8051 MICROCONTROLLER: INTERFACING

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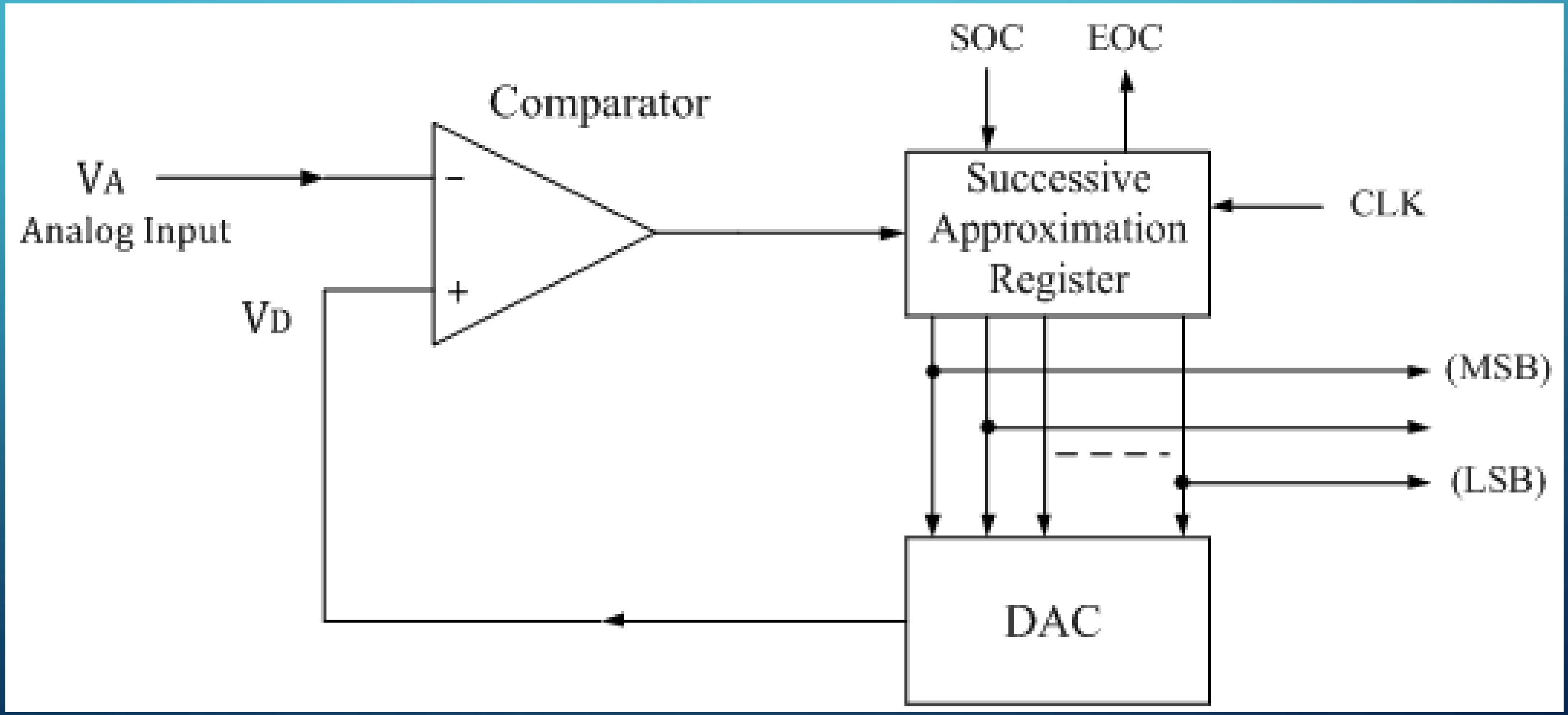
ANALOG TO DIGITAL CONVERTER

- ADC are most widely used devices for data acquisition.
- Digital computers use binary (discrete) values, but in the physical world everything is analog (continuous).
- Humidity, temperature, pressure are example of physical quantities that we deal in our day today life. These are measured using sensors and the output of sensor is in the form of voltage or current.
- Therefore, we need an analog to digital converter to translate the analog signals to digital so that microcontroller can read and process them.

