ANALOG DEVICES

AN-35 APPLICATION NOTE

ONE TECHNOLOGY WAY • P.O. BOX 9106 • NORWOOD, MASSACHUSETTS 02062-9106 • 617/329-4700

Understanding Crosstalk in Analog Multiplexers

INTRODUCTION

One of the most troublesome errors in analog multiplexers is crosstalk. Various schemes have been devised to reduce its effects. One designer will terminate the multiplexer in a 10kΩ resistive impedance. Another will short the multiplexer node to ground between address changes with an analog switch. A third engineer will terminate the multiplexer node in 1MΩ because he doesn't want to live with the attenuation which comes about with any lower impedance. What is confounding about these three situations is that the solution is correct in each case. THE CORRECT SOLUTION IS DICTATED BY THE APPLICATION.

To understand why the solution is application dependent, it is necessary to dig rather deeply into what crosstalk really is. When this is done, crosstalk is found to have not one, but three components in a multiplexer. To differentiate the components one from the other, it is convenient to give them names:

1. Static crosstalk (CT)
2. Dynamic crosstalk (DCT)
3. Adjacent Channel crosstalk (ACCT)

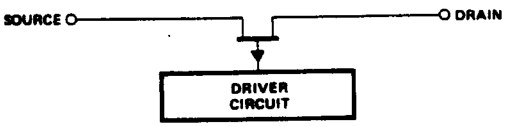
This application note explains the three crosstalk components qualitatively and quantitatively. The qualitative discussion tells what component(s) should be considered in various applications. The quantitative discussion uses both theoretical and empirical information to arrive at conclusions about what performance should be expected.

STATIC CROSSTALK (CT)

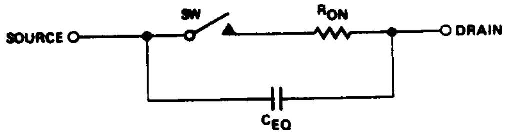
To introduce the concept of crosstalk, Figure 1 is helpful. A basic analog switch may be constructed with a FET (JFET or CMOS) and a suitable driver which switches it OFF and ON, as shown in Figure 1a. The equivalent circuit, as shown in Figure 1b, models the analog switch such that when the ideal switch (SW) is closed, the switch has an ON resistance R_{ON}. When SW is open, the OFF impedance is determined by C_{EQ}. A two-channel multiplexer circuit, made up of two analog switches connected as shown in Figure 1c, shows how signals from one channel can be coupled into the other channel. Theoretically, V_{OUT} consists of e_1 modified by the resistor divider formed by R_{ON1} and R_L (assumes reactance of C_L is $\gg R_L$). However, the capacitance of switch number two (C_{EQ2}) does couple some portion of e_2 into V_{OUT}. This is the simplest example of crosstalk.

The model which explains static crosstalk is relatively simple and may be derived from the OFF isolation model. Figure 2a shows the OFF isolation model as capacitive coupling from the input to the output of an OFF switch. This condition may be duplicated in Figure 1c by opening SW_1 and setting $e_2 = 0$. Coupling from input to output is accomplished through C_{EQ}, and this parameter may be computed from measurements of V_{IN}, V_{OUT}, and frequency. In the case of static crosstalk, C_{EQ} is shown coupling into a parallel combination of R_{ON} with R_L and C_L (Figure 2b). The two channel multiplexer shown in Figure 1c reduces to the circuit in Figure 2b, where $e_1 = 0$, $e_2 = V_{IN}$, and C_{EQ} is the coupling capacitance from e_2 to V_{OUT}.

(a) FET ANALOG SWITCH + DRIVER



(b) ANALOG SWITCH EQUIVALENT CIRCUIT



(c) 2-CHANNEL MULTIPLEXER

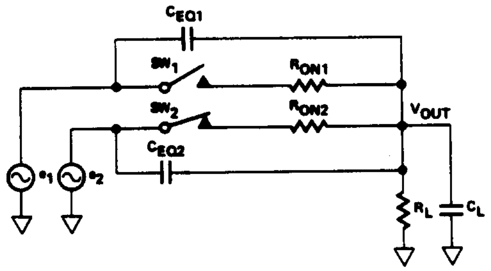


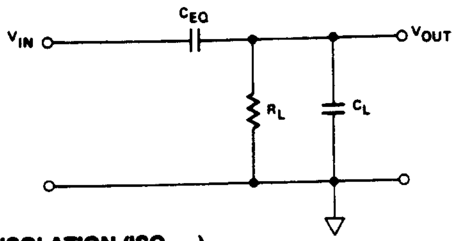
Figure 1. Essentials of an Analog Multiplexer

Since R_L is generally 10kΩ or more, and typical analog switches are less than 1kΩ, static crosstalk is much smaller than OFF isolation. The crosstalk and OFF isolation numbers quoted on analog multiplexer data sheets are derived from the models shown in Figure 2. Unfortunately the one component of crosstalk specified is the least troublesome of the three. However the crosstalk figures on data sheets will alert the designer to those devices which absolutely will not satisfy his requirements.

