Explaining the SX/B ANALOGIN command

The SX/B ANALOGIN command converts an analog voltage to a digital value by using a method known as continuous calibration. This method requires one input pin and one output pin on the SX. The only required hardware is two resistors and one capacitor.

The ANALOGIN command syntax is:

ANALOGIN InPin, OutPin, Result [, Prime]

Where:
  InPin = Input Pin
  OutPin = Output Pin
  Result = Byte variable that will receive the value
  Prime = Number of priming cycles before taking measurement (optional default=1)

```
' Example program using ANALOGIN command
DEVICE SX28, OSC4MHZ, TURBO, STACKX, OPTIONX
FREQ 4_000_000

InPin  PIN RA.0 INPUT CMOS
OutPin PIN RA.1 OUTPUT

'RA.1 Pin ----\/\/\/-----+---\/\/\/----- Voltage to measure
'                        |
'RA.0 Pin ---------------+
'                        |  0.01uF
'                        +--|(-- GND

a VAR Byte

PROGRAM Start NOSTARTUP

Start:
  ANALOGIN InPin, OutPin, a, 2

  WATCH a
  BREAK

  GOTO Start
END
```

The method works by taking advantage of the input pin's threshold voltage. This is the voltage level that makes the input pin read as either a "0" or a "1". Normally on the SX the input threshold is set to the "TTL" level, which is 1.4 volts. So voltages above 1.4 volts are read as a "1" and voltages below 1.4 volts are read as a "0". To allow the measured voltage to range from 0 volts to Vdd we need to set the pin to the "CMOS" threshold level, which is 1/2 Vdd (or 2.5 volts when operating the SX from a 5 volt supply).

For this example we will assume the SX is operating from 5 volts, and that you have set the input pin to "CMOS" threshold levels (the easiest way to do this is to use the PIN definition "AIn PIN INPUT CMOS").

Here is how the components are connected:

```
                    10K            10K
SX Output Pin ----\/\/\/-----+---\/\/\/----- Voltage to measure
                             |
SX Input Pin  ---------------+
                             |  0.01uF @ 4MHz or 0.001uF @ 50MHz
                             +--|(-- GND
```

What the ANALOGIN command does is read the input pin, and make the output pin the opposite of what the input pin reads. If the input pin reads "0", it makes the output pin a "1". If the input pin reads "1", it makes the output pin a "0". It does this 255 times, and keeps a count of how many times the input pin was a "1". This count is what is returned as the result of the command. This value is proportional to the voltage level.

Basically the ANALOGIN command attempts to keep the input pin right at the threshold voltage. If the voltage input was not connected, and the capacitor wasn't there, the output would just toggle from high to low. And the count would end up being 128. Now if you added the cap, the output pin would still toggle, but not every time (since it takes the cap some time to charge and discharge), but over the long run it would still return a count of 128.

Now imagine if you have the complete circuit connected and the voltage input is 0 volts. The input pin will read as a "0" so it will make the output pin high (5 volts). So now we have 0 volts through a 10K resistor and 5 volts through a 10K resistor. That will make the junction (where the cap and input pin are connected) equal 2.5 volts. So the input pin will never get above 2.5 volts regardless of how long the output pin stays high, so it will always read as a "0" and our count will be zero.

Now imagine if the input voltage is 5 volts. The input will read as a "1", so it will make the output low (0 volts). Now we have the same situation reversed. The voltage at the input pin can never get below 2.5 volts regardless of how long the output pin stays low, so it will always read as a "1" and our count will be 255.

When the input voltage is between 0 volts and 5 volts, then things get interesting. If the input voltage is 1.25 volts (1/4 the maximum), then the input pin will see a pattern of 0's and 1's such that the number of 0's is 3 times the number of 1's. Over 255 samples it will return a count of 63 (since only 1 in 3 reads of the input pin were 1’s). Depending on the clock speed of the SX and the value of the capacitor, the pattern may be something like "000100010001" or it may be something like "000000110000001100000011". But over the 255 samples you will still get a count of about 63 1's in the pattern.

It may take some experimentation to get the optimum values for the capacitor. In general the faster the SX clock, the lower the capacitor value, and the slower the SX clock, the higher the capacitor value.

Another factor that affects the stability of ANALOGIN is that the method assumes the input pin is already at the threshold voltage before it starts counting the 1's read at the input pin. To accomplish this the ANALOGIN command actually primes the capacitor by running 255 samples BEFORE starting to count the pulses. Then it runs another 255 samples while counting the 1's. There is an optional parameter that can be used with the ANALOGIN command if you want or need more priming cycles (255 samples per cycle). More priming cycles allow the use of a larger capacitor and that gives more stable readings, but takes more time to complete the ANALOGIN command. So if you can afford the extra time, and want a more stable reading, then increase the value of the capacitor and increase the number of priming cycles.

Okay so what if you want to read voltage ranges other than 0 volts to 5 volts. Well if you want get full scale values from a voltage lower than 5 volts, one easy way is to just set the input pin to it’s default setting of “TTL” threshold levels. Since the “TTL” threshold level is 1.4 volts, and the ANALOGIN values range from 0 volts to 2x the threshold level, this will result in 0 for 0 volts and 255 for 2.8 volts. Wider voltage ranges can be read by using asymmetrical resistor values. If you make the resistor connected to the measured voltage a larger value than the resistor connected to the SX output pin, you can read voltages greater than 5 volts.

Note that the values returned by ANALOGIN will be dependent on the impedance of the voltage being measured. The resistors used should be several times larger than the impedance of the input voltage. For example if you were using a 10K pot to create voltage from 0 to 5 volts the resistance of the pot would effectively be added to the 10K resistor. This would make the resistor values unequal. Let’s suppose the pot was centered. The output of the pot would equate to a 2.5K resistor connected directly to a 2.5 volt supply. This 2.5K resistance would be in series with the 10K resistor connected from the pot to the cap. Since the pot would have effectively zero resistance when turned to each end point, you would still get the full range of values, but the values would not be linear through the range of the pot.