SUCCESSIVE APPROXIMATION ADC

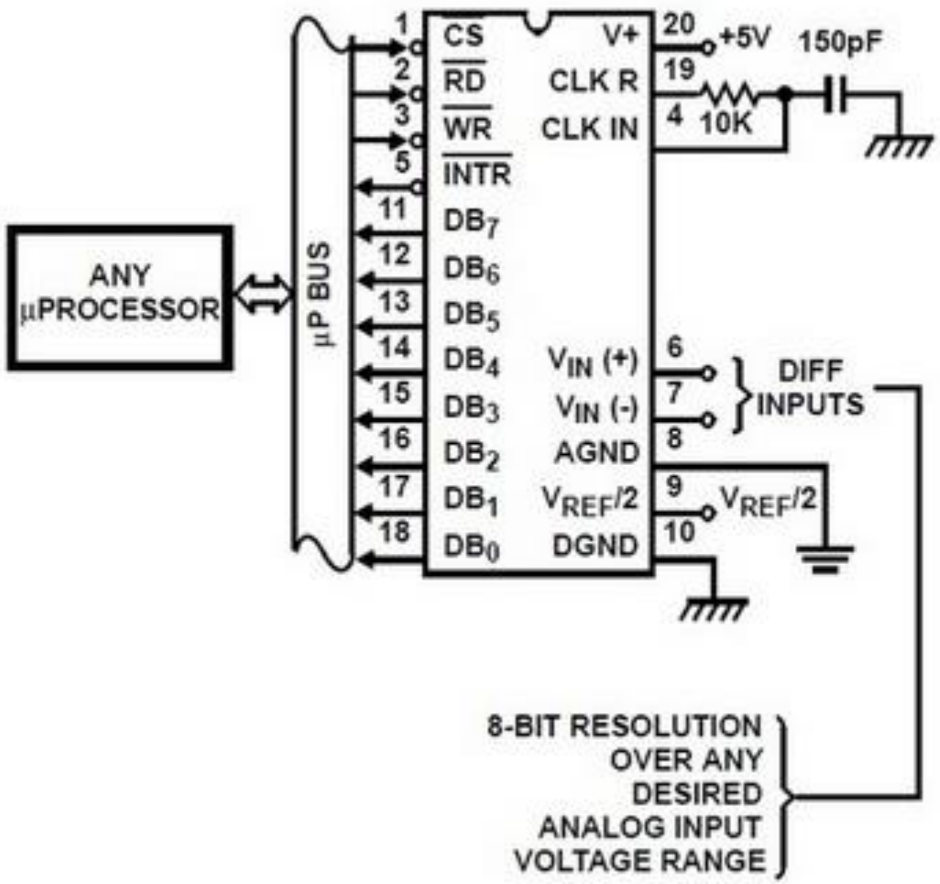
- ADC0804 IC is an 8 bit successive approximation analogue to digital converter from National semiconductors.
- It includes three major elements: D/A converter, successive approximation register and the comparator.
- The basic principle of this type of A/D converter is that the unknown analog input voltage is approximated against an n-bit digital value by trying one bit at a time, beginning with the MSB. This type of ADC operates by successively dividing the voltage range by half, as explained in the following steps.

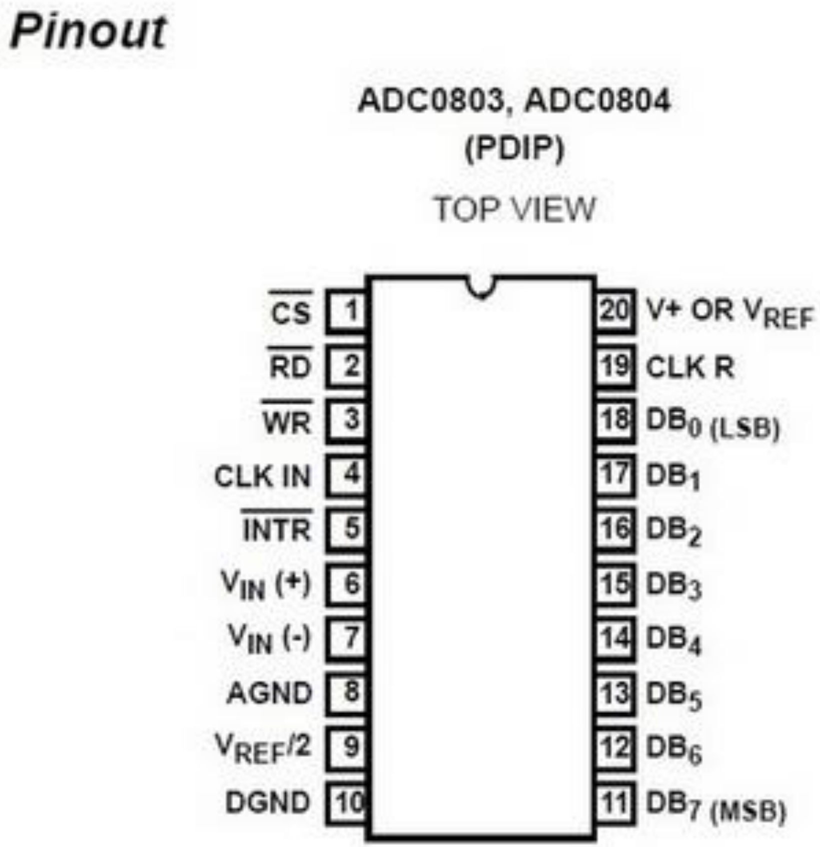
- (1) The MSB is initially set to 1 with the remaining three bits set as 000. The digital equivalent voltage is compared with the unknown analog input voltage.
- (2) If the analog input voltage is higher than the digital equivalent voltage, the MSB is retained as 1 and the second MSB is set to 1. Otherwise, the MSB is set to 0 and the second MSB is set to 1. Comparison is made as given in step (1) to decide whether to retain or reset the second MSB.