There are applications where the static crosstalk specification given on data sheets is adequate. When the multiplexer is being used as a one-of-many switch, and is not being cycled through all channels on an automatic basis, then the static crosstalk component will give accurate prediction of the actual performance. Examples of such applications are:

1. Audio/Video Selector Switch
2. Programmable Gain Amplifier
3. Programmable Power Supply

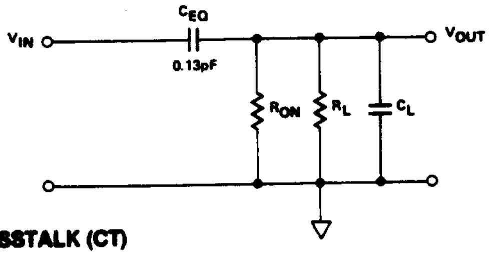
(a) OFF ISOLATION EQUIVALENT CIRCUIT



"OFF" ISOLATION (ISO_{OFF})

The proportionate amount of a high frequency analog input signal which is coupled through the channel of an "OFF" device. This feedthrough is transmitted through $C_{DS(OFF)}$ to a load comprised of $C_{D(OFF)}$ in parallel with an external load. Isolation generally decreases by 6dB/octave with increasing frequency.

(b) STATIC CROSSTALK EQUIVALENT CIRCUIT



CROSSTALK (CT)

The proportionate amount of cross-coupling from an "OFF" analog input channel to the output of another "ON" output channel.

ure 2. Model for Static Crosstalk

DYNAMIC CROSSTALK (DCT)

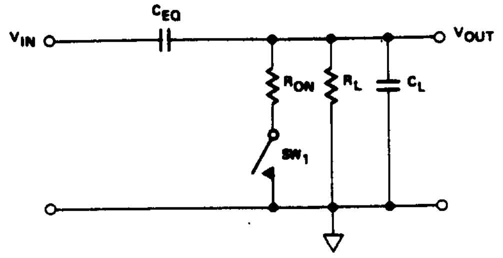
The dynamic crosstalk model can be derived from Figure 3. The switch SW_1 represents one condition on the multiplexer node (SW_1 is open). Actually SW_1 is continually switching between OFF and ON. This is represented in Figure 3b. In order to reduce crosstalk, multiplexers are designed to have break-before-make switching so that no two channels are addressed at the same time. The finite open time of SW_1 (shown in Figure 3b) represents the break-before-make action. There are two "open" conditions on the multiplexer node per cycle of the clock; thus the equivalent nodal resistance (R_{EQ}) may be computed as given in Figure 3b. Table I shows some typical values of static and dynamic crosstalk. Static crosstalk values are given in lines 1 and 12. There is a change in crosstalk as the clock frequency (f_{CLK}) is varied. Starting at line 4 notice the variation in crosstalk as R_L is varied from 10kΩ to 100kΩ while f_{CLK} remains constant at 100kHz. While Table I yields some theoretical values which give insight into the operation of dynamic crosstalk, a working multiplexer will have different values of f_{CLK} with respect to the maximum value of f_{SIG}. The real world situation will be analyzed in a later section of this paper.

Examples of multiplexer applications which are dynamic in nature are:

1. Industrial Process Control
2. Telephony
3. Data Acquisition Systems
4. Telemetry

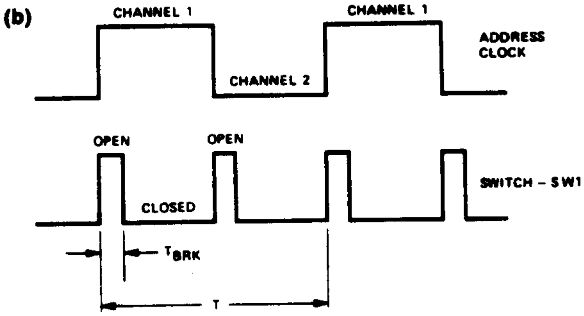
Each one of the above applications are a form of Time Division Multiplexing. In other words, these are sampled-data

(a) DYNAMIC CROSSTALK EQUIVALENT CIRCUIT



NOTE: SWI is a time dependent switch. Its characteristic is shown in Figure 3b.

(b)



T = Period of address clock

T_{BRK} = Break-Before-Make Time

$$\text{If } R_L \gg R_{ON},\ R_{EQ} \cong \frac{R_{ON}(T - 2T_{BRK}) + 2R_LT_{BRK}}{T}$$

Figure 3. Model for Dynamic Crosstalk

Table 1. Computed Values of Static and Dynamic Crosstalk

LINE NO.	f_{SIG} Hz	f_{CLK} Hz	T µsec	T_{BRK} µsec	R_{ON} OHMS	R_L OHMS	R_{EQ} OHMS	C_{EQ} pF	CROSS-TALK dB
1	10K	0	—	0.80	300	10K	291	0.30	105
2	10K	20K	50	0.80	300	10K	602	0.30	99
3	10K	40K	25	0.80	300	10K	913	0.30	95
4	10K	100K	10	0.80	300	10K	1845	0.30	89
5	10K	100K	10	0.80	300	20K	3448	0.30	84
6	10K	100K	10	0.80	300	40K	6850	0.30	78
7	10K	100K	10	0.80	300	100K	16.25K	0.30	70
8	20K	50K	20	0.80	300	10K	1068	0.30	88
9	20K	50K	20	0.80	300	20K	1872	0.30	83
10	20K	50K	20	0.80	300	40K	3474	0.30	78
11	20K	50K	20	0.80	300	100K	8275	0.30	70
12	20K	0	—	0.80	300	100K	291	0.30	99

systems where each channel is being continuously sampled and the information for a given channel is contained in a given time slot. In these applications, the static crosstalk is almost meaningless, since the wrong choice of R_L (or f_{CLK}) can be disastrous.

