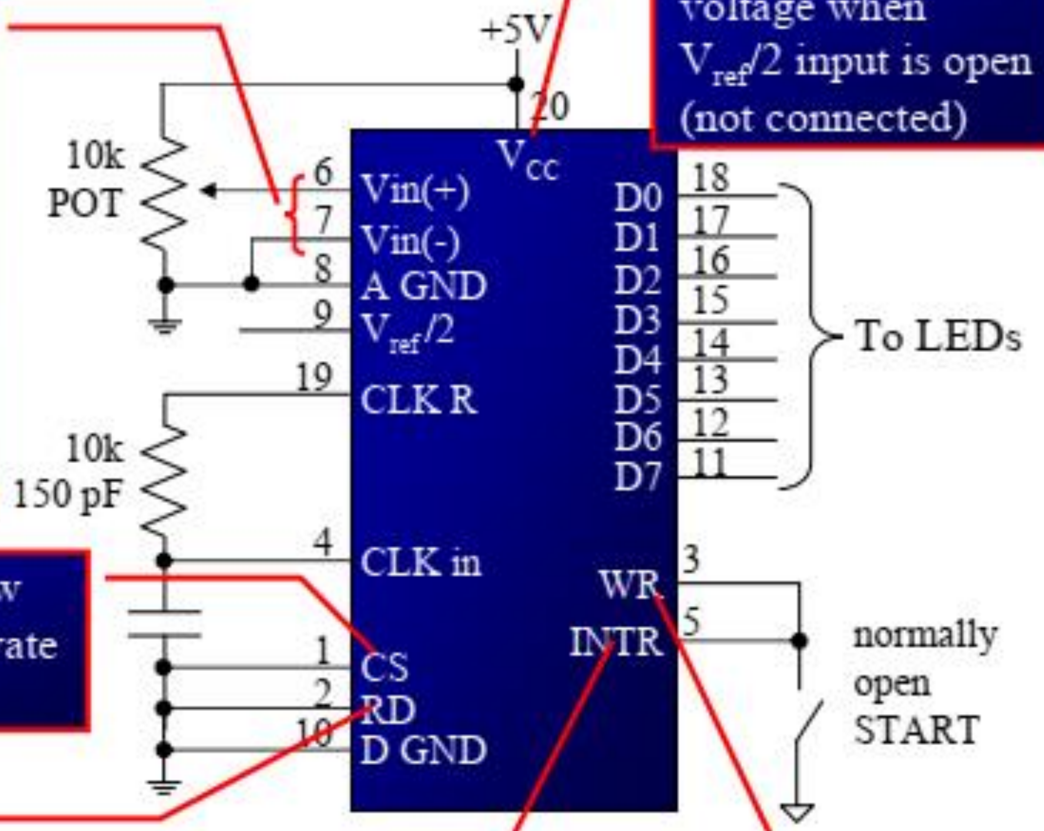
- ADC804 IC is an analog-to-digital converter
  - It works with +5 volts and has a resolution of 8 bits
  - *Conversion time* is another major factor in judging an ADC
    - Conversion time is defined as the time it takes the ADC to convert the analog input to a digital (binary) number
    - In ADC804 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')

Differential analog inputs where $V_{in} = V_{in}(+) - V_{in}(-)$
Vin (-) is connected to ground and Vin (+) is used as the analog input to be converted

+5V power supply or a reference voltage when $V_{ref}/2$ input is open (not connected)

