Voltage Monitoring with the ispPAC30

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Application Note AN6025

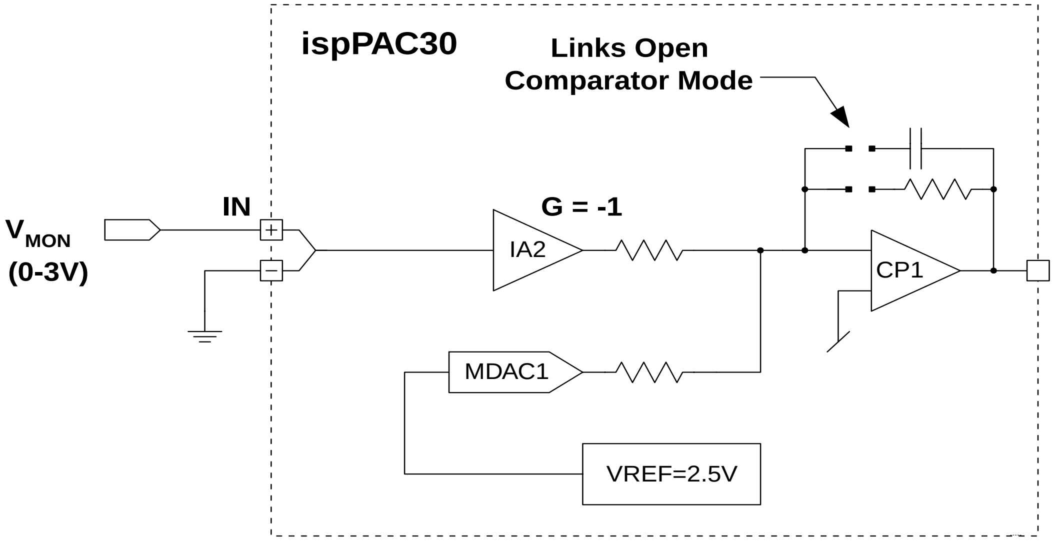
Introduction

One application for the ispPAC®30 is monitoring whether or not a voltage exceeds a preset threshold, and reporting this information as a digital true/false signal. Examples of where voltage monitoring is used are in power management circuits, industrial process controls, and sensor assemblies. Voltage monitors are used in power-management circuitry to tell the rest of a system when power has reached stable levels and the system can begin normal operations. In many cases it is also important for a system to be aware when power is removed, so as to be able to perform an orderly shutdown. In process controls and sensor assemblies, a physical parameter (e.g. temperature, speed, pressure) is often compared to some arbitrary preset threshold. The most convenient way to do this is to use a sensor to convert the physical parameter into an electrical signal, such as a voltage, and then monitor the voltage. When the measurement exceeds the threshold, an alarm signal is generated, either instructing a piece of equipment to take some action, or calling for operator intervention. Because of its combination of non-volatile EE-memory, differential instrumentation-amplifier inputs, and on-the-fly reprogrammability under SPI control, the ispPAC30 is well suited to implementing voltage monitors for these applications and many more. This application note shows several ways in which the Lattice ispPAC30 can be used to implement voltage monitoring functions.

Monitoring Positive Voltage

Figure 1 shows the simplest way in which an ispPAC30 may be used as a voltage monitor. This circuit monitors a single-ended input signal which may range from 0 to +3 V, which may be compared against a threshold ranging from 0 to 2.5V. When the input voltage exceeds the reference value, the output swings HIGH (+5V), and when the input voltage falls below the reference value the output swings LOW (0V).

Figure 1. Basic ispPAC30 Voltage Monitor Circuit



This circuit operates by detecting the difference between the input voltage and a fixed reference voltage. MDAC1 and VREF are used to generate a desired reference voltage. The input signal (V_{MON}) is routed through IA2, which is set to a negative gain value, resulting in a negative signal level at its output. Even though the ispPAC30 runs from a single +5V supply, its internal differential structure can readily represent ‘negative’ signal values. When the positive reference from the MDAC is summed with the input signal from IA2, the result will be negative if the magnitude of the input signal exceeds the magnitude of the reference, and positive if it is less than the reference.

