

A precise analog digital converter with ICL7135

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1. Basics

The BASIC-Tiger™ with its 4 analog inputs has a sufficient equipment for the most problems. Resolutions of 8 or 10 bits are standard, with mathematical interpolation are 12 bits reachable. Table 1 shows the conditions with this resolutions:

| Resolution (bit) | Number of steps | Steps in 0V...5V range (approximately) |
|------------------|-----------------|--|
| 8 | 256 | 20 mV |
| 10 | 1024 | 5 mV |
| 12 | 4096 | 1 mV |

Table 1 data of the BASIC-Tigers® internal ADC

But there are some problems with the real resolutions of 8 or 10 bits.

How each other ADC the integrated ADC of the BASIC-Tiger™ has failures caused in analog and digital parts of the circuit, for instance the digit failure (+/- 1 digit). That means 1 V could be 0.98 V or 1.02 V at a resolution of 8 bits. An other problem comes from the range of measurements. With 8 bits in the 5 V range one step is 19.53 mV, not 20 mV like in table 1 showed (5 V / 256 steps). This is the reason to choice a “strange” range of 0...4.096 V in some measurement systems with 12 bits (1 step is 1 mV). Multimeters or other measuring devices with digital display use an other way to solve this problem. The range and the resolution are not bit oriented but optimized to display the results. A typical multimeter for instance has a range from -2.000 V to + 2.000 V, this means 4000 steps with exactly 1 mV. Better systems have resolutions of 0.1 mV or less in the same range.

If you need such resolutions, the high precision ADC ICL7135 can solve your problem.

Such displaying measurement devices are mostly not so fast like the ADC integrated in the BASIC-Tiger™. They are working at the dual slope principle with some advantages like high precision, good matching of the range with display, high input impedance and so on. Problems are the low speed and the mostly integrated drivers for LC or LED displays. This is the reason of choice the ICL7135 with μ P oriented outputs instead of segment drivers.

2. Conception of circuit with ICL 7135 ADC

This ADC is cheap and is offered by many distributors. With some external devices the analog part is working autonomous. The resolution in the +/- 2 V range is -1.9999...+1.9999, that means 40000 steps (!). Completing table 1 with this data of the ICL7135 the result will be (table 2):

| Resolution (bit) | Number of steps | Steps in 0V...5V range (approximately) |
|------------------|-----------------|--|
| 15 ... 16 | 40000 | 0.1 mV |

Table 2 data of ICL7135

Datasheet ICL7135: <http://209.1.238.250/arpdf/1496.pdf>

The 28 pin AD converter has an analog part typical for many multimeter applications (the complete circuit see the picture at the end). The components are uncritically, important for higher accuracy are only the capacitors and the voltage reference. You can derive the voltage reference (1,0000 V) with a resistor divider either from the operating voltage (less exactly) or from a band gap reference (high exactly).

The digital part is designed to work together with microprocessors. The measured values come in the BCD-format. There are 4 BCD outputs B1, B2, B4, B8 for the value of the digit and 5 digit outputs D1, D2, D3, D4, D5 for the place of the digit. Inside the ICL7135 forms the complete measured values over 5 Digits and send them BCD coded one after another:

0 = 0000
1 = 0001
2 = 0020
:
9 = 1001

The actual digit has high level (1) at the digit outputs D1...D5. Under this conditions the BASIC-Tiger™ could work already together with the ICL7135 but it would need 4 BCD lines, 5 digit lines, 1 line for over range output and 1 line for polarity, that are more than a complete port of the Tiger. With a trick we can reduce the number of lines so that the port 8 is enough for communication. This is good for normal use of the other components of the BASIC-Tiger™ system. The trick is to use a priority encoder CD4532 to reduce the needed lines for digit choice. This IC scans at 8 inputs I0...I7 the most significant bit with high level. In our circuit over range output of ICL7135 has the highest priority. If over range is high, the outputs O2...O0 of the CD4532 become high (HHH) independence of the level of the other inputs. If over range is low (inactive), the digit 5 has the highest priority and the outputs O2...O0 of the CD4532 become the information HHL and so on. In this way the digits (and over range) will be reduced from 6 to 3 bits.