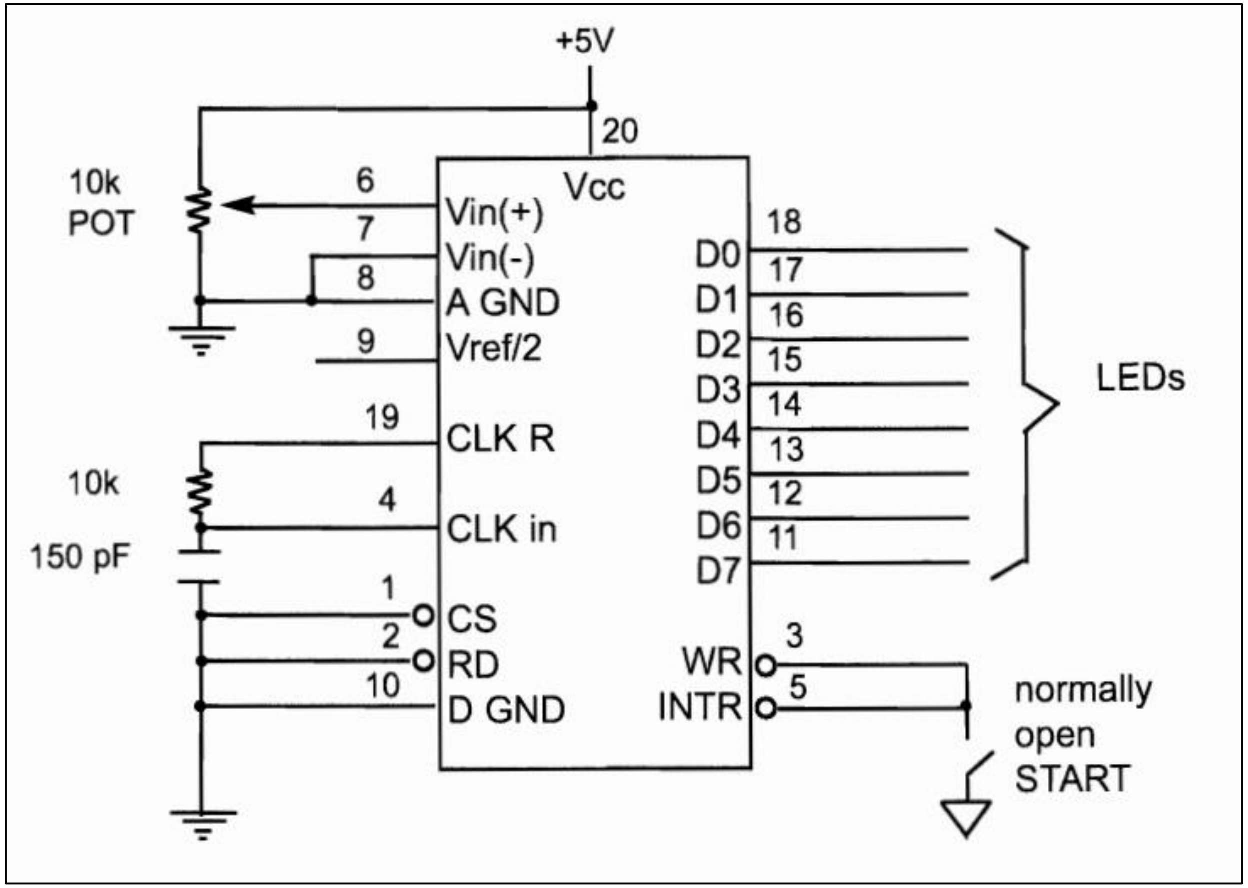


CS is an active low input used to activate ADC804

"output enable"
a high-to-low RD pulse is used to get the 8-bit converted data out of ADC804

"end of conversion"
When the conversion is finished, it goes low to signal the CPU that the converted data is ready to be picked up

"start conversion"
When WR makes a low-to-high transition, ADC804 starts converting the analog input value of V_{in} to an 8-bit digital number



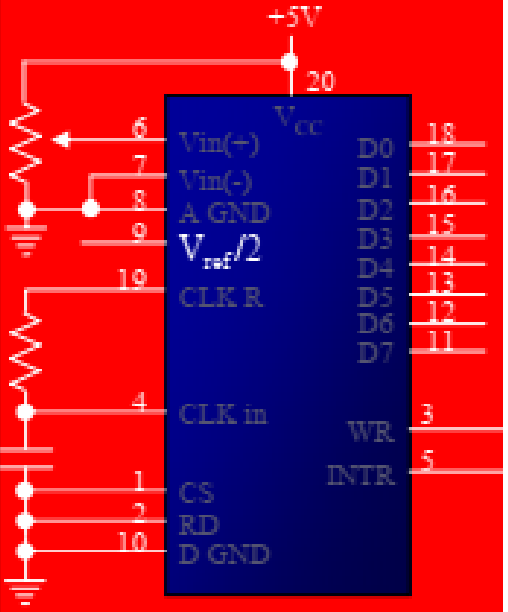
- CLK IN and CLK R
  - CLK IN is an input pin connected to an external clock source
  - To use the internal clock generator (also called self-clocking), CLK IN and CLK R pins are connected to a capacitor and a resistor, and the clock frequency is determined by

