Using the ispPAC®20 for Temperature Monitoring

Introduction

The ispPAC20 is a member of the Lattice Semiconductor family of In-System Programmable (ISP™) analog circuits. Analog building blocks in the ispPAC family replace traditional analog components such as op amps and active filters and eliminate the need for most external resistors and capacitors. The device is programmed while it is in-circuit, using Windows®-based PAC-Designer® software. After simulation in PAC-Designer, the design is downloaded to the part, which utilizes nonvolatile E^2CMOS® technology to configure such things as circuit topologies, gains, and feedback capacitor values.

Figure 1 is a block diagram of the ispPAC20. The device includes two programmable gain blocks, called PACblocks, with differential instrumentation-amplifier inputs, differential outputs, and variable gains from ± 1 to ± 10 in integer steps. The feedback capacitors in these blocks can be selected from a 128-value range of approximately 1 pF to 63 pF for active filter applications. The feedback resistors of these devices can also be switched in for gain or switched out so they act as integrators. One of the PACblock inputs has a two-position multiplexer, and another has a pin-controllable inverter, which can also be controlled from certain internal nodes. In addition, an 8-bit DAC and two comparators are included in the ispPAC20. Comparator connections can be made directly inside the device, or an external, differential comparator input may be applied. The comparison threshold voltage can be set by the DAC, and the output of one comparator can also be clocked in a register, or used with the output of the second comparator in an exclusive-OR gate or to drive an RS flip-flop for additional logic functionality. Reference voltages of 1.5V and 3.0V are available, as is a standard 2.50V bandgap reference. All of these features make the ispPAC20 a very versatile device for solving analog circuitry problems.

In this application note, the ispPAC20 will be configured to monitor temperature by sensing the voltage from an externally connected temperature sensor. The combination of gain and DAC-controlled comparator threshold voltages can give a variety of monitoring choices. It will be seen that these plus the comparator sections make the ispPAC20 an ideal device for temperature measurements.

