Poor Man's A/D Converter

By Dave Wissel at Wave Technology

Years ago some of the then-old engineers working in the cost-completive area of consumer electronics told me, "If it can't be done with a handful of resistors, caps, a 1N4148 diode and an MPS3904 or MPS2907 transistor, it ain't worth doing." At the time it made me laugh but one has to marvel at just what can be done with such low-cost "2 cent" components; in fact it's an art form to do so--simplicity has elegance all to itself.

This circuit was born of necessity though, for a quick demo. I needed a quick way to read a thermistor in a voltage-divider circuit and I didn't have an available micro (on-hand, that moment) with an internal A/D….and I didn't have the pin-count to do the R2R approach. The micro I was using already had a comparator built-in on two of its pins. Yes, I probably had an op-amp to do the constant-current source but didn't have a whole lot of board space as I had already cobbled-up the board space. Besides…I had a whole bin full of PN2222's and 1N4148's staring me in the face. Why not "take the challenge" of the old guys?

COMPARATOR, RAMP GENERATOR AND TIMER APPROACH TO A/D CONVERSION

In order to make a poor-man's A/D with a comparator one needs to generate a ramp-voltage over time and feed this to the spare input of a comparator. The other input of the comparator gets whatever analog-level one is trying to convert. (In my case I had a thermistor I needed to crudely measure so this becomes a voltage input via a divider circuit.) One also needs the timer of a microcontroller.

One starts a timer on the ramp beginning and when the comparator toggles due to the level of the comparator-input to be measured, one stops the timer. The value of the timer is the value of the analog signal.

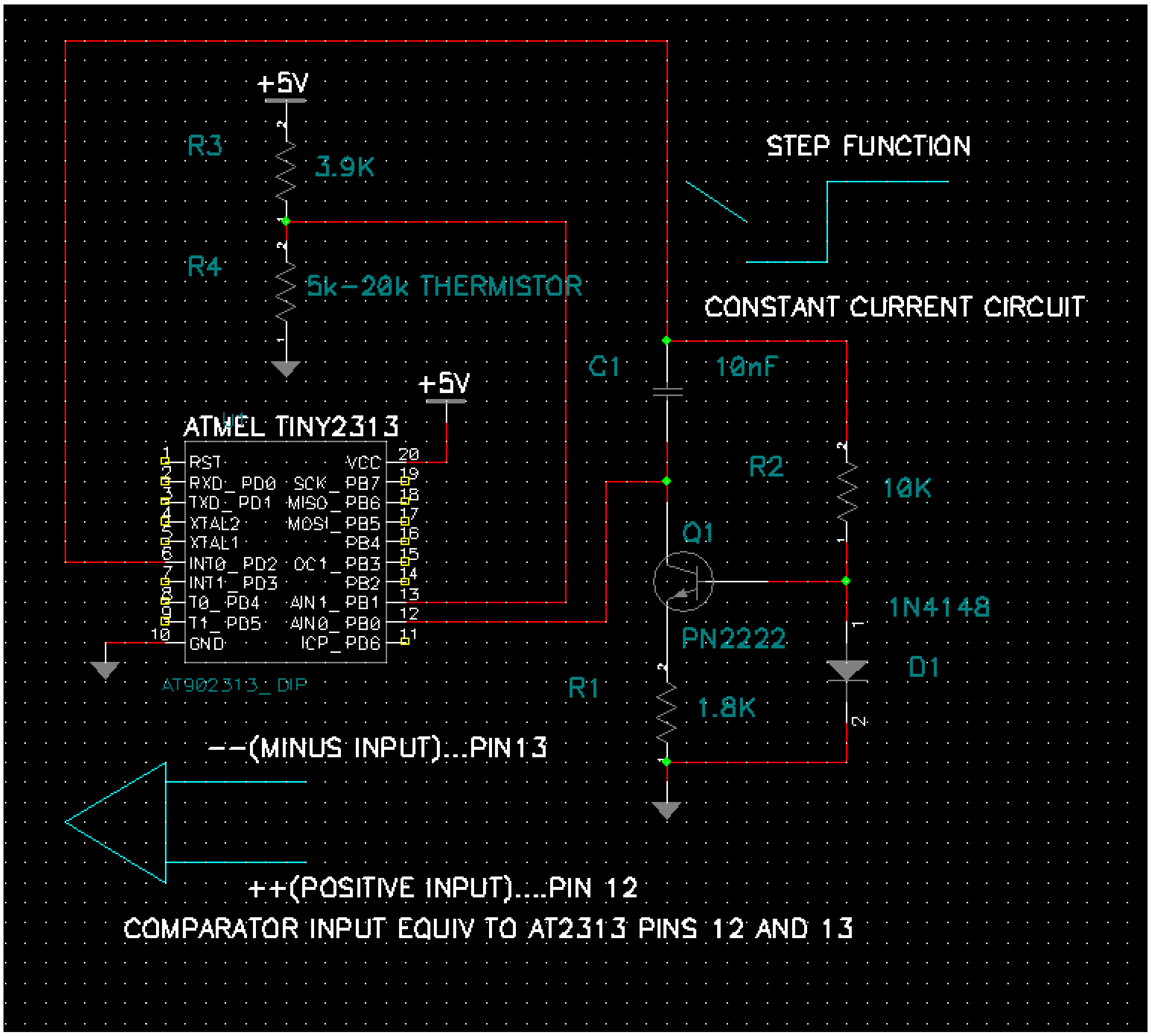
The way to generate the ramp voltage is with a constant current source fed into a capacitor. This is born-out by the voltage across a capacitor as related to time and current:

$$V(t)= 1/c \int i(t)\, dt$$

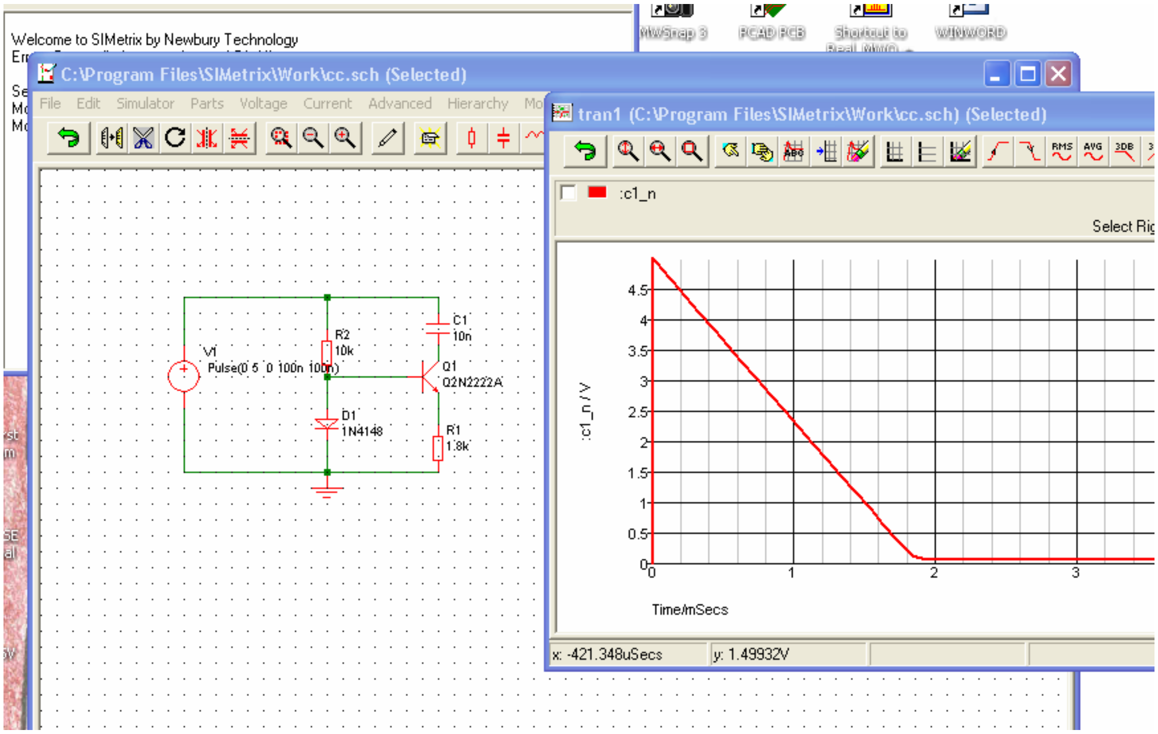
If i(t) is a constant (I) than this is simply: V(t)=1/c I t which is a constantly increasing linear voltage over time.

The way to create a constant current source is with some form of amplifier. An op-amp can do this function well but we're limiting ourselves to cheap transistors.