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

    - 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

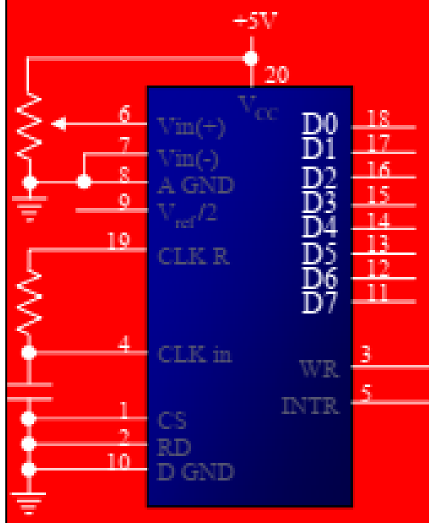
$V_{ref}/2$ Relation to V_{in} Range

$V_{ref}/2$(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

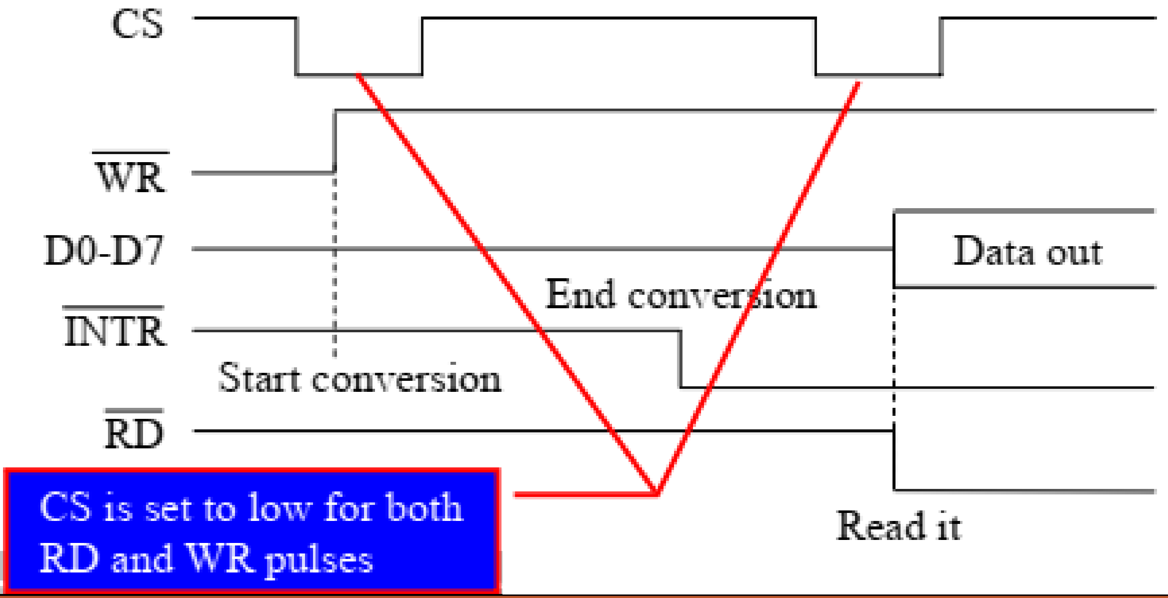
$$D_{out} = \frac{V_{in}}{step\ size}$$

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

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

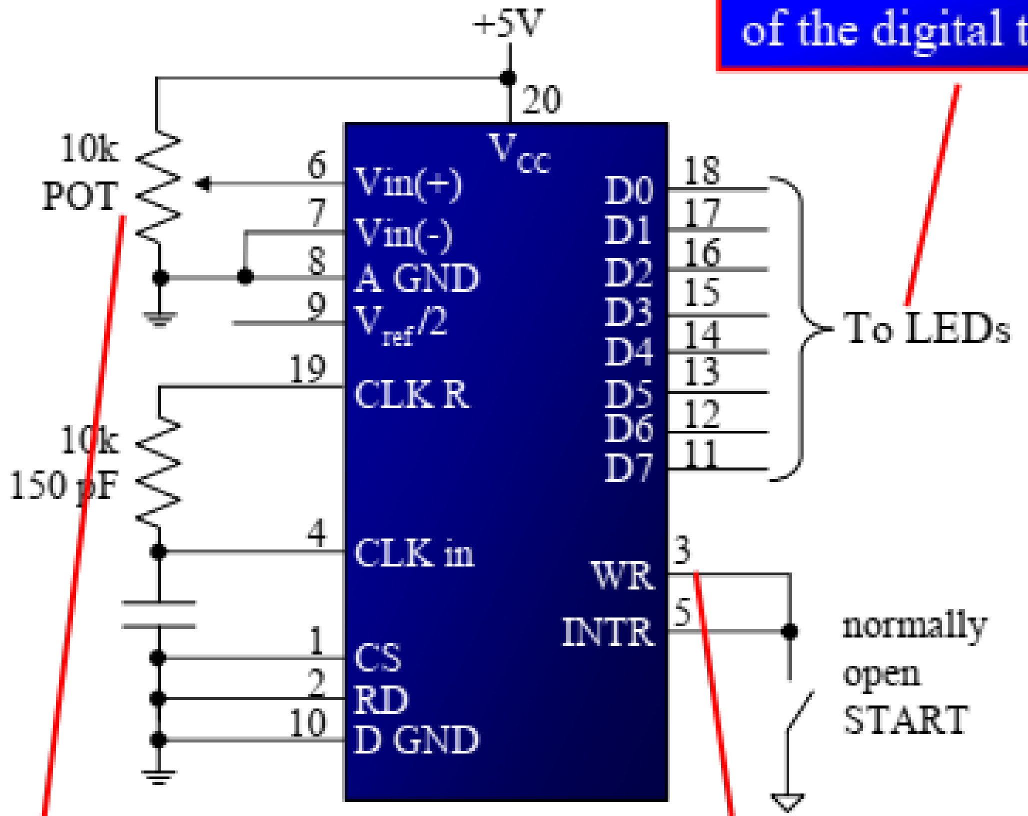


INTERFACING TO ADC AND SENSORS

Testing ADC804

ADC804 Free Running Test Mode

The binary outputs are monitored on the LED of the digital trainer



a potentiometer used to apply a 0-to-5 V analog voltage to input Vin (+) of the 804 ADC

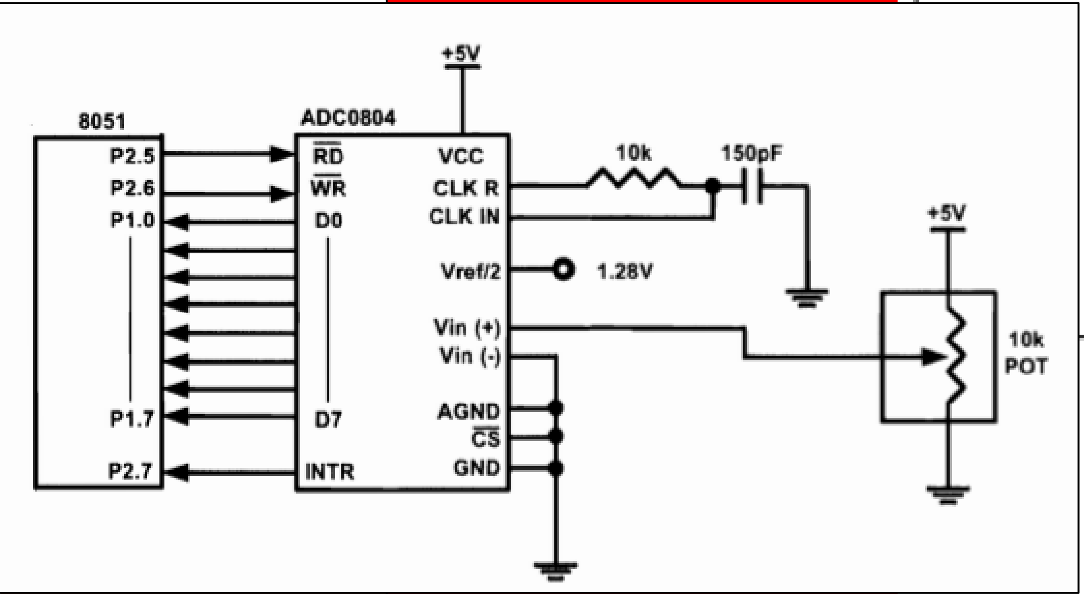
The CS input is grounded and the WR input is connected to the INTR output

