INTERFACE

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IN LAST month's *Interface* article a simple eight bit Analogue to Digital Converter was described, together with a simple temperature sensor. This month we continue on the same theme, with an improved temperature sensor circuit. This provides greater resolution and a wider temperature range.

SIGNAL PROCESSING

The main problem with the basic design described last month is that it provides a resolution of only one degree Centigrade. Over a temperature range of 0 to 100 or 110 degrees, it is actually possible to obtain a much more useful resolution of 0.5 degrees using an 8-bit converter.

A second problem with the original design is that it lacks accuracy at low temperatures. This is partially due to limitations of the temperature sensor, and partially due to problems in removing the slight zero offset of the converter.

The circuit diagram for the Improved Temperature Sensor is shown in Fig. 1. Like the original circuit, this is based on the LM35DZ temperature sensor (IC1), which is usable over a 0 to 100 degree Centigrade temperature range. If the more expensive LM35CZ is used, the upper end of the range is extended to 110 degrees Centigrade.

The LM35 provides an output voltage that is equal to 10 millivolts per degree Centigrade, with no d.c. offset. This matches the 10 millivolt resolution of the Analogue to Digital Converter (last month), giving the one degree resolution. Simply amplifying the output from the LM35 by a factor of two boosts the output voltage to 20 millivolts per degree, and gives 0.5 degree resolution. With a maximum temperature of 100 or 110 degrees Centigrade, this gives a maximum output potential of 2.0 or 2.2 volts, which is still within the 2.56 volt maximum of the converter.

CIRCUIT

Component IC2 is a simple non-inverting amplifier which is d.c. coupled and has a voltage gain of two times. Its gain must be set very precisely at this figure in order to obtain accurate results. The gain has therefore been made adjustable, and VR2 is used to trim it to precisely the correct figure.

Potentiometer VR1 is an offset null control. Conventionally an offset null control is used to compensate for offset voltages in the operational amplifier's biasing. It will do so in this case, but it can also be used to compensate for any slight offsets in the analogue to digital converter, or in the temperature sensor.

Note that the output of this circuit must connect directly to the analogue input terminal of the ZN448E in the converter circuit. The input attenuator and zero adjustment circuits of the converter should be omitted.

SOFTWARE

Taking readings from the interface is achieved in much the same way as for the original temperature interface. First output a dummy value to in/out address 768 in order to initiate a reading. After a delay of at least nine microseconds, the converter is read at input/output address 768. Simply divide the returned values by two in order to convert them into readings in degrees Centigrade.

I have assumed here that the converter is at the base address of the thirty two address "prototype card" block. If the unit is placed elsewhere in the input/output map, then obviously the appropriate address must be used instead of address 768.

The accompanying Listing.1 is for a program that takes readings at one second intervals. It displays the current temperature on the screen, together with maximum and minimum readings.

This program is useful for testing and calibration purposes, as well as for use when utilizing the system for temperature monitoring. It is suitable for the Quick BASIC compiler, or the QBASIC interpreter supplied with MS/DOS 5.0. It might work with other PC BASICs, but if not it should certainly be quite easy to convert it to work with other PC BASICs.

CALIBRATION

The original temperature interface circuit does not require any calibration, but it does not exactly offer the ultimate in accuracy. This version can provide much better accuracy, but only if it is calibrated accurately.

Calibration requires two accurate temperatures, and one of these can be iced water at 0 degrees Centigrade. The other

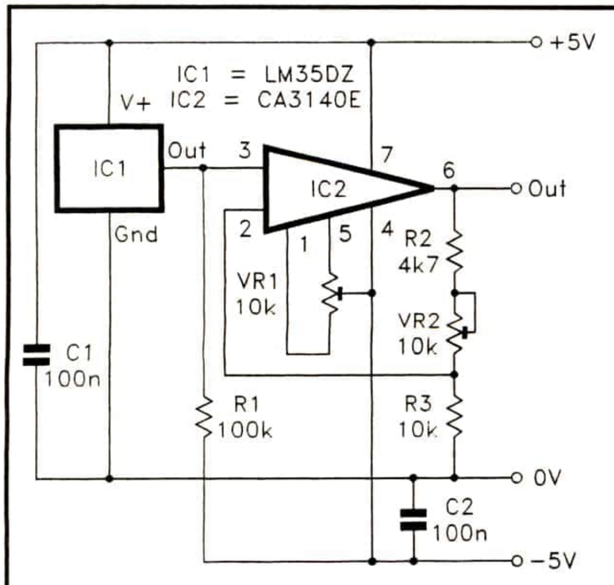

Fig. 1. Circuit diagram for the Improved Temperature Sensor Interface.