ADJACENT CHANNEL CROSSTALK (ACCT)

Adjacent channel crosstalk is the most confusing component of crosstalk. In addition to its confusing nature, in some cases, it is the most dominant component. While both static and dynamic crosstalk are capacitive in nature, i.e., they vary with frequency at 6dB/octave, the adjacent channel crosstalk is **invariant with frequency**. In other words, it is possible to have crosstalk **when multiplexing DC signals** such as the outputs of thermocouples, pressure transducers, etc. The parameters which must be dealt with are R_L, C_L, R_{ON}, and f_{CLK}. In addition, the break-before-make time (= T_{BRK}) of the multiplexer is of importance. Before diving into the details of this component of crosstalk, it will be helpful to define what is meant by ACCT.

The term "adjacent" refers to time only. In other words, channel two is adjacent to channel one if channel two **immediately** follows channel one in time slots. Since the channel following is the "adjacent" channel, then channel one is not adjacent to channel two, but rather the other way around. Figure 4 illustrates the concept of adjacent channels. Assuming the multiplexer had, say, 1V on channel one, 2V on channel two. etc., then the output would look like the curve labeled "channel addressed." What is important about the waveforms in Figure 4 is the way the adjacent channel (in time) is shown. Note that while channel two is adjacent to channel one, channel one is itself adjacent to channel eight.

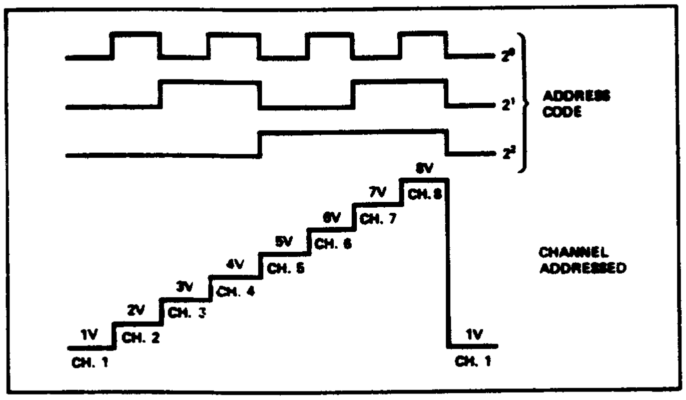


Figure 4. Adjacent Channel Concept

The fact that information is "carried forward" from one channel to the next (in time) suggests a storage mechanism as causing ACCT. Thus the multiplexer nodal capacitance becomes the prime suspect. Figure 5 illustrates how information is carried forward from one channel to the next as the addresses are changed. The address code is shown in Figure 5a, while Figure 5b shows the theoretical multiplexer output. Note that the even numbered channels have zero volt on them, while the odd channels have their channel number in volts. This arrangement best illustrates how the information is transferred to the adjacent channel (as shown in Figure 5c). While the theoretical MUX output switches from channel three (3 volts) to channel four (0 volt) at the moment of the address change, note the delay in the actual MUX output caused by T_{BRK}. During this time the MUX node discharges along an RC curve determined by the load capacitance (C_L), and the load resistance (R_L). When the break-before-make time (T_{BRK}) is over, channel four is turned ON and the RC product is suddenly reduced to $R_{ON}C_L$. A curve which details how this all takes place is shown in Figure 6. Before leaving Figure 5, the arrangement suggests a method of avoiding adjacent channel crosstalk. In other words, the alternate grounding of channels prevents channel one signals from reaching channel three... channel three from reaching channel five, etc.

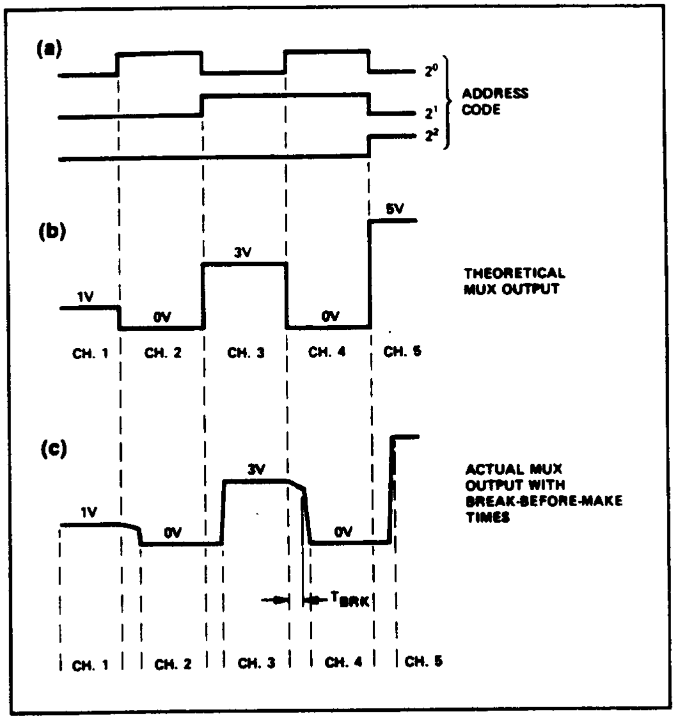
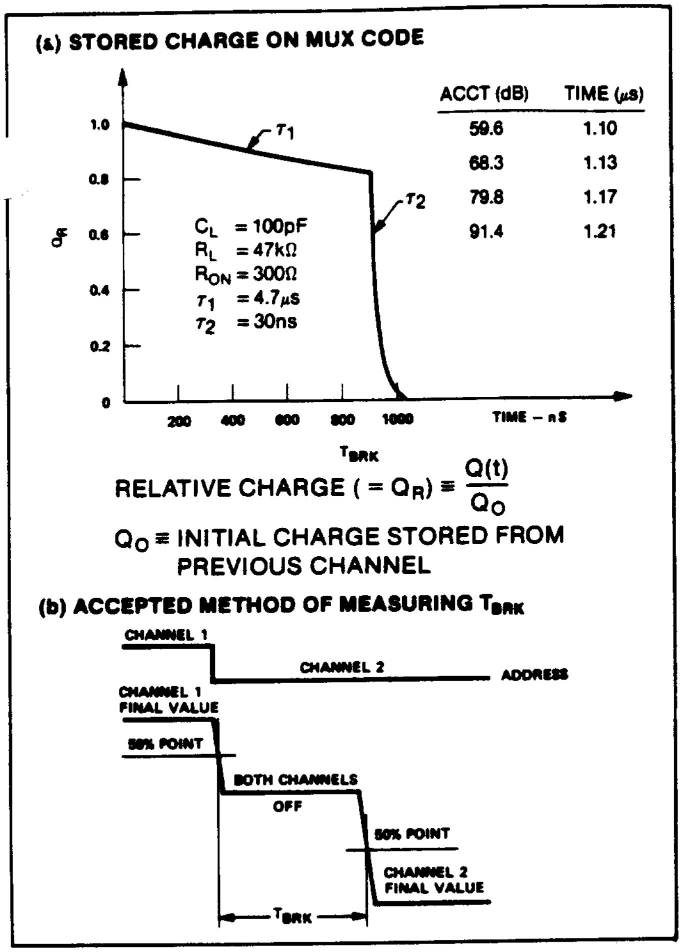