Referring to the circuit diagram if the top of C1 and R2 is a constant voltage just after the 5 volt step function, the voltage at the base of the transistor will be about 0.55 volts. The voltage drop of the transistor is just below this amount such that the emitter voltage is about 35mv. The action of the base emitter junction keeps this voltage constant such that the resistor has 35mv/1.8K or about 20microamps of current. As the voltage is constant, this current is constant. From the [V(t)=1/c I t] equation for a voltage of 5 volts takes 2.5msec with a 10nF capacitor and 20uA of current. All that ones needs is a timer that counts to roughly 255 over 2.5msec while the ramp is happening.

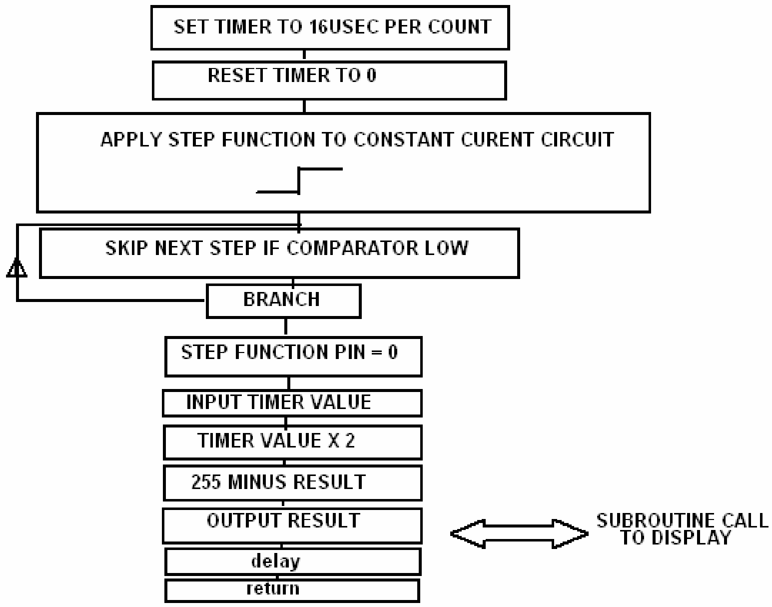


I included a quick Simmetrix spice analysis of this circuit so one can see the effect of the step-function; the step function is the “round” source in the drawing below on the left. The curve is the voltage on the collector of the circuit showing the linear curve of voltage vs. time resulting from a constant current across the capacitor. The spice time shown is less than the measured 2.5 msec due to the 2N2222 and 1N4148 models being generic. In addition the capacitor in the actual circuit was slightly larger than 10nf due to tolerance.



The circuit has limitations such that the time is highly dependant on the diode drops of the diode and the transistor. As such the time will vary. In addition the lower range is limited to just above zero which more precisely is tied to the voltage drop across R1 and Q1B-E. But…for a poor man's A/D I was able to swap PN2222's and 1N4148's from different lots with very little difference.

Here is a flow chart of code to do the conversion. Note that one must subtract the reading as shown from 255 if the comparator inputs are as I show in the schematic.



Poor Man's A/D Subroutine Block Diagram

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;*******************ATMEL AVR…POOR MAN'S A/D USING COMPARATOR*******
; The registers called Temp, Temp1, Temp2 are registers in the r16 to r31 defined earlier
;CCSTART is an output on Port D defined earlier
;We defined a pin called DEBUGPIN earlier in the code to test the timing on a scope
;A 16usec timer was being used for another function…so it was used x2

HARVESTTEST:
            LDI TEMP, 0X03
            OUT TCCR0, TEMP    ; SETS TIMER CLOCK DIVIDE BY 64 (62.5khz;
16usec per count)
            cbi portd, debugpin
            sbi portd, debugpin
            cbi portd, debugpin
            sbi portd, ccstart; starts the constant current source
            ldi temp, 0x00
            out tcnt0, temp  ;rests timer to zero
            nop
            nop
            nop
            nop
            nop
            nop
```

```
		nop
		nop
		nop ;needed to let CCstart ramp up

Harvesttestloop:
		sbic acsr,5		;skip if comparator is low
		rjmp harvesttestloop
		sbi portd, debugpin	;sets the debug pin out
		cbi portd, ccstart; stops cc source sets back to zero
		in temp, tcnt0
		lsl temp;multiplies by two
		ldi temp3, 255
		sub temp3, temp ;swaps it around so high value is low value
		rcall DISPLAYDATA ; YOUR SUBROUTINE CALL TO DISPLAY TEMP3
		ldi temp,0
		out tcnt0,temp	;resets timer counter
		rcall delay ; a delay routine
		ret
```