Datasheet CD4532: <http://www-s.ti.com/sc/psheets/schs082/schs082.pdf>

The price we have to pay for this bit number reducing is a more complicated hardware and software. Now it is necessary to encode the allocation of the digit, BCD and over range information on the Port 8 of the BASIC-Tiger™. The following table 3 should serve for the better understanding. As an example the measured value +13479 is shown how the information are encoded:

| Port line of BASIC-Tiger™ | 87 | 86 | 85 | 84 | 83 | 82 | 81 | 80 | Decimal value of upper 3 bits decimal (digits, over range) | Sign | Decimal value of lower 4 bits (BCD) |
|---------------------------|------------|------|------|------|-----------|------|------|------|--|------|-------------------------------------|
| Pin name | O2 | O1 | O0 | POL | B8 | B4 | B2 | B1 | | | |
| Output of | 4532 | 4532 | 4532 | 7135 | 7135 | 7135 | 7135 | 7135 | | | |
| | Digit-Code | | | Sign | BCD-value | | | | | | |
| OVRG active | H | H | H | H | L | L | L | L | 224 | + | * |
| Digit 5 active | H | H | L | H | L | L | L | H | 192 | + | 1 |
| Digit 4 active | H | L | H | H | L | L | H | H | 160 | + | 3 |
| Digit 3 active | H | L | L | H | L | H | L | L | 128 | + | 4 |
| Digit 2 active | L | H | H | H | L | H | H | H | 96 | + | 7 |
| Digit 1 active | L | H | L | H | H | L | L | H | 96 | + | 9 |

Table 3 decoded information (*over range is always shown as 00000)

The information of each byte for Port 8 of the BASIC-Tiger™ consists from 3 parts:
 the 4 bit BCD value of each digit (lower part, bits 0...3)
 the sign, 1 positive, 0 negative (bit 4)
 the encoded value for the active digit in consideration of the over range (upper part, bits 5...7)

The software now has to decode this complicated “mix of data” again.

Out of some passive devices for the analog part of the ICL7135 we use an IC 7660 to generate a negative voltage (-5 V) and a timer NE555 to generate a clock for the ICL7135. The links for this devices:

Datasheet ICL7660: <http://209.1.238.250/arpdf/1017.pdf>

Datasheet NE555: <http://www-s.ti.com/sc/psheets/slfs022/slfs022.pdf>

3. Software

The little program BT7135E1.TIG makes the circuit to work as a digital voltmeter. At the begin you find definitions and installations used for the LC display, keyboard and so on. After this we declare variables and the print format. The port 8 is used as input completely.

The first question of the program is: “is there an over range?”. In this case the ADC shows a “1” at the ORNG pin and all outputs of the CD4532 are “1”. The BASIC-Tiger™ reads this upper bits with a BITAND 11100000 as 224 (128+64+32) and sets the sign indicator L (variable) to “over range = 1”. This procedure is similar for each digit, if a digit is decoded, the program reads the matching BCD information with a BITAND 00001111. At the end the single digits were completed to a full five digit information on the LC display of the BASIC-Tiger™. As a sample for the new opportunities and a hint for own experiments you find a calculation of the maximum value.

4. Results

Now we have built a digital voltmeter but the question is: couldn't we have a commercial voltmeter cheaper? The answer is: yes! But we want to do more than measure any voltages. We can add the time and date to the measuring results. We can send it via the serial port to the PC. We can switch any devices on or off in dependence of the measuring results, get more analog inputs with an analog multiplexer and so on...

The ADC can be built as a complete board with BASIC-Tiger™ or as an additional board for the Plug-and-Play-Lab. In this case you have only to build the framed part of the schematic, to connect power lines GND / Vcc and the 8 data lines with port 8 of the BASIC-Tiger™.