Figure 5. Adjacent Channel Crosstalk

The curve in Figure 6a shows a typical nodal discharge for a set of real world conditions. The curve is normalized and T_{BRK} is chosen to be 900nsec. An accepted method of measuring T_{BRK} is from the 50% point of the channel which has been turned OFF to the 50% point of the channel which is being turned ON. This concept is illustrated in Figure 6b. In this case (Figure 6a) T_{BRK} is measured from the moment of the address change. While this is not totally correct, the agreement between theoretical and actual results is good enough to justify the simpler model which is derived. Since most designers are interested in crosstalk which is less than the resolution of the discharge curve, the ACCT vs. time graph gives crosstalk down to 90dB. In other words, the ACCT is down 90dB in less than 1.25µsec.

Adjacent channel crosstalk is a problem in every application where dynamic crosstalk must be considered; however there are techniques to minimize its effects. A popular way to diminish adjacent channel crosstalk is to short the



ACCT (dB)	TIME (μs)
59.6	1.10
68.3	1.13
79.8	1.17
91.4	1.21

$$\text{RELATIVE CHARGE } (= Q_R) \equiv \frac{Q(t)}{Q_O}$$

$Q_O \equiv$ INITIAL CHARGE STORED FROM PREVIOUS CHANNEL

ure 6. Stored Charge Decay and Definition of T_{BRK}

multiplexer node to ground between address changes. This requires an additional analog switch which should be fast and have low R_{ON}. An alternative approach to reducing adjacent channel crosstalk is to ground every other channel in a multiplexer. This technique was illustrated in Figure 5.

MEASUREMENT OF STATIC CROSSTALK

Figures 7 and 8 give the element values for a typical PMI JFET MUX-08 on channel three. In the case shown, the OFF isolation was first measured and found to be 75dB. With R_L and f_{SIG} known, then C_{EQ} was calculated. Once C_{EQ} is known, then R_{EQ} may be calculated from the static crosstalk measurement made in Figure 8. R_{EQ} is the parallel combination of R_L and R_{ON}; thus it is possible to compute R_{ON} and this value is also shown in Figure 8. The measurements thus far are relatively simple and only require a voltmeter which is capable of measuring signals which are 100dB below the reference signal. On the other hand, the measurement of dynamic crosstalk is a bit more involved, and requires a more complex system.

MEASUREMENT OF DYNAMIC CROSSTALK

The crosstalk measuring system shown in Figure 9 is to be used for measuring dynamic crosstalk. The signal from M_5 is fed into M_1 where it is multiplexed onto the OUT terminal.

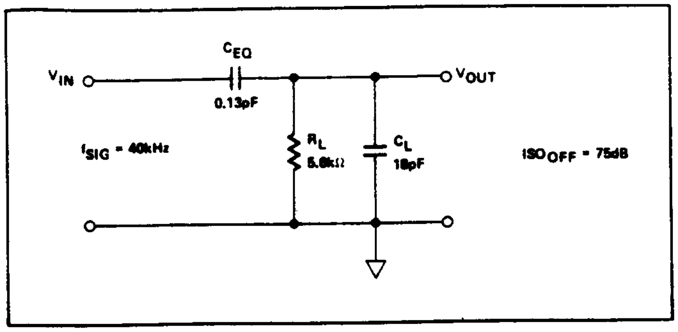


Figure 7. Typical OFF Isolation Element Values

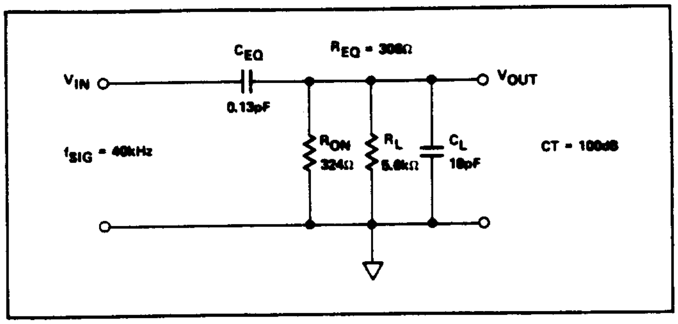


Figure 8. Typical Static Crosstalk Element Values

M_1 contains the multiplexer under test and a decoding circuit. The decoding circuit allows the selection of any two channels to be used as a two channel multiplexer. M_2 is a high-speed buffer used for driving the IN terminal of M_3. M_3 contains a multiplexer operated in a demultiplexer mode, along with decoding circuitry to allow several combinations of two channel demultiplexing. The signal which appears on S_{3A} is fed through M_4 (high-speed buffer) to M_8 for spectrum analysis. In short, if no errors are introduced by the multiplexer-demultiplexer system, the output should be the same as the input.