The difference between the reference voltage and input signal is then detected by the output amplifier (OA1). To use OA1 as a threshold detector requires that it be set into comparator mode, with both the feedback capacitor and feedback resistor switched out of the circuit. Switching the feedback capacitor out of the circuit minimizes OA1's response time. Switching out the resistive feedback causes OA1 to operate open-loop, with an effective gain exceeding 80dB. In this mode, the output of OA1 will swing from 0-5V with rise and fall times of a few microseconds in response to small differences in input signal. As shown, this circuit will provide a HIGH output (+5V) when V_{MON} is below the reference setpoint, and a low output (0V) when V_{MON} rises above the setpoint.

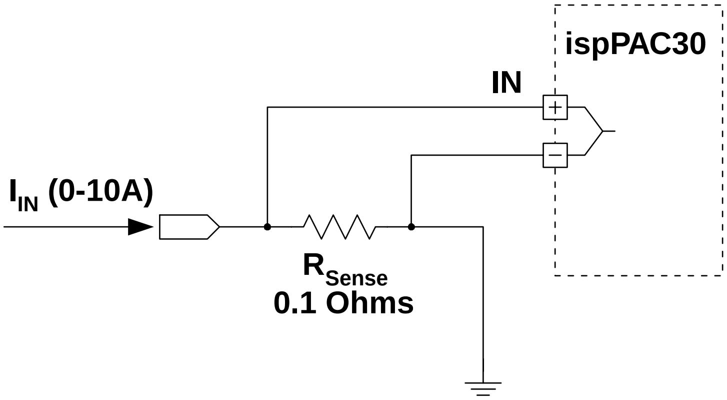
Because the threshold is set by a combination of VREF and MDAC1 settings, there are several possible ranges of threshold settings and resolutions from which to choose. Table 1 summarizes the available ranges.

Table 1. MDAC Resolution vs. VREF Setting

VREF Setting (mV) (Maximum Threshold)	Resolution (mV)
64	0.5
128	1
256	2
512	4
1024	8
2048	16
2500	19.5

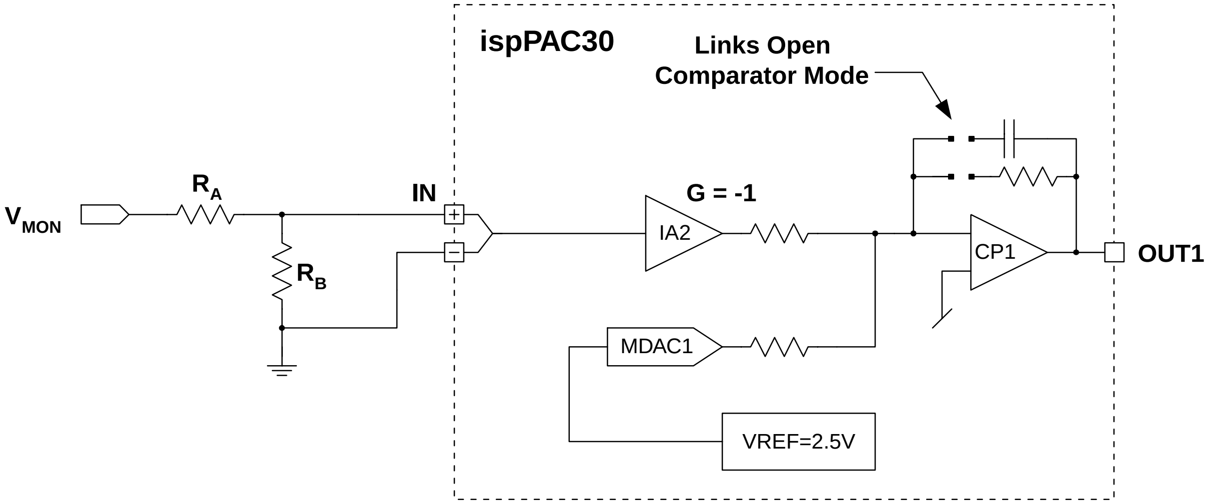
Because the ispPAC30 has differential inputs, it is also possible to monitor differential voltages, as long as the voltages present at both the '+' and '-' input terminals are both within the common-mode range of the device (0-3V). One monitoring application in which a differential signal is often preferable to a single-ended one is in a resistive current-sensing circuit, such as the example shown in Figure 2. In this circuit, current flowing back to ground is measured by a 0.1 Ohm current-sensing resistor. Because interconnections such as wiring and PCB traces can have resistance that is either a significant fraction of, or comparable to that of the current-sensing resistor, it is important that the voltage measured across the resistor actually be measured differentially right at the resistor terminals.