- Let us assume that the 4-bit ADC is used and the analog input voltage is VA = 11 V. when the conversion starts, the MSB bit is set to 1.
- Now VA = 11V > VD = 8V = $[1000]_2$
- Since the unknown analog input voltage VA is higher than the equivalent digital voltage VD, as discussed in step (2), the MSB is retained as 1 and the next MSB bit is set to 1 as follows
- VD = 12V = $[1100]_2$
- Now VA = 11V < VD = 12V = $[1100]_2$
- Here now, the unknown analog input voltage VA is lower than the equivalent digital voltage VD. As discussed in step (2), the second MSB is set to 0 and next MSB set to 1 as
- VD = 10V = $[1010]_2$
- Now again VA = 11V > VD = 10V = $[1010]_2$
- Again as discussed in step (2) VA>VD, hence the third MSB is retained to 1 and the last bit is set to 1. The new code word is
- VD = 11V = $[1011]_2$
- Now finally VA = VD , and the conversion stops.

- **4-bit A/D converter**
- Initially Bit D3 is turned on first.
- The output of the DAC is compared with an analog signal.
- If the comparator changes the state, indicating that the output generated by D3 is larger than the analog signal, bit D3 is turned off and D2 is turned on.
- The process continues until the input reaches bit D_0.





ADC0804 Chip

ADC0804 PIN OUT DESCRIPTION

- CS- Chip select is an active low input used to activate the ADC0804 chip. To access the ADC0804, this pin must be low.
- RD (Read)- This is an input signal and is active low. The ADC converts the analog input to its binary equivalent and holds it in an internal register. RD is used to get the converted data out of the ADC0804 chip. When CS=0, if a high-to-low pulse is applied to the RD pin, the 8-bit digital output shows up at the D0_D7 data pins The RD pin is also referred to as output enable.
- WR (Write)- This is an active low input used to inform the ADC0804 to start the conversion process. When the data conversion is complete the INTR pin is forced low by the ADC0804.

- CLK IN and CLK R- CLK IN is an input pin connected to an external clock source when an external clock is used for timing. ADC0804 has a internal clock generator, to use the internal clock CLK IN and CLK R pins are connected to a capacitor and a resistor and the clock frequency is:

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

- INTR- This is an output pin and is active low. It is normally high pin and when the conversion is finished, it goes low to signal the CPU that the converted data is ready to be picked up. After INTR goes low, we make CS=0 and send a high-to-low pulse to the RD pin to get the data out of the ADC0804 chip.

- Vin (+) and Vin(-)- These are the differential analog inputs where Vin=Vin(+)-Vin(-). Often Vin(-) pin is connected to ground and the Vin(+) pin is used as the analog input to be converted to digital.
- Vcc- This is a +5 volt power supply. It is also used as a reference voltage when the Vref./2 input is open.
- Vref./2- Pin 9 is an input voltage used for the reference voltage. If this pin is open, the analog input voltage for the ADC0804 is in the range of 0 to 5 volts.

Vin/2 (V)	Vin (V)	Step Size (mV)
not connected	0 to 5	5/256=19.53
2.0	0 to 4	4/256=15.62
1.5	0 to 3	3/256=11.71
1.28	0 to 2.56	2.56/256=10

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

- D0-D7- These are the digital data output pins since ADC004 is a parallel ADC chip. Output voltage can be calculated by the following formula:

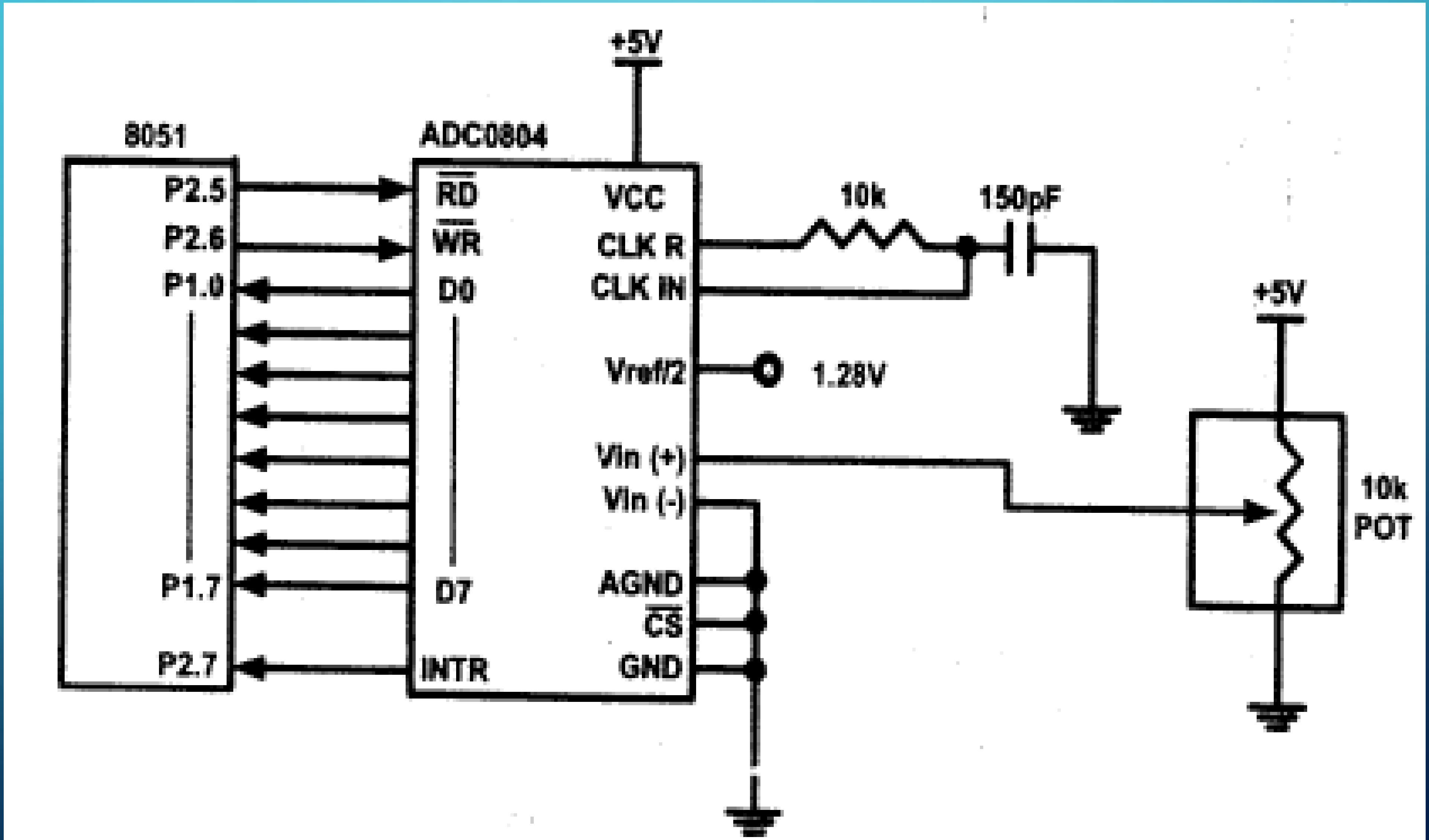
$$Dout = \frac{Vin}{Step\ Size}$$

- Analog ground and digital ground- These are the input pins providing the ground for both the analog signal and digital signal.

Steps for the data conversion by the ADC0804 chip

- Make CS=0 and send a low-to-high pulse to pin WR to start the conversion.
- Keep monitoring the INTR pin. If it is low, conversion is finished, otherwise keep polling until it goes low.
- After the INTR has become low, make CS=0 and send a high-to-low pulse to the RD pin to get the data out of the AD0804 IC chip.