Since the system in Figure 9 is capable of measuring dynamic crosstalk, a good check of its performance is to repeat the static crosstalk measurements. M_3 is set to have IN connected to S_{3A} at all times. M_1 is set to have S_3 connected to OUT, and the signal thus measured is taken as the reference signal. Static crosstalk is measured by connecting S_1 (or S_8) to OUT, with V_{IN} still applied to S_3, and again measuring V_{OUT}. The relative signal levels represent static crosstalk. This measuring technique was used to verify the accuracy of the system.

The measurement of dynamic crosstalk leaves M_3 exactly as in the static case. With V_{IN} connected to S_3, M_1 is switched between S_1 and S_8. The signal frequency (f_{SIG}) was 40kHz and f_{CLK} was 100kHz (see Figure 10). From the crosstalk measured, the equivalent resistance (R_{EQ}) is computed to be 1150Ω (see Figure 10a). To verify the validity of this measurement, R_{EQ} was calculated using the formula in Figure 10c (T_{BRK} was measured separately). Since there is very good agreement between these two independently derived values, both the measurement technique and the dynamic crosstalk model are valid.

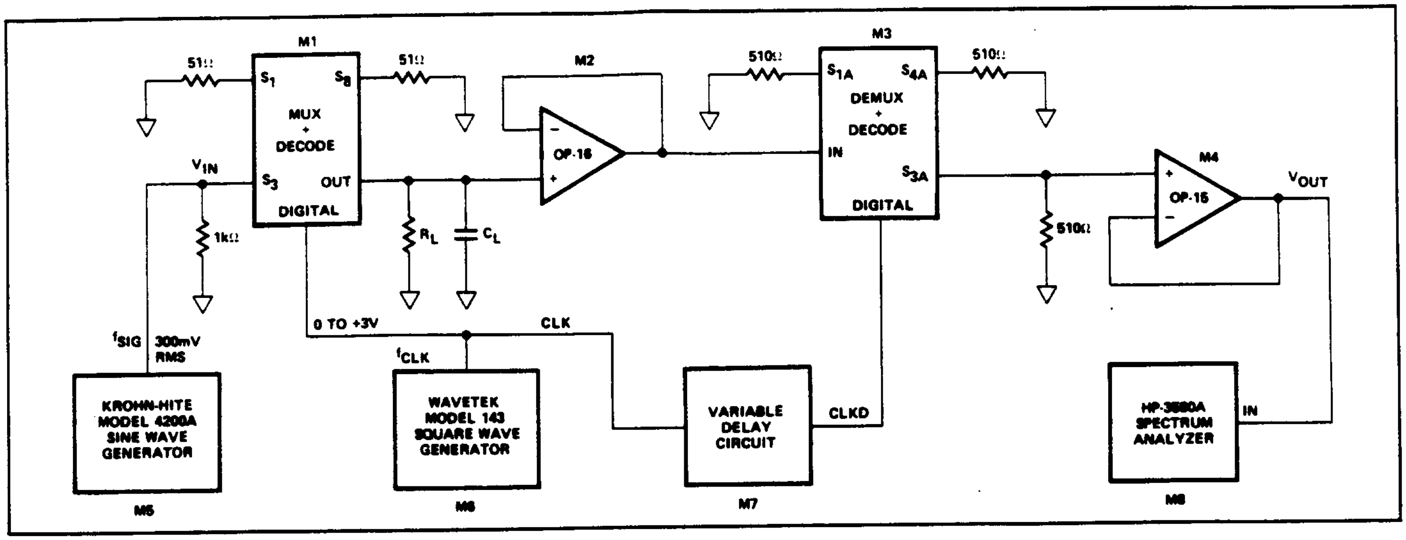
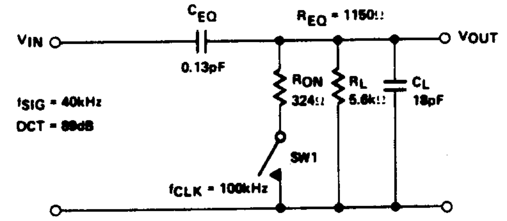


Figure 9. Dynamic Crosstalk Measuring System

(a) TYPICAL DYNAMIC CROSSTALK ELEMENT VALUES

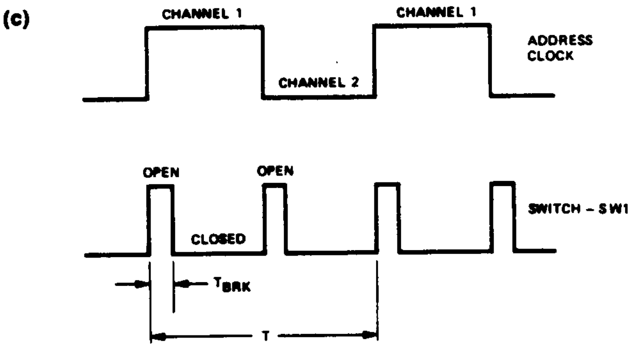


NOTE: SWI is a time dependent switch. Its characteristic is shown in Figure 10c.