Figure 2. Monitoring a Differential Voltage



In many cases, one will want to monitor voltages that far exceed the 0-3V input range of the ispPAC30. One way to do this is to put a resistive divider between the voltage source being monitored and the input of the ispPAC30, as shown in Figure 3.

Figure 3. Extended Range Positive Voltage Monitor



There are several considerations for choosing the input resistors; among the most important are the input voltage range and the desired input impedance. The input division ratio between V_{MON} and the input of the ispPAC30 (IN) is given by:

$$\frac{V_{IN}}{V_{MON}} = \frac{R_B}{R_A + R_B} \quad (1)$$

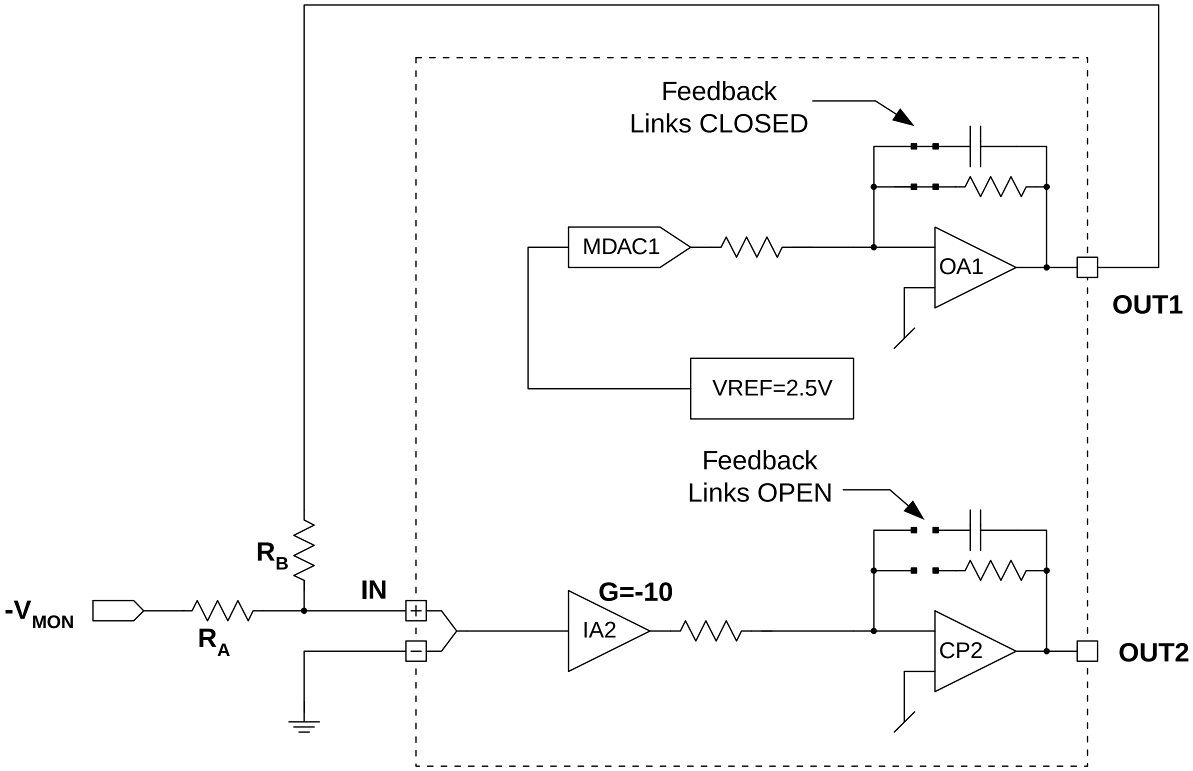
The input impedance looking into the resistive divider from V_{MON} is simply $R_A + R_B$. When using a resistive divider, the first thing one should specify is the minimum desired input impedance, and then determine a suitable set of resistor ratios to divide the input voltage down into the operating range of the ispPAC30. As an example, consider the design of a monitor for a system in which the voltage ranges from 0-15V, and for which the trip-point can be varied from 0 to 12.5V. A minimum input impedance of 100kΩ is assumed to be satisfactory for this design. Setting R_A to 100kΩ will ensure that the input impedance meets this requirement. The ratio between the maximum threshold voltage (12.5V) and the maximum MDAC output voltage (2.5V) is 5. This V_{MON} to V_{IN} ratio can be met by using a resistor ratio (R_A:R_B) of 4:1. Since R_A is already set to 100kΩ, R_B becomes 25KΩ.