INTERFACING ADC WITH 8051 MICROCONTROLLER



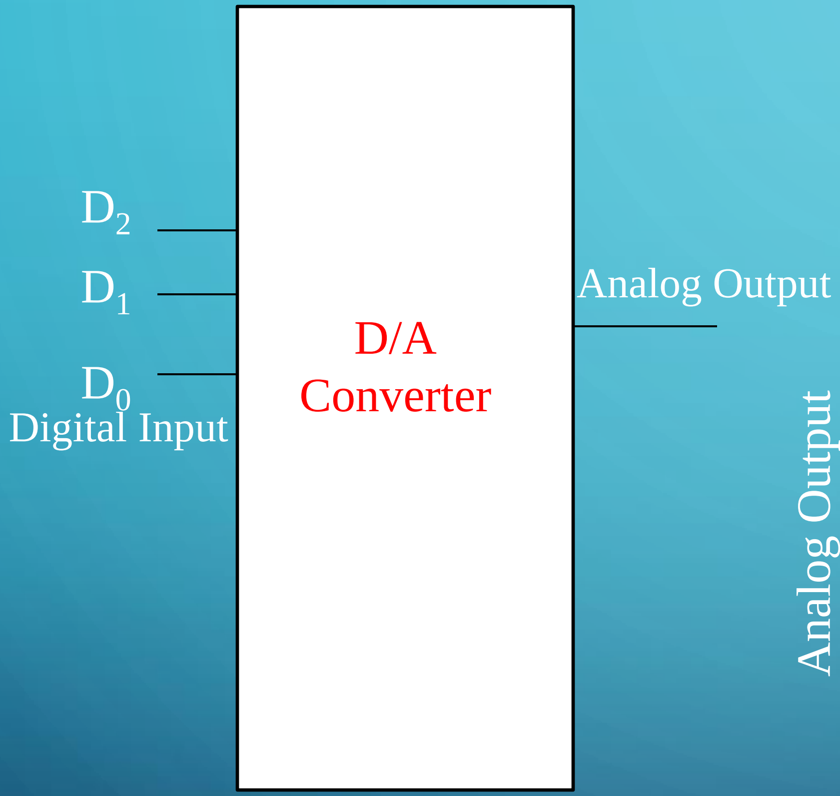
PROGRAMMING ADC0804 IN C

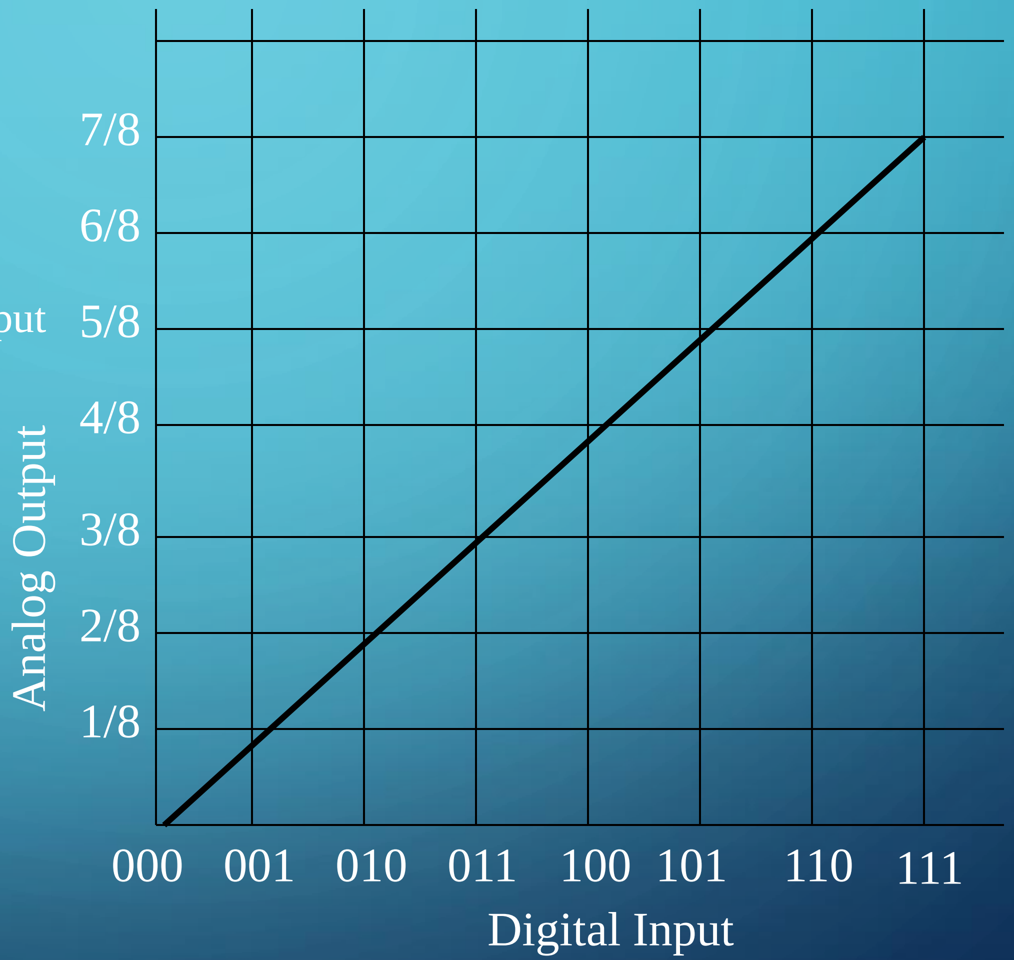
```
#include <reg51.h>
sbit RD =P2^5;
sbit WR = P2^6;
sbit INTR = P2^7;
sfr MYDATA =P1;
void main ()
{
  unsigned char value;
  MYDATA =0XFF;
  INTR = 1;
  RD = 1;
  WR = 1;
```

```
while (1)
{
    WR = 0;
    WR = 1;
    while (INTR = = 1);
    RD = 0;
    value = MYDATA;
    ConvertAndDisplay (value);
    RD = 1;
}
```

DIGITAL TO ANALOG CONVERTER

- The digital-to-analog converter (DAC) is a device widely used to convert digital pulsed to analog signals.
- There are two methods for DAC: binary weighted and R/2R ladder.
- The criteria for judging a DAC is its resolution, which is a function of the number of binary inputs.
- The number of data bit input decides the resolution of the DAC since the number of analog output levels is equal to 2^n, where n is the number of data bit inputs.
- Therefore, an 8-input DAC such as DAC0808 provides 256 discrete voltage levels of output.