(b) SYSTEM DYNAMIC CROSSTALK

f_{SIG}	f_{CLK}	R_L	R_{EQ}	DCT (C_{EQ} = 0.13pF)	DCT (C_{EQ} = 0.5pF)
Hz	HZ	Ω	Ω	dB	dB
10K	100K	10K	1718	97.1	85.4
10K	100K	22K	3463	91.0	79.3
10K	100K	33K	5059	87.7	76.0
10K	100K	47K	7090	84.7	73.0
10K	100K	100K	14.78K	78.4	66.7

(c)



$T = 5\mu s$

$T_{BRK} = 725ns$

$R_{EQ} = 1089\Omega$

T ≡ Period of Address Clock

T_{BRK} ≡ Break-Before-Make Time

$$\text{If } R_L \gg R_{ON},\ R_{EQ} \cong \frac{R_{ON}\,(T - 2T_{BRK}\,(+\,2R_L\,T_{BRK})}{T}$$

Figure 10. Computed Dynamic Crosstalk for Actual Multiplexer

The numbers shown in Figure 10 apply to the measurement system, but are unlikely in a real multiplexer. To satisfy sampling theory limitations, f_{SIG} must be less than one-half the sampling frequency. Assuming $f_{CLK} = 200kHz$ then each channel in a multiplexer is addressed for 5μsec. This means that it takes 40μsec to sample all channels of an eight channel multiplexer. In other words, each channel is sampled at a 25kHz rate. Thus the maximum value of f_{SIG} would be 12.5kHz. Figure 10b gives values of dynamic crosstalk (DCT) which would be experienced if the values of R_{ON} and T_{BRK} shown in Figures 10a and 10b were used. The first DCT column lists the values for a C_{EQ} of 0.13pF (measured value of channel three). The second DCT column shows the performance for $C_{EQ} = 0.5pF$. The purpose for the second column is to point out how critical minimizing stray capacitance is to good crosstalk performance.

MEASUREMENT OF ADJACENT CHANNEL CROSSTALK

The system shown in Figure 11 was used to measure adjacent channel crosstalk (ACCT). M_1 drives the address lines of the MUX system and the gating input of M_4. By setting the period of M_4 (T_2) to 10μsec, the pulse rate out of M_4 is controlled by the pulse rate of M_1 (40μsec) coming into the gate input of M_4. The output of M_4 is in the complement mode

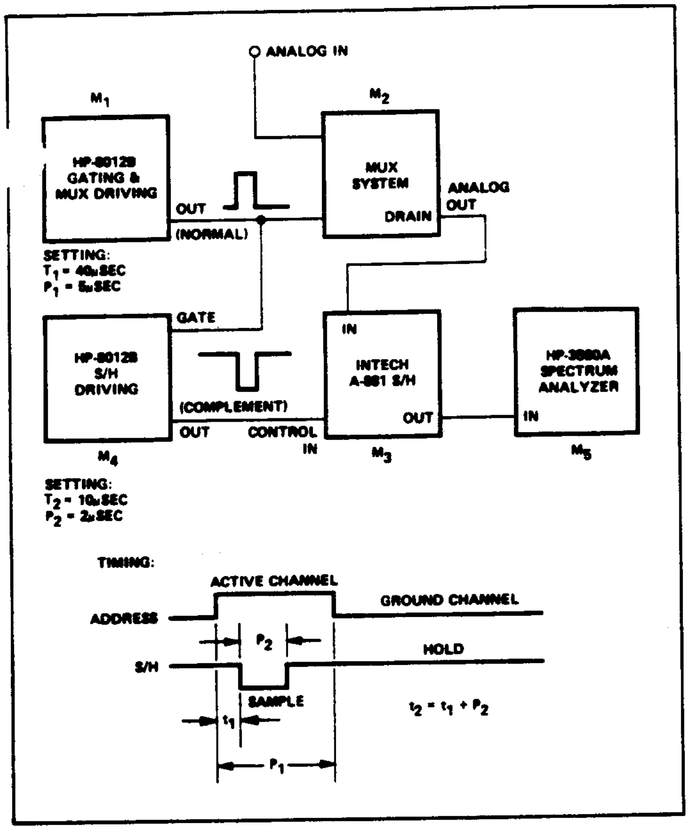
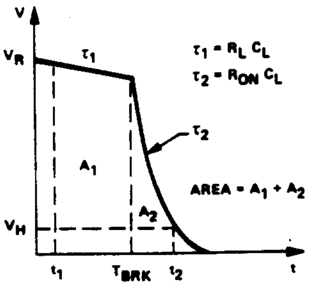


Figure 11. Adjacent Channel Crosstalk Measuring System

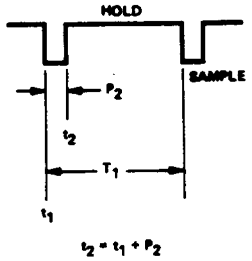
because the control input to M_3 causes the S/H to HOLD when the input is high (1). Thus the sample period occurs ring the time P_2. M_4 also can delay its pulse relative to the pulse out of M_1, thereby allowing measurements of crosstalk versus t_1 (start of the sample time). This information is valuable because in many systems, a sample/hold is used with a successive approximation ADC to encode the analog output of the MUX. As will be shown, the ACCT can be made negligible if a sufficient time elapses before going to the HOLD mode for encoding the data. Since "time is money," the term "sufficient time" becomes important.