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.

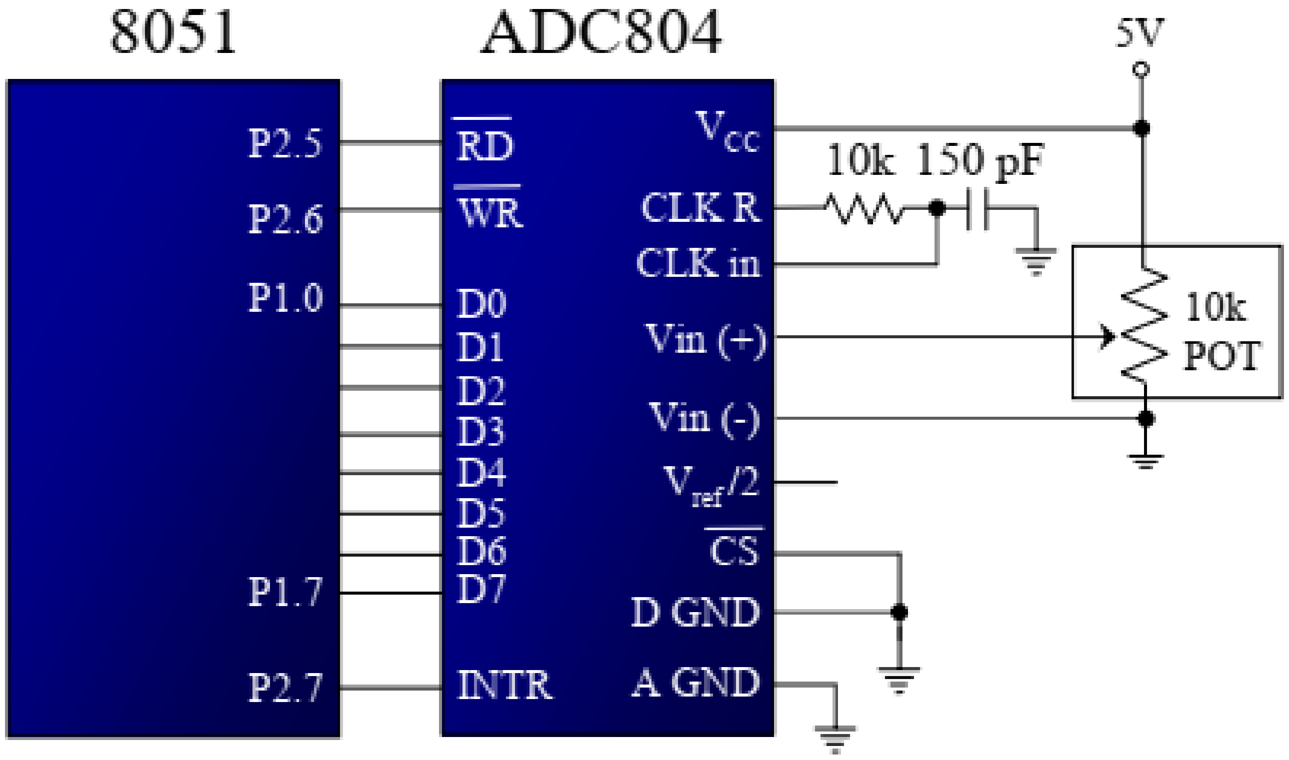
```
;p2.6=WR (start conversion needs to L-to-H pulse)
;p2.7 When low, end-of-conversion)
;p2.5=RD (a H-to-L will read the data from ADC chip)
;p1.0 – P1.7= D0 – D7 of the ADC804
;
       MOV    P1,#0FFH      ;make P1 = input
BACK:  CLR    P2.6          ;WR = 0
       SETB   P2.6          ;WR = 1 L-to-H 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

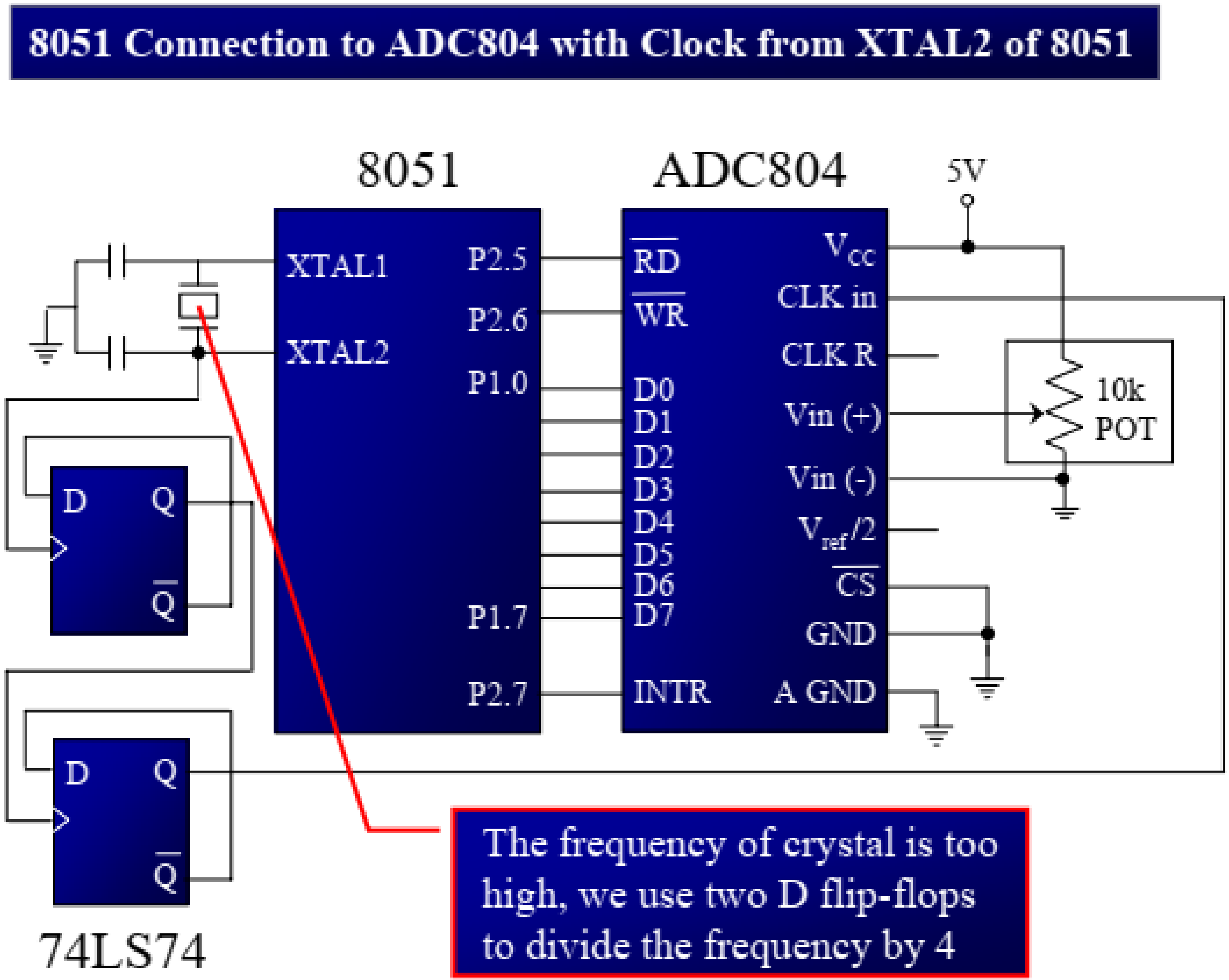
Testing ADC804 (cont')