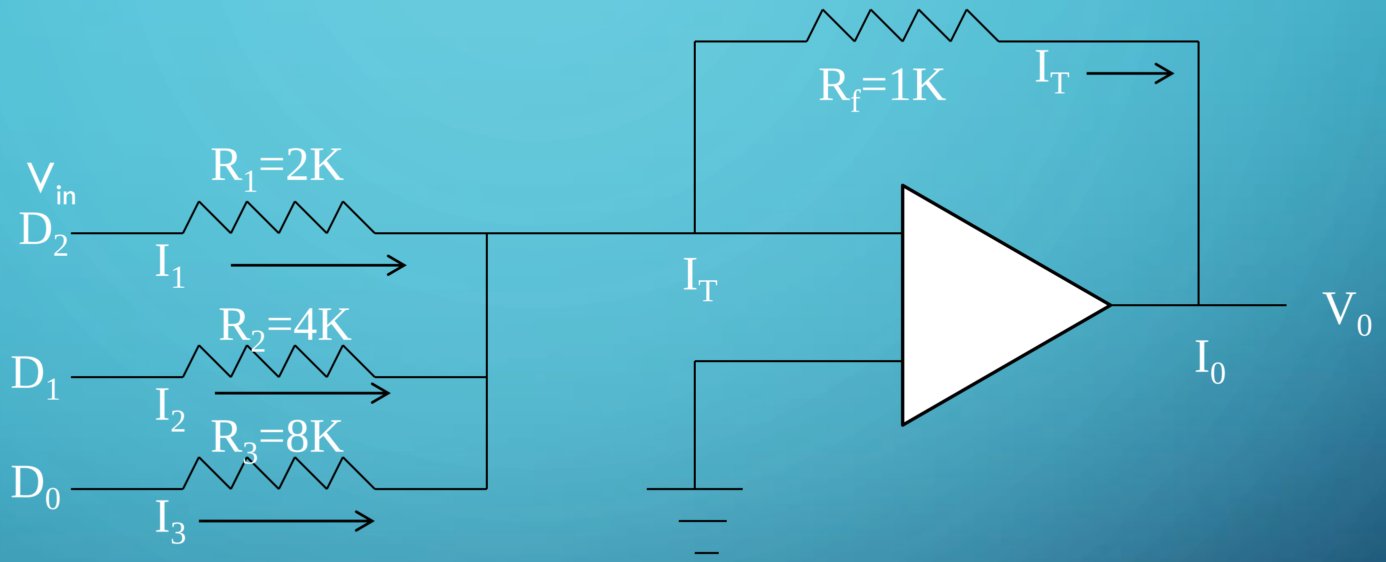




A 3-Bit D/A Converter

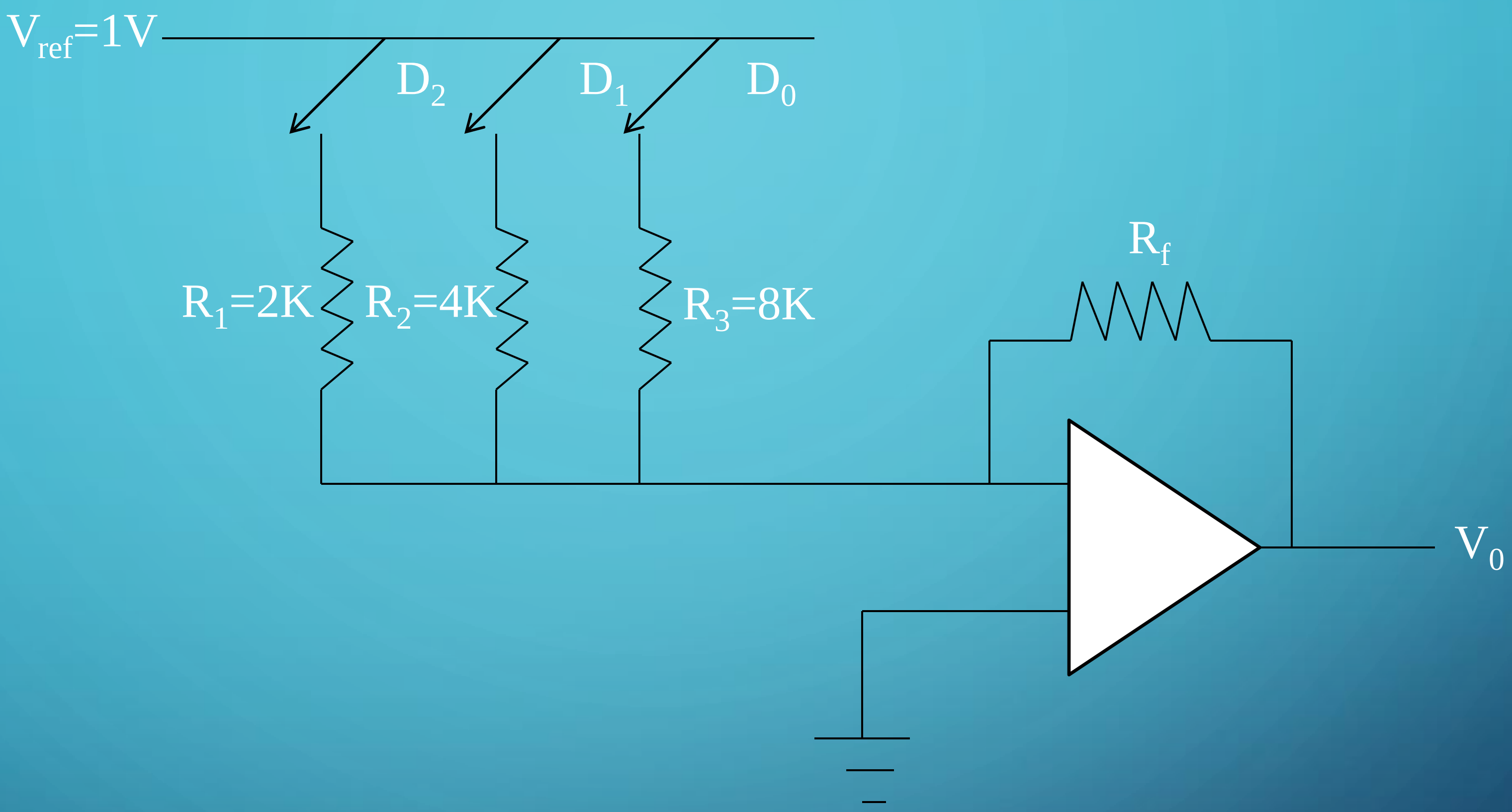
- N-bit D/A converter has n input lines, it can have 2^n input combinations.
- If the full scale analog voltage is 1V, the smallest unit or LSB is equivalent to $1/2^n$ of 1V. This is defined as resolution.
- The MSB represents the half of the full-scale value.
- For the maximum input signal, the output is equal to the value of the full scale input signal minus the value of the 1 LSB input signal.