The nature of sample/holds and the nature of spectrum analyzers can cause some apparent discrepancies in the data observed by this measurement system. It is important to note the spectrum analyzer "**sees**" the **average** of **everything** that is presented to its input terminals. While it is true the sample/hold holds the last value it "saw," the spectrum analyzer also looks at the signal present during the sample/hold's sample time. Thus the equation which expresses the signal level present as a function of time must also account for the true averaging of the spectrum analyzer. Figure 12 shows the equations (12c) and the definitions of the terms used in the equations (12a and 12b). The term N_O is the **relative** signal level which the spectrum analyzer measures. If the model of the signal decay shown in Figure 12a is the correct one to explain the ACCT, then the computed value of N_O should correspond to the measured values. As will be shown in Figure 14, the agreement does in fact justify the model; however it was necessary to choose the measurement conditions **very carefully.**

(a) VOLTAGE DECAY ON MUX OUTPUT



(b) SAMPLE/HOLD



(c)

EQUATIONS:

1. $\frac{V_O}{V_R} = N_O = \frac{N_H(T_1 - P_2) + S_1 + S_2}{T_1}$; Where

2. $\frac{V_H}{V_R} = N_H = EXP\left[\frac{-t}{\tau_1}\right], t \le T_{BRK}$

$$= EXP\left[\frac{-T_{BRK}}{\tau_1}\right] EXP\left[\frac{T_{BRK} - t}{\tau_2}\right], t \ge T_{BRK}$$

3. $\frac{A_1}{V_R} = S_1 = \tau_1\left[EXP\left(\frac{-t_1}{\tau_1}\right) - EXP\left(\frac{-T_{BRK}}{\tau_1}\right)\right]$

4. $\frac{A_2}{V_R} = S_2 = \tau_2\, EXP\left[\frac{-T_{BRK}}{\tau_1}\right]\left[1 - EXP\left(\frac{T_{BRK} - t_2}{\tau_2}\right)\right]$

Figure 12. Predicting the Measurement System Response

In order to get good correlation between lab data and theoretical predictions, it was necessary to use fairly long time constants ($R_L = 22k\Omega$ and $C_L = 1000pF$). With $R_L = 22k\Omega$ and $C_L = 50pF$ ($R_{ON} = 300\Omega$), the theoretical plot of ACCT (as measured on the spectrum analyzer) vs. t_1 is shown in Figure 13. Note that the data is plotted between 900nsec and 1025nsec. The curve shows that a **10nsec error in t_1 can cause a 6dB error** in reading on the spectrum analyzer. The results shown in Figure 14 confirm the necessity of using large capacitances to obtain predictable results. The theoretical curve tracks the actual data well in both cases; however the 1000pF curve is better than the 300pF curve. Notice that there is good agreement both at DC and at 4kHz.

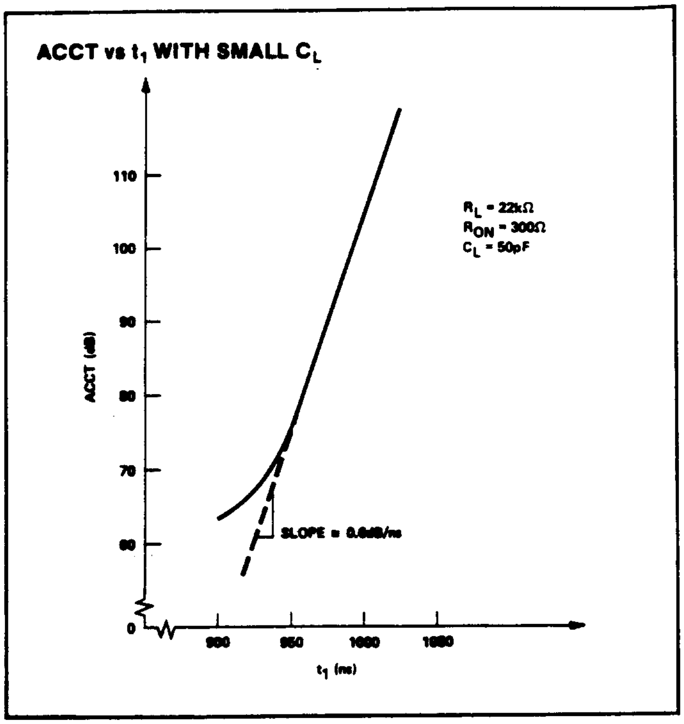


Figure 13. Measurement Errors Due To Small C_L

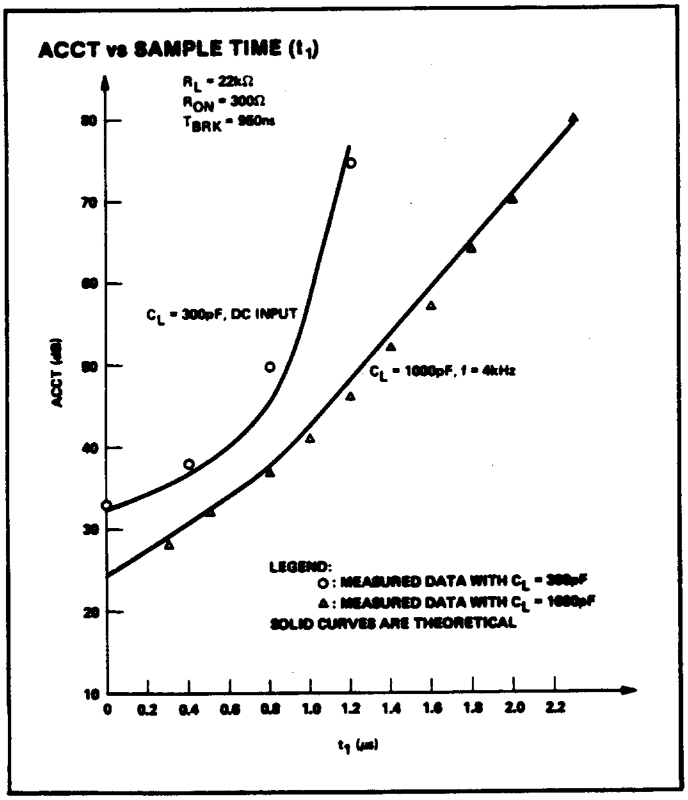


Figure 14. Agreement Between Measured and Computed ACCT

PREDICTING AND CONTROLLING ADJACENT CHANNEL CROSSTALK

The equations in Figure 12c can be used to predict how much adjacent channel crosstalk one might expect in an actual system. An all analog system will follow the MUX with a

