Multiplexed Data Acquisition System Considerations

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A Practical Multiplexer Application

Figure 1 illustrates a practical data acquisition system hookup using an analog multiplexer, a monolithic sample-and-hold and an A/D converter. The HA-242X and HA-53XX sample-and-holds are particularly good choices for this type application because they eliminate the need for a separate high impedance, high slew rate buffer amplifier. Their acquisition time is consistent with CMOS multiplexer settling times and most available A/D conversion times. Errors, after initial adjustment, are consistent with up to 12 bit absolute accuracy over a wide temperature range.

A. Accuracy
DC error sources include:

1. Multiplexer:
   a. input offset = R_{SOURCE} x $I_{S(OFF)}$
   b. output offset = $R_{(ON)}$ x [$I_{D(ON)}$ + $I_{bias\ (S/H)}$]
2. Sample-and-Hold
   a. input offset voltage
   b. charge injection; sample-to-hold offset
   c. gain error during “hold”
   d. drift during hold
3. A/D converter:
   a. linearity
   b. gain drift
   c. offset drift

Items 1(a) and (b), and 2(d) become significant only at very high temperatures. 2(a) and (b) are initially adjusted out with the offset adjustment pot on the S/H. 2(c) is usually adjusted out by A/D gain adjustment, but could also be removed by a voltage divider feedback on the S/H to give a slightly greater than unity gain during “sample”. After initial adjustments, typical S/H errors are less than 0.5mV over 0^{o}C to +75^{o}C. Note that after adjustment, there may be an appreciable offset at the S/H output when switching from sample to hold. This is not a problem, since accuracy is required only during “hold”, and the system is adjusted for this.

The largest system errors are usually 3(b) and (c) due to drifts with temperature and time. If two multiplexer channels can be dedicated for stable (+) and (-) reference voltage inputs, then the data processor can continuously calibrate the system, effectively removing all errors, except 1(a) and 3(a) which are usually negligible.

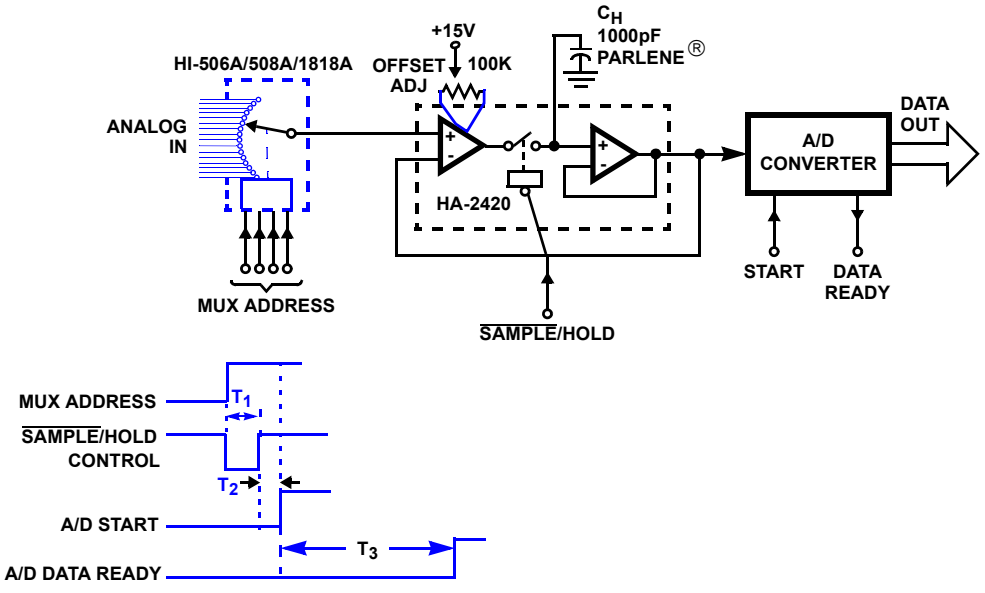

FIGURE 1. TIMING DIAGRAM

B. Timing

The timing diagram in Figure 1 indicates the necessary system delays for each multiplexer address:

- T_1 is the combined acquisition time for the multiplexer and S/H.
- T_2 is the short interval required for the sample-to-hold transient to settle.
- T_3 is the A/D conversion time.

The following table indicates minimum recommended timing for ±10 volt input range for acquisition/settling times to 1/2 LSB accuracy:

MINIMUM RECOMMENDED TIMING FOR ±10 VOLT V_{IN}

	T_1	T_2
10 bit:	6µs	1µs
12 bit:	12µs	2µs

The multiplexer, by itself, requires about 2µs and 9µs settling to 10 bit and 12 bit accuracy, respectively; but fortunately this can be concurrent with S/H acquisition time. This is longer than would be predicted by the R_{ON} C_D time constant; probably because of internal distributed capacitance, a rather long period is required to traverse the last few millivolts towards the final value.