Figure 1. ispPAC20 Block Diagram

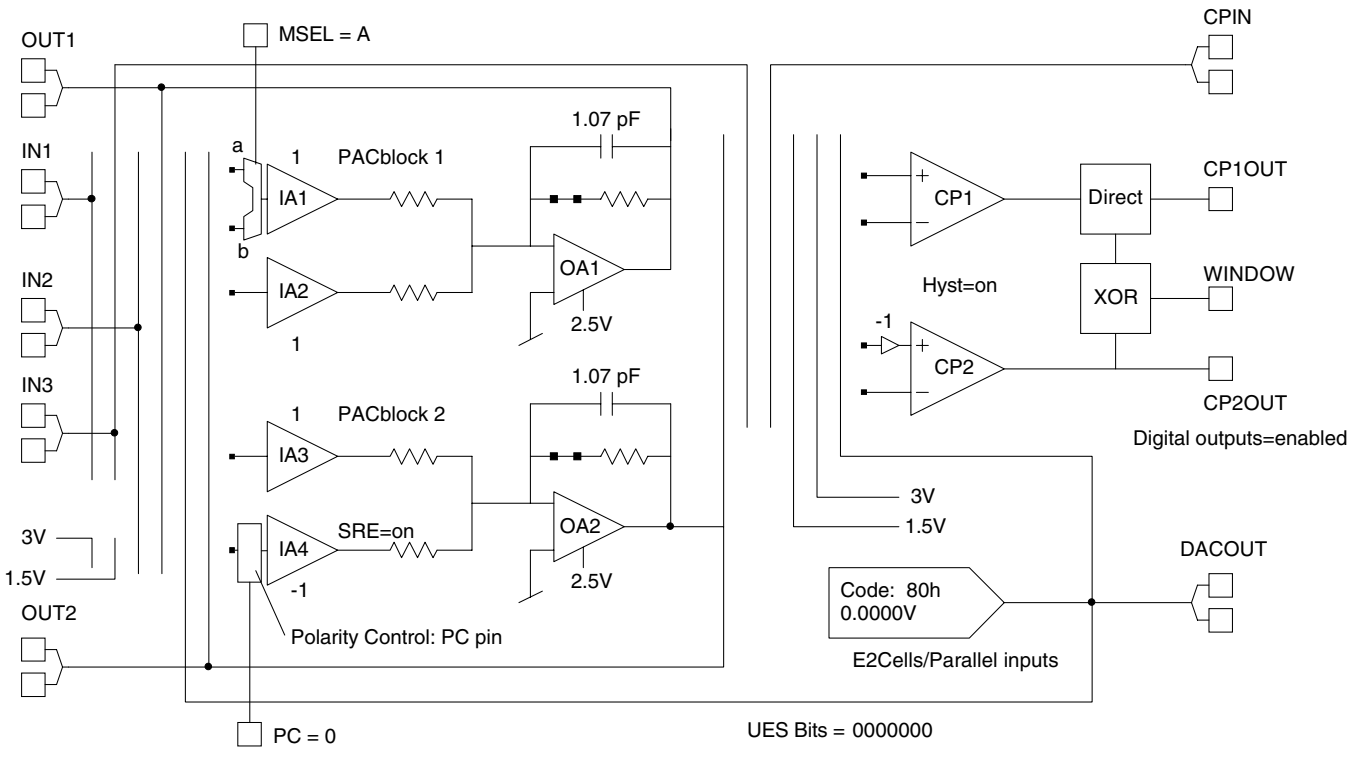

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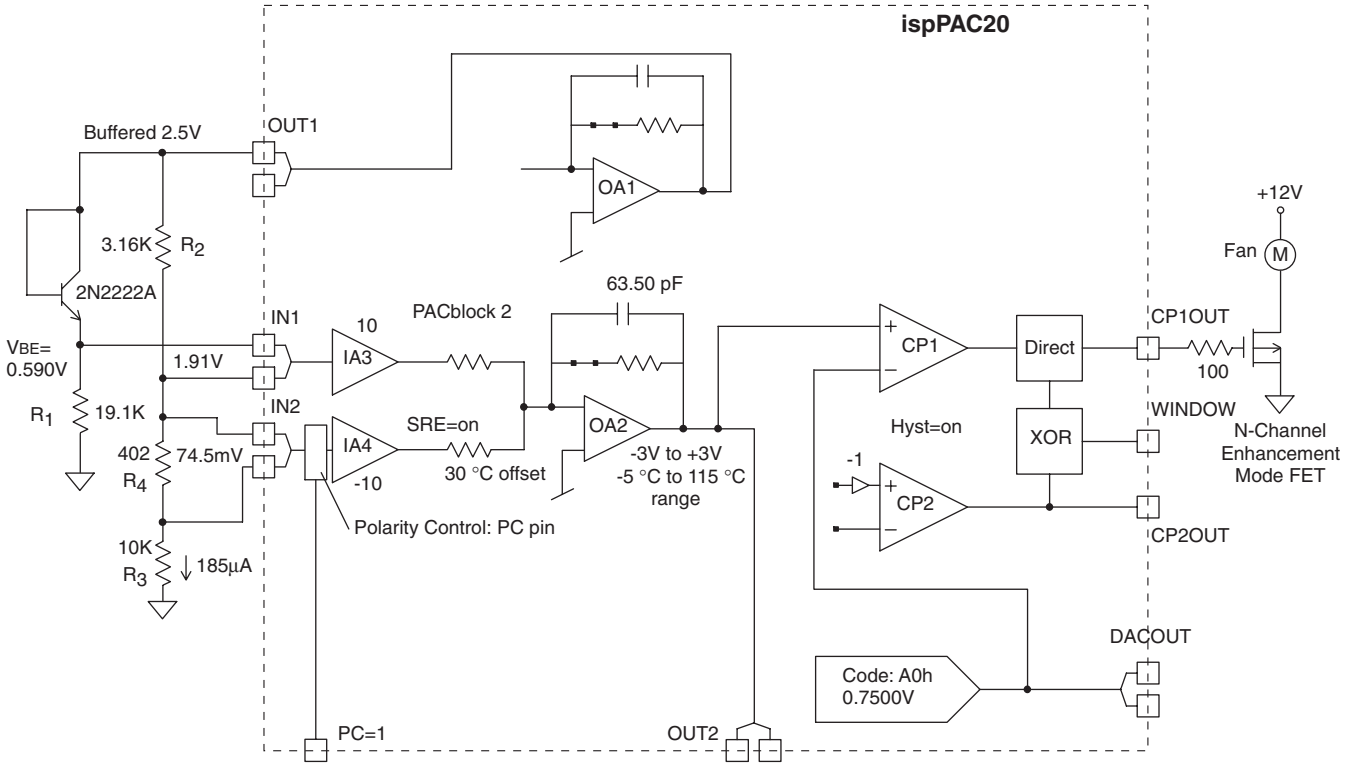
Figure 2. Temperature Monitoring