If high voltages or transients are present at the input of the divider network, numerous additional issues must be considered. When monitoring high voltages, the resistor's maximum power ratings become important, as well as their ability to withstand the applied voltage safely. In cases where transients and surges are expected, not only must the resistors be able to survive them, but additional components such as capacitors, ferrite beads, and surge suppressor diodes may need to be placed at the input to the ispPAC30.

Negative Voltage Monitor

Even though the ispPAC30 inputs will only accept inputs ranging from 0-3V, it can also be used to monitor negative voltages. This can be accomplished by the circuit shown in Figure 4.

Figure 4. Negative Voltage Monitor



This circuit works by balancing an input voltage against a known reference voltage, except that the balancing in this circuit is performed by the external resistor network. A positive reference voltage determined by the configurations of VREF and MDAC1 appears at OUT1. When the following relationship is true, the voltage at the ispPAC30's input terminals is zero.

$$\frac{V_{OUT1}}{R_B} = \frac{-V_{MON}}{R_A} \qquad (2)$$

If V_{MON} is more positive, V_{IN} will become positive, while if V_{MON} is more negative, V_{IN} will become negative. Because the detection threshold is therefore '0' volts, the signal can be fed to OA2 without being summed with any other signals. In this example IA2 is set to a gain of -10 for two reasons. The first is that providing additional gain results in more clearly defined logic levels and faster edge transitions at the output of OA2. The second reason is that varying the sign of IA2's gain allows one to control the polarity of the output. Setting IA2 to a negative gain will provide a logic '1' (+5V) output when VMON goes more negative (greater magnitude) than the threshold, while a positive gain results in a logic '0' (0V) output for the same condition.

As an example of how to design a negative voltage monitor with the previous circuit, consider the case where one needs to monitor a voltage with trip-points adjustable over the range of 0 to -15V. Because the ratio between R_A and R_B is proportional to that of the input monitor range and the reference (0-2.5V):