Listing One: Temperature Reading

```
SCREEN 0
WIDTH 40, 25
CLS 2

Tmax = 0
Tmin = 127
f$ = "£££.££"

LOCATE 8, 6
PRINT "Temp."
LOCATE 8, 18
PRINT "Max"
LOCATE 8, 31
PRINT "Min"
LOCATE 15, 1
PRINT "Press SPACE BAR to exit"

WHILE INKEY$ <> " "
     OUT 768, 0
     SLEEP 1
     Tnow = INP(768) / 2
     IF Tnow > Tmax THEN Tmax = Tnow
     IF Tnow < Tmin THEN Tmin = Tnow
     LOCATE 10, 5
     PRINT USING f$; Tnow
     LOCATE 10, 17
     PRINT USING f$; Tmax
     LOCATE 10, 30
     PRINT USING f$; Tmin
WEND
```

temperature must be much higher, and this could be water at about 50 degrees Centigrade or so. A good quality thermometer should be used to accurately monitor the precise temperature of the water.

The calibration process is very straightforward. Start with both VR1 and VR2 set at roughly the centres of their adjustment ranges. Place IC1 in the iced water and adjust VR1 for a reading of zero. Next place IC1 in the hot water, and adjust VR2 for the correct reading. Repeat this procedure a few times until no further adjustment is necessary. The unit should then work with good accuracy over the full temperature range.

When calibrating and using the unit, bear in mind that IC1 should not be directly immersed in liquids. It must be mounted inside a container of some kind, such as a small test-tube, so that no liquid comes into contact with its leadout wires.

It is a good idea to use some silicon grease to give a good thermal contact between the container and IC1. Even so, the response time will not be particularly fast. It will take the sensor several seconds to respond to large and rapid changes in temperature. Be careful to allow sufficient adjustment time when calibrating the unit.

NEGATIVE TEMPERATURES

The LM35CZ can handle negative temperatures down to −40 degrees Centigrade. Unfortunately, these negative temperatures provide negative output voltages which the converter can not handle. One way around this difficulty is to use VR1 to provide an offset, so that the output voltage from IC2 is always positive.

For example, suppose that the unit must measure temperatures down to −10 degrees Centigrade. With IC1 at this temperature, VR1 would be adjusted for a reading of zero. With IC1 then set at the higher calibration temperature, VR2 would be adjusted for a reading ten degrees higher than the actual calibration temperature.

In order to obtain readings in degrees Centigrade, the software would first have to divide readings by two, and then deduct ten to compensate for the deliberate offset. This would give a usable temperature range of −10 to −110 degrees Centigrade.

Some initial experiments would suggest that a 10 degree offset can be handled with no significant degradation in accuracy. This might not be the case with the full 40 degree offset needed to read down to the −40 degree minimum of the LM35CZ.

However, if you need to read down to such low temperatures it might be worthwhile experimenting along these lines. VR1 certainly seems to be able to handle a 40 millivolt input offset. Of course, if the unit is made to read right down to −40 degrees, you have to accept some loss of coverage at the other end of the range. The maximum input voltage of the converter would be reached at a temperature of 87.5 degrees.

There is plenty of scope for experimentation with a unit of this type. With suitable software you can do such things as monitoring heating systems, the outside temperature, etc. Most PCs have good graphics capability these days, and it should not be too difficult to produce software to log readings and then display them as graphs.

PC INCOMPATIBILITIES

There are hundreds of different PC expansion cards, monitors, etc. currently available, and with a few provisos, they should all work perfectly well together. In reality there seems to be the occasional problem, which I suppose is inevitable with so many products being produced by so many different companies around the world. This means that you need to be a little careful when buying PC hardware.

Possibly I have been unlucky, but I have encountered numerous PC compatibility problems over the last few years. The worst case was a 12MHz AT motherboard which only seemed to work with about one-in-two expansion cards! With some swapping around of cards between various computers I did eventually managed to produce a complete computer based on this motherboard, but why did some cards refuse to work with it while others were fine?

More recently I have had problems with non-Intel maths co-processors which worked in some computers but not in others, and a monitor which worked with some VGA cards in all modes, but refused to respond to others when used in the 800 x 600 super VGA mode.

In the case of the monitor the problem seemed to be due to differences in the scan rates of VGA cards. The super VGA modes are not properly standardised, and this clearly leaves room for incompatibility problems. Many VGA cards now have a configuration switch which enables you to select between two sets of scanning frequencies. A lower set than any super VGA monitor should be able to handle, and a higher one for "flicker-free" viewing on suitable monitors.

The expansion card problem and (possibly) the co-processor one seems to be something more fundamental. Modern motherboards and expansion cards are largely devoid of TTL chips, and instead use a variety of LSI chip technologies. This seems to result in occasional conflicts where two sets of chips do not agree about what constitutes valid logic 0 and logic 1 voltages. This usually results in the computer completely hanging up, or crashing soon after switch-on.

There also seems to be problems with drive currents, with some chips simply not having sufficiently powerful outputs. This factor seems to be responsible for some computers being unable to drive some printers via their parallel ports.

It would seem to be a good idea, where possible, to check that PC hardware will work properly with your system before handing over any money. Alternatively, make sure that you can return the equipment for a refund if there are any incompatibility problems.

Next month: We will continue with PC interfacing, and the subject of digital to analogue converters will be covered.