Temperature Monitoring Application

An excellent application of the ispPAC20 is temperature monitoring. The PAC device can apply gain and offset to the voltage from a solid-state temperature sensor (which can be as simple as a pn-diode junction or a transistor base-emitter junction) and apply the output to one of its comparators. The resulting signal can be used to turn on a heating or cooling element, depending on whether the temperature is above or below the threshold.

As mentioned in AN6010, *ispPAC10 Low Cost Temperature Measurement*, silicon diode junctions can be used as temperature sensors because their forward-voltage changes by approximately -2.2 mV for every 1 °C increase. A typical example circuit is shown in Figure 2. The transistor V_{BE} is biased from the buffered bandgap reference voltage to give approximately 100 µA of emitter current, creating a V_{BE} of approximately 590 mV. A resistor divider from the same buffered $VREF_{OUT}$ to ground gives approximately the same voltage (1.91V) for comparison. Additional offset is generated across R4 to effectively raise the nominal temperature range. The DAC output voltage can then be programmed to set the threshold anywhere in this range. For the values shown in Figure 2, R4 has about 185 µA flowing through it, generating a voltage of about 74.5 mV. When amplified by ten and inverted, this corresponds to an approx. 30 °C offset in the temperature range, which then becomes -5 °C to +115 °C. To set the comparator threshold to 85 °C in this example, the DAC output voltage would need to be set for (85 - 25 = 60 °C) - 30 °C offset = 30 °C. This corresponds to 0.741V above 2.500V, or 3.241V. A DAC code of A0h gives 0.750V above 2.500V, which is close to the desired value. Other temperature ranges and offsets can be set by varying the PACBlock's gain and resistor values.

The threshold can be varied in 23.4 mV steps, which is about 0.947 times the 24.7 mV/°C that comes from the PACblock output (which is somewhat dependent on individual transistor characteristics). In other words, the resolution of the DAC allows the temperature to be set in approximately one-degree increments if the temperature sensor is followed by a gain of ten.

The hysteresis of the comparators is set to "on" and is typically 2 lsb's, corresponding to a difference of 46.8 mV, or approximately 1.9 °C (after the gain of ten) in the present circuit. This is more than sufficient hysteresis to keep the temperature control circuit from "hunting" between on and off.

Summary

An application circuit using the ispPAC20 to monitor temperature has been shown. The IC's voltage reference is buffered and used to drive a bipolar transistor's V_{BE} in a temperature-sensing application. The reference voltage may also be used to add an offset into the temperature measurement, centering the range on a more-useable value. This application utilizes most of the circuitry in an ispPAC20. With two comparators and a DAC in addition to two programmable-gain PACblocks, the device permits a number of applications where a settable comparison threshold needs to be part of the circuitry. The instrumentation-amplifier gain blocks allow signals to be amplified and conditioned before being applied to the comparators, which enhances the utility of the part. Additional logic functions in the device, such as a two-channel input multiplexer and a pin-selectable inversion as well as an output exclusive-OR gate or R-S flip-flop, while not discussed in this paper, also enhance possible applications.

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[1] AN6010 "ispPAC10 Low Cost Temperature Measurement", Lattice Semiconductor, September, 1999.