BINARY WEIGHTED INPUT RESISTORS



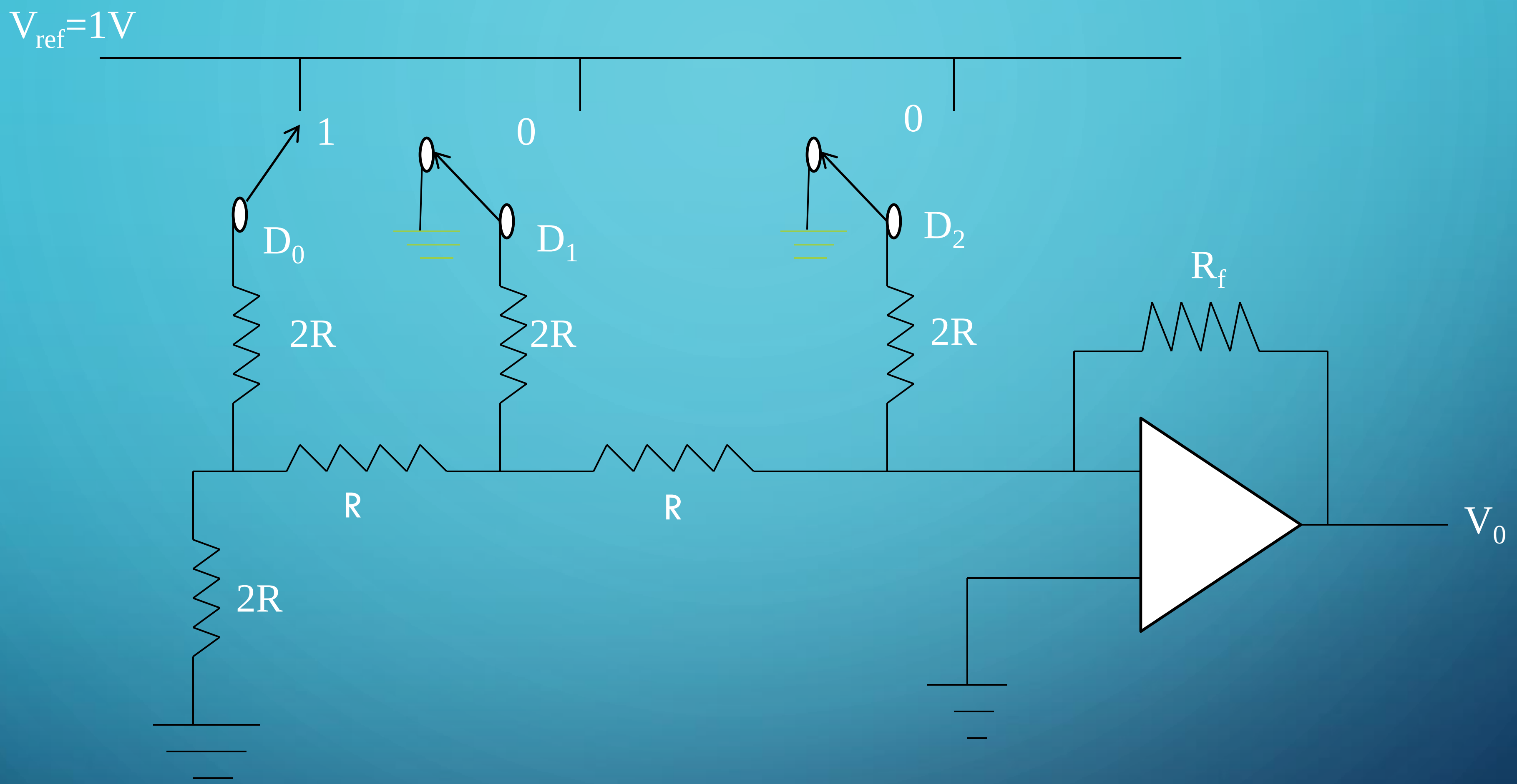
$V0 = -R_f I_T$

$$Io = \left(\frac{V_{in}}{2} + \frac{V_{in}}{4} + \frac{V_{in}}{8}\right)$$



Weighted Resistor D/A Converter

R/2R LADDDER NETWORK



R/2R Ladder Network

DAC 0808 CHIP

- DAC0808 use the R/2R method since it can achieve a much higher degree of precision
- 8 bit parallel digital data input
- Fast settling time (typical value): 150 ns
- Relative accuracy at ±0.19% maximum error
- Full scale current match: ±1 LSB
- Non-inverting digital inputs are TTL and CMOS compatible
- High speed multiplying input slew rate: 8 mA/µs
- Power supply voltage range: ±4.5V to ±18V
- Low power consumption: 33 mW@ ±5V
- Maximum Power dissipation: 1000 mW
- Operating temperature range: 0°C to +75°C