8051 Connection to ADC804 with Self-Clocking



INTERFACING TO ADC AND SENSORS

ADC804 Clock from 8051 XTAL2



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

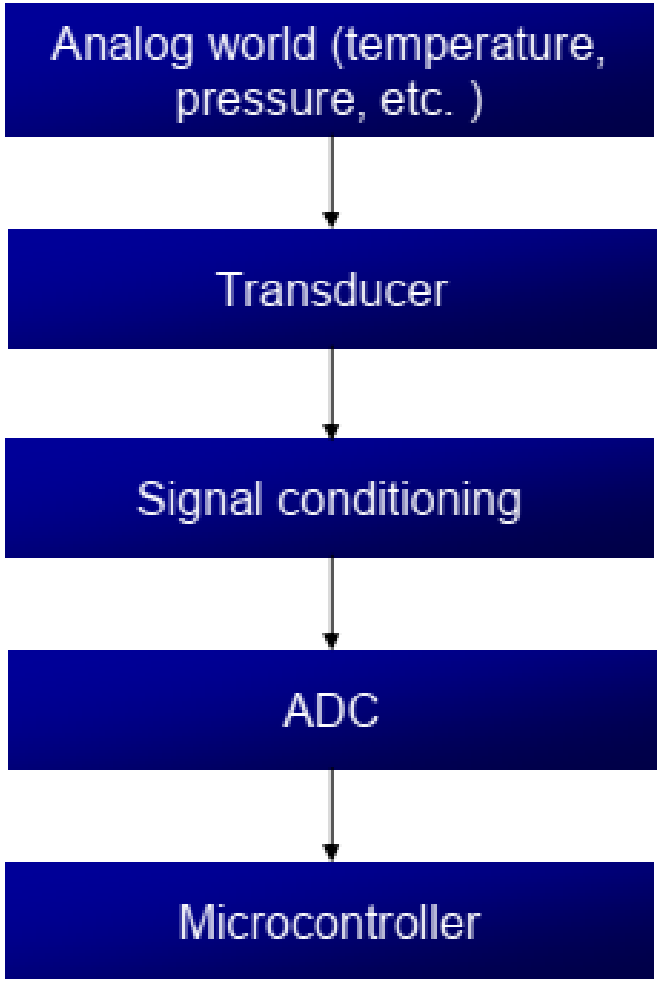
Signal Conditioning and Interfacing LM35

- *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



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.

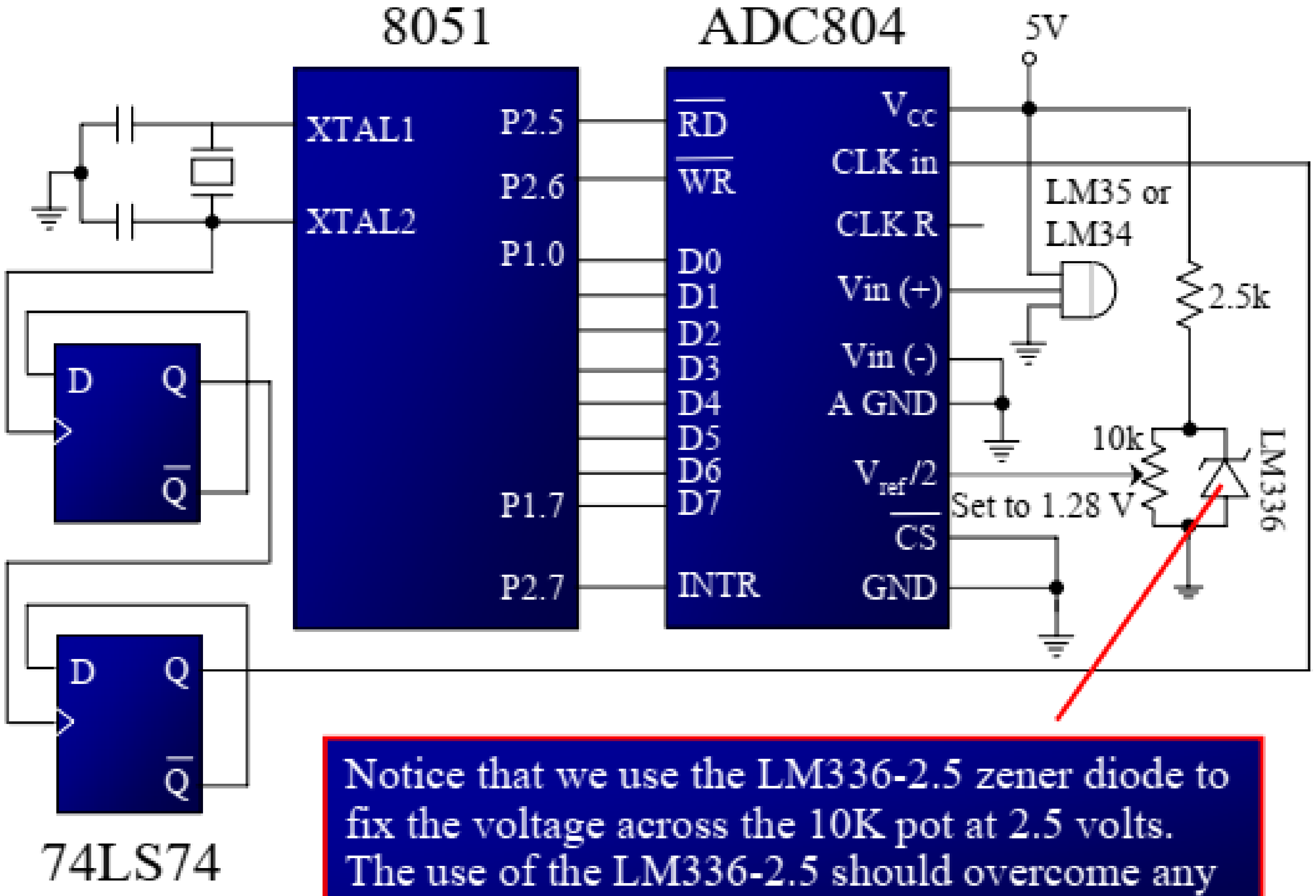
Temperature vs. Vout of the ADC804

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

Example 13-1