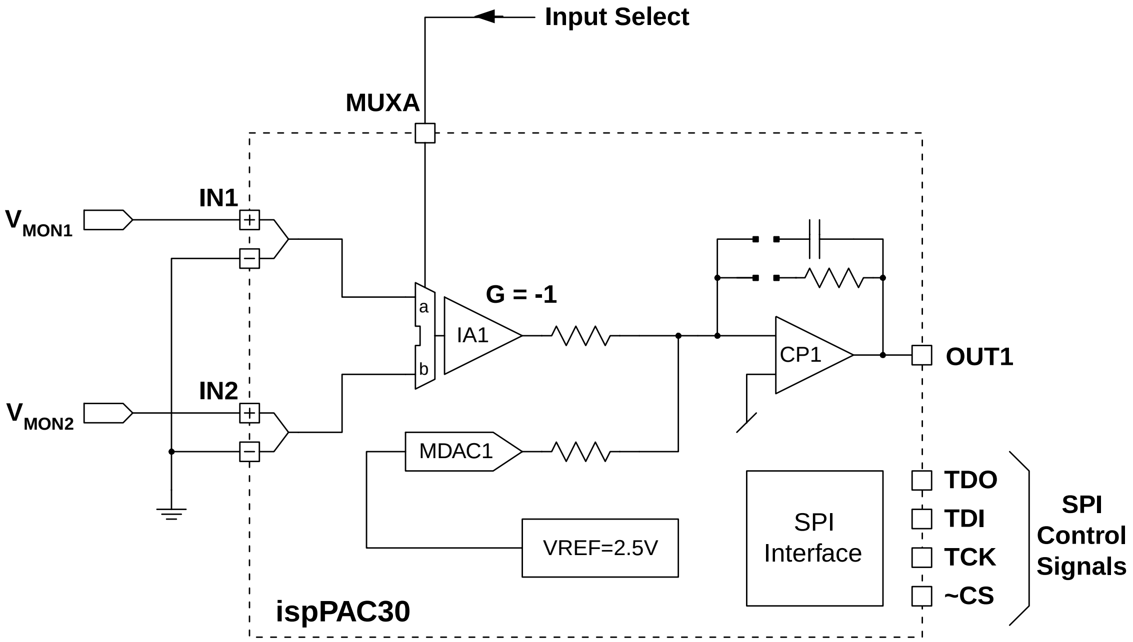
$$\frac{R_A}{R_B} = \frac{15}{2.5} = 6 \qquad (3)$$

One important consideration in the design of this circuit is limiting the maximum current that can flow through $R_{A.}$ This is because in the case of a negative overload, the ispPAC30's input protection diodes can be turned on. Excessive current through these diodes can cause the IC to behave improperly or in extreme cases (>100mA) can even damage it. For this reason one should select a value of R_A that limits input current to a worst case of +/-100µA. For a system with expected inputs ranging from 0 to -15V, a reasonable choice for R_A might be 300kΩ. This will result in a R_B being 50kΩ (330kΩ / 6). To set a monitor threshold of -12V requires an OUT1 voltage of 2V (1.992V is the closest available).

Multiplexed Monitoring

The ispPAC30 can also monitor multiple inputs, up to a maximum of four, using its input multiplexers in combination with the two OA stages. Figure 5 shows how a single OA and reference/MDAC combination can be used to monitor two separate voltages. The voltage to be monitored (IN1 or IN2) is selected by the MUXA pin.