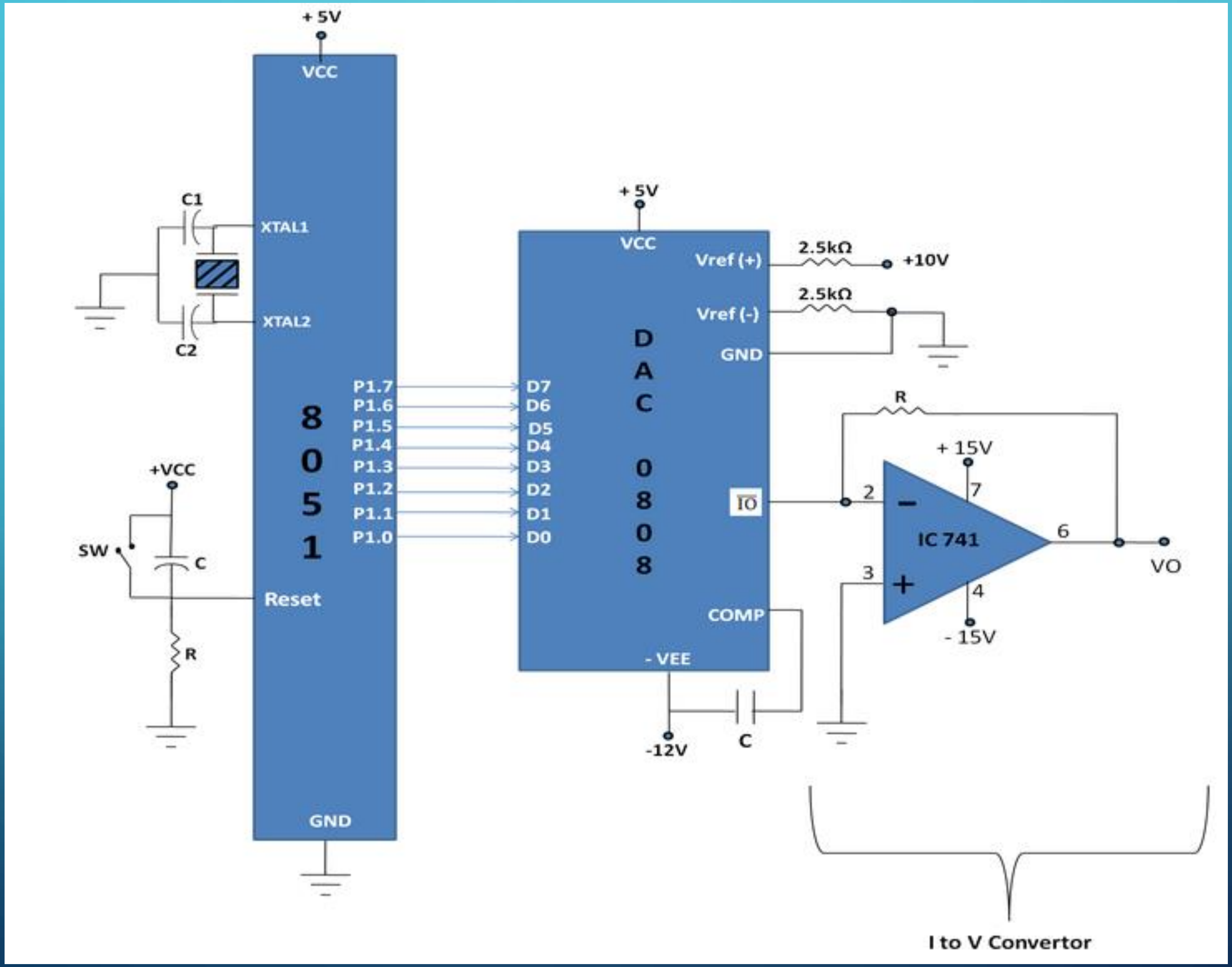
WORKING OF DAC0808

- This DAC0808 IC converts digital data into equivalent analog Current.
- The total current provided by the I_{out} pin is a function of the binary numbers at the D0-D7 inputs of the DAC0808 and the reference current (I_{ref}) and is given as:

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

- The I_{ref} current is generally set to 2.0mA.
- Hence we require an I to V converter to convert this current into equivalent voltage.

INTERFACING DAC WITH 8051



- Ideally we connect the output pin I_{out} to a resistor, convert to voltage and monitor the output on the scope.
- In real life, however, this can cause inaccuracy since the input resistance of the load where it is connected will also affect the output voltage.
- Thus, I_{ref} current output is isolated by connecting it to op-amp such as the 741 with R-5K ohms for the feedback resistor.