For a given ADC0848, we have $V_{ref} = 2.56$ V. Calculate the D0 - D7 output if the analog input is: (a) 1.7 V, and (b) 2.1 V.

Solution:

Since the step size is 2.56/256 = 10 mV, we have the following.

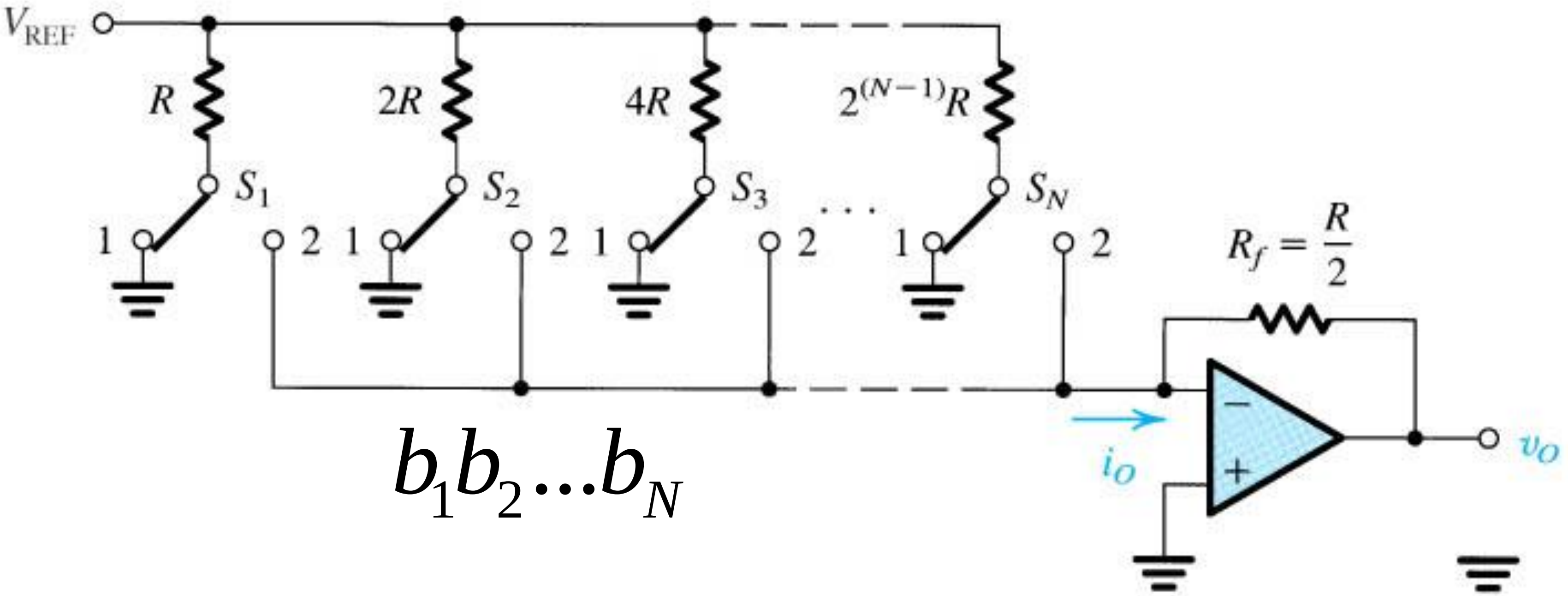
(a) D_{out} = 1.7 V/10 mV = 170 in decimal, which gives us 10101011 in binary for D7 - D0.

(b) D_{out} = 2.1 V/10 mV = 210 in decimal, which gives us 11010010 in binary for D7 - D0.

DAC Interfacing

D/A Converter Circuits

- **Binary-weighted registers**



$$b_1 b_2 \ldots b_N$$