It should be noted that impedance conditions at the multiplexer inputs can affect the necessary acquisition time. At the instant the multiplexer switches from one channel to a new one, there is appreciable current pulled through the new channel input in order to charge C_D from its old level to its new level. This can cause ringing on signal lines, or glitches at signal conditioning amplifier outputs which require longer periods to settle. It is best for signal conditioning amplifiers to be wideband types, such as the HA-5170, so that their high frequency output impedance is low and recovery from load transients is fast, even though the signal to be measured is very low bandwidth.

The T_1 and T_2 times could be eliminated by alternating two S/H circuits, acquiring a new signal on the second while A/D conversion is taking place. The two S/H circuits would have inputs connected together, and outputs alternately connected to the A/D by an analog switch. Total time, then, would be T_3 plus the analog switch settling time.

If the MUX input channels are sequentially switched, each channel will be sampled at a rate of:

$$FS = \frac{1}{N(T_1 + T_2 + T_3)}$$

samples per second, where N is the number of channels. The frequency spectra of the input signals must then be no higher than $\frac{FS}{2}$.

In many systems, however, each channel carries a different maximum frequency of interest, and it may be desirable to depart from simple sequential scanning. Quickly varying signals, for example, could be addressed several times during a scanning period.

C. Adding Channels

For more than sixteen channels, several multiplexers may be tied together at the outputs, and addressed in parallel, but with only one “enabled” at a time. The MUX output offset will be increased, since I_D (OFF or ON) is additive. Also, output capacitance, C_D, is additive, creating increased access times.

These errors can be minimized in large systems by having several tiered levels of multiplexing; where the outputs of a number of MUXs are individually connected to the inputs of another MUX.

D. Differential Multiplexing

When low level analog signals must be conducted over a distance, it is generally better, from a noise pickup standpoint, to use a balanced transmission line carrying signals which are differential with respect to ground.

A differential multiplexer is used for this purpose, as shown in Figure 2. Two sample-and-hold circuits plus an op amp form a high impedance differential sample-and-hold with gain. At gains greater than 4, the minimum sampling time (T_1 in previous example) must be increased proportionately to gain to allow for overdamped settling characteristics.

When handling low level, or high impedance signals, consideration should be given to adding signal conditioning amplifiers at the signal sources, since this can often produce less troublesome, more accurate, lower cost systems.

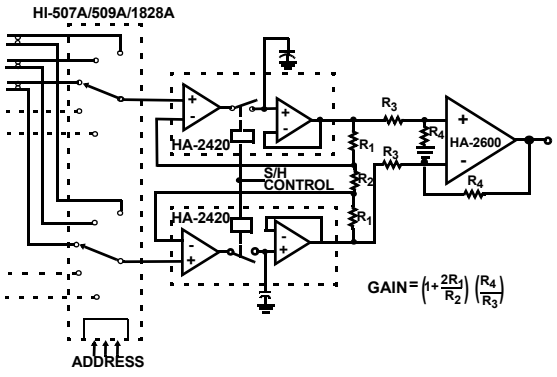

FIGURE 2. DIFFERENTIAL MULTIPLEXER

E. Demultiplexing

Since the switches in a CMOS MUX conduct equally well in either direction, it is perfectly feasible to use it as a single input-selected multiple output switch. Figure 3 illustrates its use as a demultiplexer, with capacitors to hold the output signal between samples. When the address lines are synchronous with the address of the original multiplexer, the output lines will create the original inputs, except level changes will be in steps.

Overvoltage protection is not effective with signals injected at the normal MUX output, so an external network should be added, if necessary.

A more accurate demultiplexer could be constructed using the HA-2420/2425 sample-and-hold for each channel, connecting inputs together and sampling each channel sequentially.

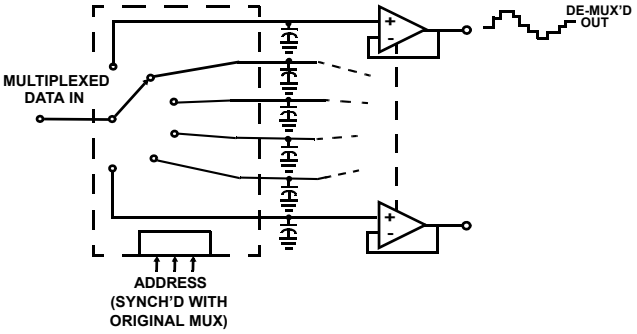

FIGURE 3. DEMULTIPLEXER

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