Figure 5. Monitoring Two Voltages with Multiplexer



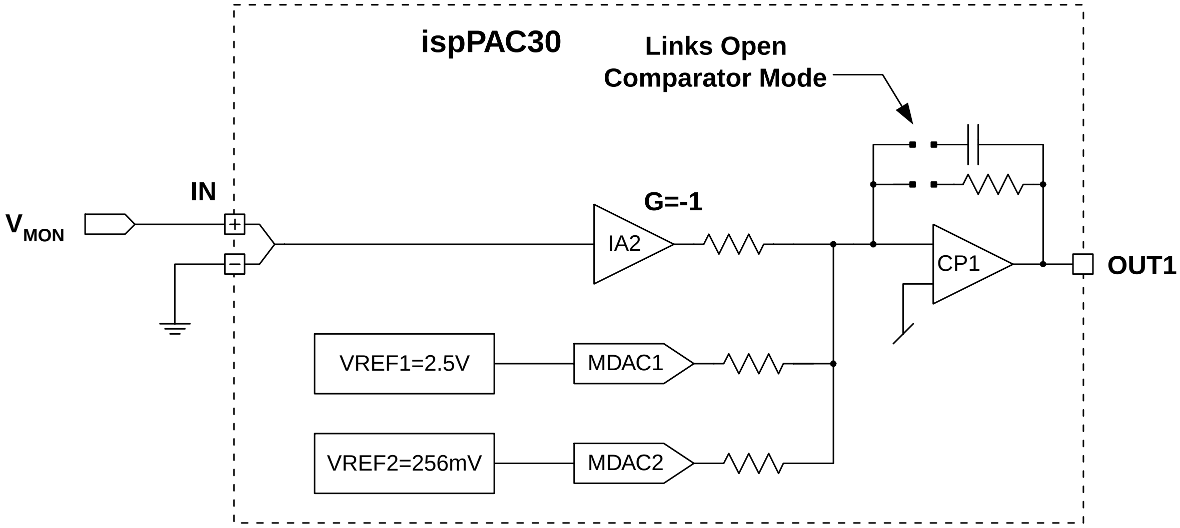
Because both inputs are compared against the same reference, it might seem at first glance that the trip threshold must be the same for both the IN1 and IN2 channels. Since the MDAC and reference settings can be changed dynamically over the ispPAC30's SPI port, however, it is possible to have unique threshold settings for both input channels. To do this requires additional external circuitry such as a microcontroller that controls both the MUXA pin and the SPI port. Whenever the multiplexer is switched, the appropriate set of values will need to be written into the ispPAC30's configuration SRAM to set the corresponding threshold.

Increasing the Resolution

Because the value of the ispPAC30's voltage references can be set to several output voltages, ranging from 64mV to 2.5V, it is possible to use high-value MDAC settings (>50% Full Scale) to synthesize most desired thresholds. This means that that a given threshold (32mV or greater) can be set with a resolution of +/-0.8%.

If a higher degree of resolution is needed, the two voltage references and MDACs can be combined in a coarse-fine adjustment scheme, as shown in Figure 6. In this circuit VREF1 and MDAC1 provide an adjustment range of 0-2.5V with 19.7mV of resolution, while VREF2 and MDAC2 provide an adjustment range of +/-64mV with 0.5mV of resolution. By adding these two sources together one gets a total adjustment range of 0-2.56V with an effective resolution of 0.5mV.

Figure 6. Coarse-Fine Adjustment using Two References



In this example, the effective resolution provided by combining the two references would normally require a 13-bit DAC to replicate. One should keep in mind, however, that resolution is not the same thing as accuracy. The absolute accuracy provided by an ispPAC30 using this technique is approximately equivalent to that provided by a 10-bit DAC.

In many situations, such as those in which a parameter is being interactively adjusted for optimal performance, absolute accuracy may not be of paramount importance. Stability and resolution of the adjustment are more important than the absolute accuracy of the adjustment.

