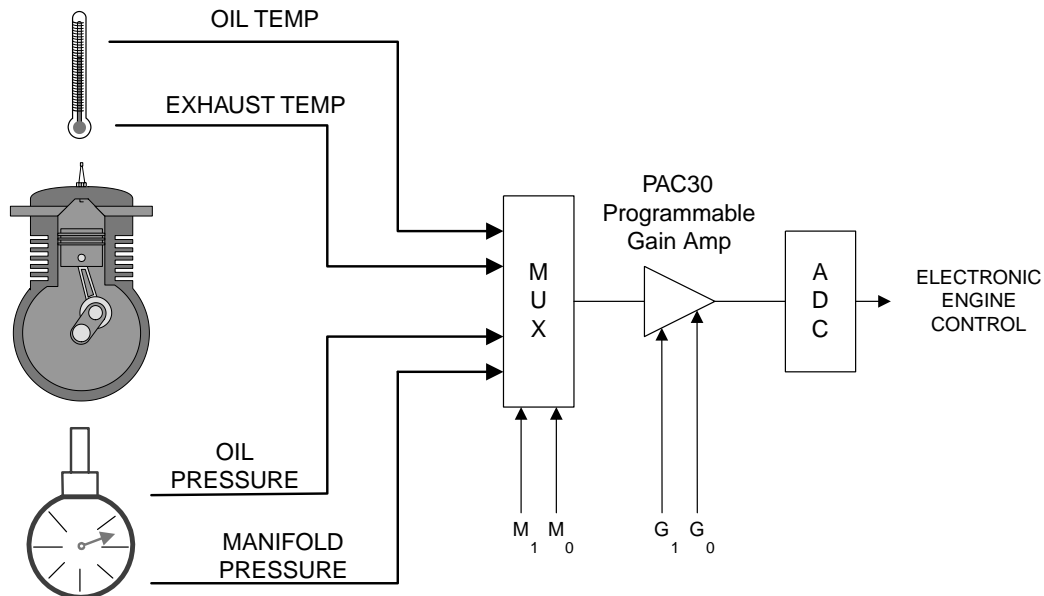


The flexibility of the ispPAC[®]30 provides circuit designers with a variety of signal conditioning solutions. One aspect of this flexibility is the ability to adjust the gain using several methods. The E²CMOS[®] memory holds the configuration of the ispPAC30 during power down states and can be reprogrammed through the standard JTAG TAP using the ispDOWNLOAD[®] cable. Direct access to the configuration registers is also available through the serial peripheral interface (SPI). Using the SPI, the user can adjust the gains, control the routing and modify the configuration an unlimited number of times. In cases where serial control of the gain is not an option, the gain of the ispPAC30 can be controlled by two logic lines. The last case is the one we discuss in this circuit solution; the serial solutions are supported in other applications literature. Often in data acquisition or control systems, a variable gain amplifier is used to condition signals in front of an analog to digital converter (ADC) to maximize the dynamic range of a given signal. This is especially true when the input signals span multiple orders of magnitude. Let's use Figure 1 for an example. In this case the four different engine signals are to be monitored by an electronic engine control unit (ECU) to optimize fuel economy and emissions control. Two temperature signals and two pressure signals are fed to a multiplexer (MUX), then to a programmable gain amplifier (PGA), and then to the ADC. The logic control lines M0 and M1 select which signal is to be routed to the PGA. Likewise, the logic control signals G0 and G1 select the gain of the PGA. All four logic control signals originate from the microcontroller in the ECU. For this example, the maximum input to the ADC is 5V. Thus the PGA is programmed to gain the full-scale signals as close to 5V as possible.