$$i_O = \frac{V_{\text{REF}}}{R} b_1 + \frac{V_{\text{REF}}}{2R} b_2 + \ldots + \frac{V_{\text{REF}}}{2^{N-1} R} b_N$$

$$v_O = -i_O R_f$$

$$I_{out} = I_{ref}\left(\frac{D7}{2} + \frac{D6}{4} + \frac{D5}{8} + \frac{D4}{16} + \frac{D3}{32} + \frac{D2}{64} + \frac{D1}{128} + \frac{D0}{256}\right)$$

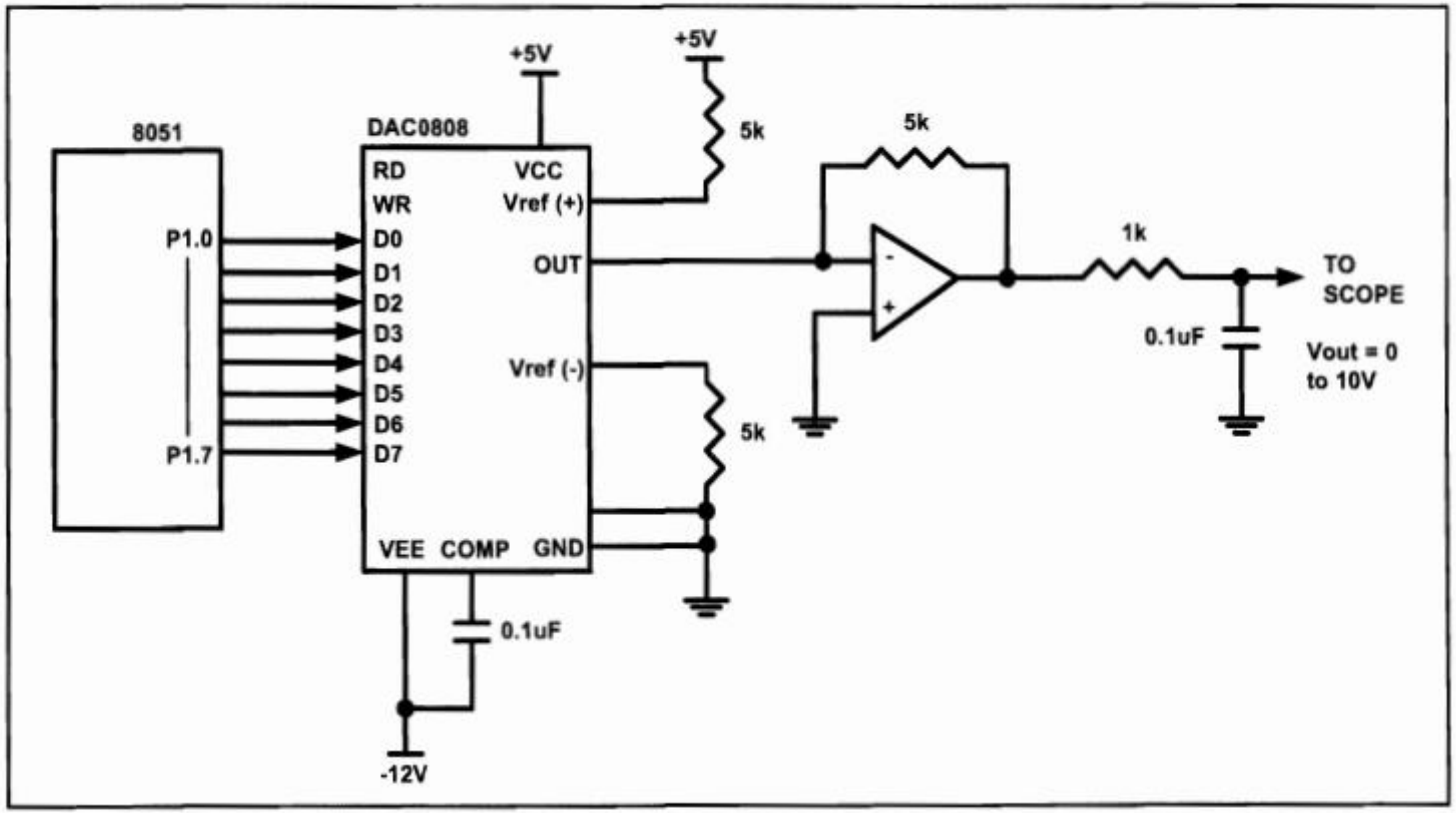


Figure 13-18. 8051 Connection to DAC808

Example:

In order to generate a stair-step ramp, set up the circuit in Figure 13-18 and connect the output to an oscilloscope. Then write a program to send data to the DAC to generate a stair-step ramp.

Solution:

```
        CLR     A
AGAIN:  MOV     P1,A        ;send data to DAC
        INC     A           ;count from 0 to FFH
        ACALL   DELAY       ;let DAC recover
        SJMP    AGAIN
```

Table: Angle vs. Voltage Magnitude for Sine Wave

Angle θ (degrees)	Sin θ	V_{out} (Voltage Magnitude) 5 V + (5 V × sin θ)	Values Sent to DAC (decimal) (Voltage Mag. × 25.6)
0	0	5	128
30	0.5	7.5	192
60	0.866	9.33	238
90	1.0	10	255
120	0.866	9.33	238
150	0.5	7.5	192
180	0	5	128
210	–0.5	2.5	64
240	–0.866	0.669	17
270	–1.0	0	0
300	–0.866	0.669	17
330	–0.5	2.5	64
360	0	5	128

Example 13-5

Verify the values given for the following angles: (a) 30° (b) 60°.

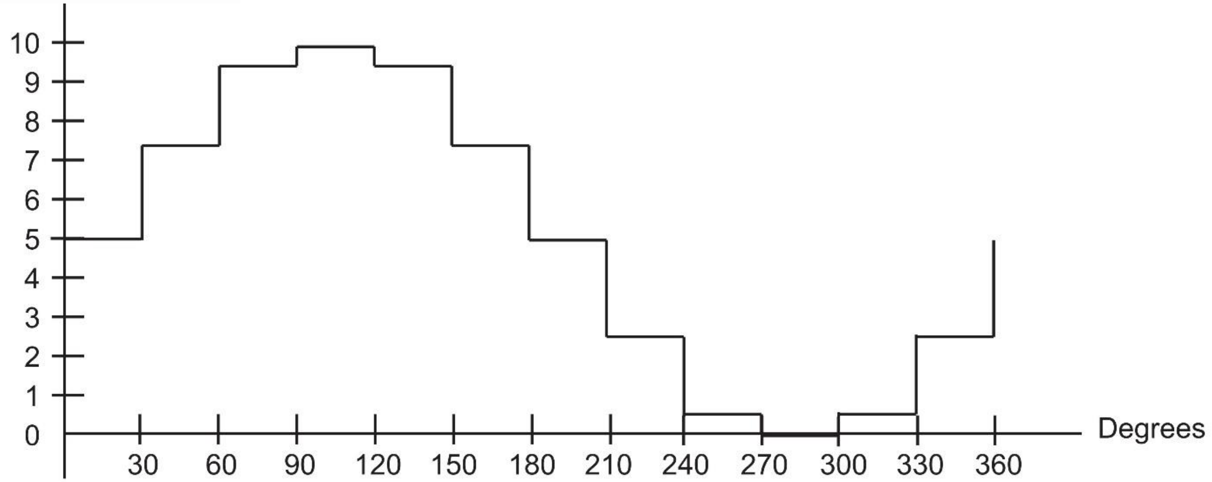
Solution:

(a) V_{out} = 5 V + (5 V x sin q) = 5 V + 5 x sin 30° = 5 V + 5 x 0.5 = 7.5 V
DAC input values = 7.5 V x 25.6 = 192 (decimal)

(b) V_{out} = 5 V + (5 V x sin q) = 5 V + 5 x sin 60° = 5 V + 5 x 0.866 = 9.33 V
DAC input values = 9.33 V x 25.6 = 238 (decimal)

Figure: Angle vs. Voltage Magnitude for Sine Wave

```
AGAIN:      MOV DPTR,#TABLE
            MOV R2,#COUNT
BACK:       CLR A
            MOVC A,@A+DPTR
            MOV P1,A
            INC DPTR
            DJNZ R2,BACK
            SJMP AGAIN
            ORG 300
TABLE:      DB 128,192,238,255,238,192 ;see Table 13-7
            DB 128,64,17,0,17,64,128
```



Thank You