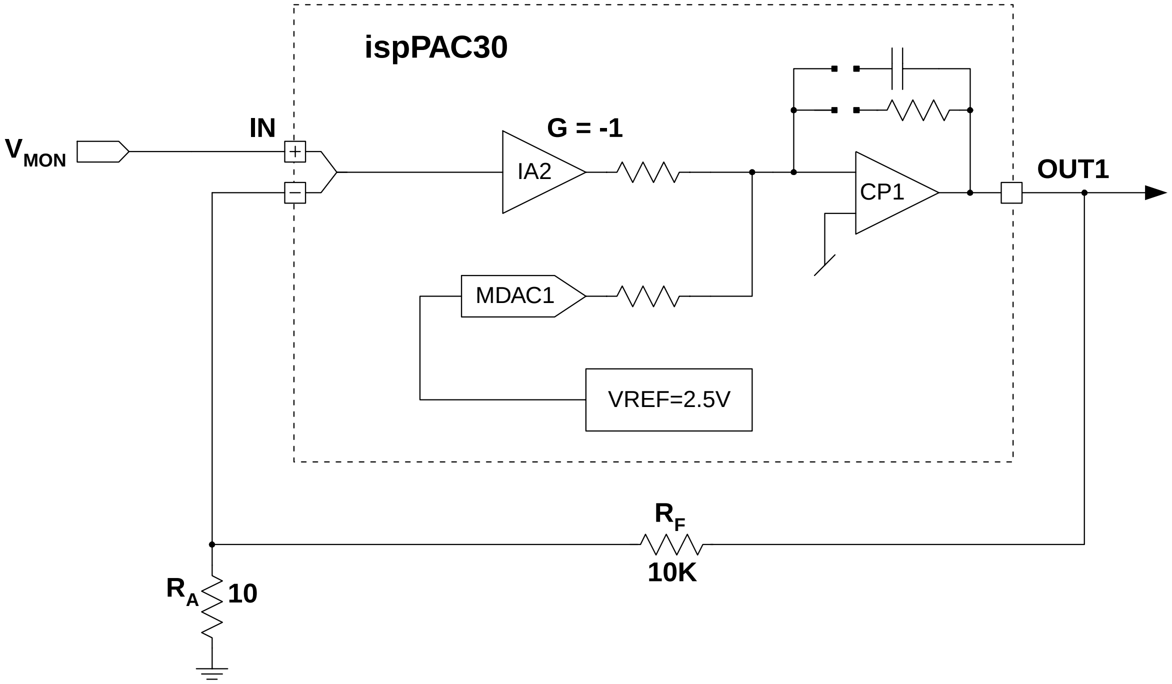
Adding Hysteresis

In cases where the input signal is either slowly varying, or contains electrical noise, the outputs of the previously described voltage monitor circuits may make multiple transitions or even oscillate when the input voltage is near the threshold voltage. This behavior occurs because only a tiny change in input voltage is required to change the state of the output. For applications in which this is unacceptable, adding *hysteresis* to the voltage monitor circuit can provide a simple solution.

Hysteresis in a monitor circuit is a small difference between the turn-on and turn-off thresholds. Once the output turns ‘ON’, it will not turn ‘OFF’ until the input signal is dropped by some preset amount. One way to add hysteresis is to provide a small amount of positive feedback around the threshold detector. In the circuit of Figure 7, positive feedback is provided external to the ispPAC30 by resistors R_A and R_F.

When VMON is higher than the threshold voltage, OUT1 will be low (0V). This will result in 0V being applied to the negative input terminal through voltage divider formed by R_A and R_F. When VMON drops below the threshold voltage, OUT1 will go high (+5V). In this case, the external voltage divider raises the voltage at the negative input terminal by approximately 5mV. Because the input is measured differentially between the positive and negative input terminals, raising the voltage at the negative terminal effectively reduces the input voltage. This change to the input voltage reinforces the high output state. Similarly, when the input voltage rises past the threshold voltage, the high-to-low transition of the output lowers the voltage at the negative input terminal, reinforcing the transition.

Figure 7. Voltage Monitor with Hysteresis



From a behavioral standpoint, adding positive feedback separates the turn-on and turn-off points for this voltage monitor by about 5mV. Because the output swing of the ispPAC30 will be approximately 5V (ground to VS), this hysteresis can be estimated by:

$$V_H = \frac{5R_A}{R_A + R_F} \tag{4}$$

In addition to being useful in the circuit shown in Figure 7, this method of adding hysteresis to a voltage monitor can also be used with suitable modifications in many of the other circuits described here.

Conclusion

This application note has shown several ways in which the ispPAC30 can be used as a voltage monitor. Example monitor circuits for positive, negative, and differential volategs were described. A simple and inexpensive means of adding hysteresis to an ispPAC30-based voltage monitor was also shown.

Technical Support Assistance

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