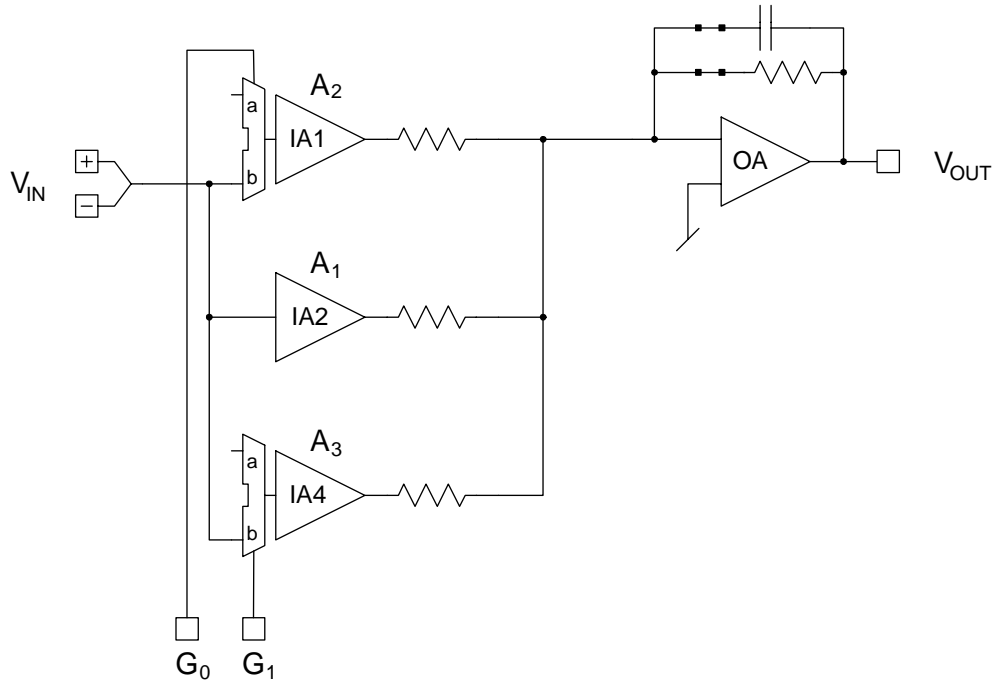
Figure 1. Simplified Schematic of System Using ispPAC30 for Programmable Gain



If the oil temperature sensor has a full-scale output of 1.25V, the PGA would be set for a gain of 4.0, resulting in a 5.0V signal to the ADC. Likewise, if the exhaust temperature sensor has a full-scale output of 1.5V, the PGA would be set to a gain of 3.0, resulting in 4.5V going to the ADC. To round out this example, if the two pressure sensors had full-scale outputs of 2.0 and 2.5V, the PGA would be set to a gain of 2.0, resulting in a 4.0 and 5.0V signal to the ADC. Figure 2 shows how the ispPAC30 can be configured to be a digitally programmable gain instrumentation amplifier. Within the ispPAC30, two Input Amplifiers (IA1 and IA4) have a built-in a/b multiplexer. By routing the input signal within the ispPAC30 to the b input of the multiplexer and leaving the a input unconnected, the multiplexer control line selects whether or not the IA output is summed at the input of the Output Amplifier (OA). The gain for both IA1 and IA4 can be preset from -10 to +10 (in integer steps). However, with both IA1 and IA4 deselected by the a/b multiplier, IA2 can pass the input signal to the OA. IA2's gain can also be preset to any integer

value from -10 to +10. Thus, the state of gain control lines G_0 and G_1 determine the net signal gain through the ispPAC30. The gain of the ispPAC30 configured in this manner is given by Equation 1. G_0 and G_1 may assume the value of one or zero and the gains (A_1 , A_2 and A_3) may have an integer value from -10 to +10.

Figure 2. ispPAC30 Configured as a Digitally Programmable Gain Amplifier



Additionally the feedback network around the OA provides a first order low pass filter with a corner frequency that is programmable in the range of 48kHz to 1.5MHz in seven steps. From either Equation 1 or Figure 2, it can be seen that several possibilities are available to the designer. We have summarized a few such designs in Table 1 (gain accuracy for the ispPAC30 is typically 1%).

While several programmable gain instrumentation amplifiers are on the market with a variety of fixed gains, Lattice Semiconductor’s ispPAC30 can be programmed via the JTAG TAP port at the point of distribution, during assembly, at final test, or calibration. Also, the gain can be adjusted dynamically through the SPI interface, which is described in additional ispPAC30 application literature. Therefore, instead of stocking several types of programmable gain amplifiers for different applications, the ispPAC30 can provide solutions to a variety of designs. Furthermore, the flexibility of the ispPAC30 programmable gain amplifier, described in this circuit solution, accommodates changes in the front end without having to redesign hardware. For our example, if the manifold pressure sensor is upgraded for a turbo charger and has a higher full-scale output, the firmware could be modified or a different set of gains could be programmed into the ispPAC30.

Table 1. Various Gains for ispPAC30 PGA

G_1	G_0	Gain	Gain	Gain	Gain	Gain
		$A_1=1, A_2=1, A_3=2$	$A_1=1, A_2=1, A_3=3$	$A_1=1, A_2=1, A_3=4$	$A_1=2, A_2=2, A_3=4$	$A_1=1, A_2=9, A_3=10$
0	0	1	1	1	2	1
0	1	2	2	2	4	10
1	0	3	4	5	6	11
1	1	4	5	6	8	20

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