A. Multiplexer-Demultiplexer System:

$N_H = 0$ Therefore

1. $N_O = \dfrac{S_1 + S_2}{T_1}$, Where $T_1 = \dfrac{1}{f_{CLK}}$ x (No. of Channels)

2. $S_1 = \tau_1 \left[\text{EXP} \left(\dfrac{-t_1}{\tau_1} \right) - \text{EXP} \left(\dfrac{-T_{BRK}}{\tau_1} \right) \right]$

3. $S_2 = \tau_2 \ \text{EXP} \left[\dfrac{T_{BRK}}{\tau_1} \right] \left[1 - \text{EXP} \left(\dfrac{T_{BRK} - t_2}{\tau_2} \right) \right]$

Where $t_1 = T_D$ (Break-Before-Make Time of DEMUX)

$$t_2 = \frac{1}{f_{CLK}} - T_D$$

B. Multiplexer — Sample/Hold System

$S_1 = S_2 = P_2 = 0$

4. $N_O = N_H = \text{EXP} \left[\dfrac{-t}{\tau_1} \right] t \leq T_{BRK}$

$$= \text{EXP} \left[\frac{-T_{BRK}}{\tau_1} \right] \text{EXP} \left[\frac{T_{BRK} - t}{\tau_2} \right], \ t \geq T_{BRK}$$

Where: $t = t_H$ (Hold Command for Sample/Hold as measured from Address Change Time)

Figure 15. Predicting Adjacent Channel Crosstalk

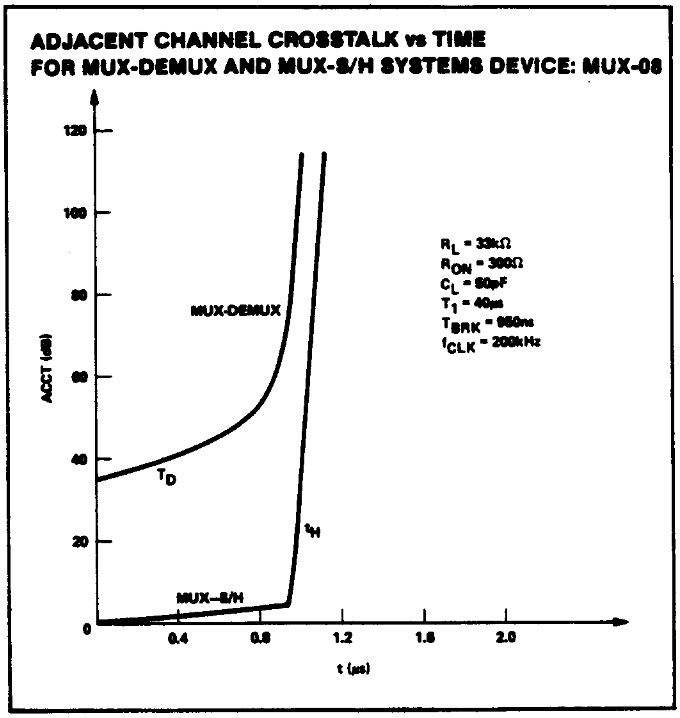


Figure 16. Computed ACCT vs Time for MUX-DEMUX and MUX-S/H Systems

demultiplexer, which will have its own break-before-make delay. An analog to digital system will have a sample/hold amplifier in front of the A/D converter. Since the equations which apply to these situations are different, they will be discussed separately. Figure 15 summarizes the conditions the equations which apply to them.

Since there is no held voltage, then $N_H = 0$ in the multiplexer-demultiplexer system. This reduces N_O to the simple form shown in equation (1). S_1 and S_2 follow in equations (2) and (3). Since $t_1 = T_D$ (break-before-make time of the DEMUX), that time will have a significant effect on ACCT. The MUX-sample/hold system imposes the condition $S_1 = S_2 = P_2 = 0$; thus $N_O = N_H$. It will be instructive to compare the levels of ACCT in these two systems versus their appropriate times.

Figure 16 looks at a "typical" system which will give approximately one percent transmission error (33kΩ R_L and 300Ω R_{ON}), and has 50pF C_L. The value of C_L is somewhat on the high side (20pF being typical for MUX-08 connected to a buffer amp), but it does give a conservative value for analysis. **What Figure 16 shows is rather startling. The adjacent channel crosstalk, while inherent in the multiplexer itself, can be eliminated in both** systems by the proper timing. In the case of the sample/hold it is only necessary to delay the hold command for approximately 1.2μsec to have the ACCT vanish completely. This is no problem, since most sample/holds need at least 2μsec to accurately acquire the signal (this is particularly true of monolithic devices). The plot for the MUX-DEMUX system relates to T_D, which is **not adjustable** for a given DEMUX. What is possible is to add some delay to the address change for the DEMUX. In this way, the DEMUX will not "look" at the MUX output until the charge from the previous channel has had a chance to dissipate.

NCLUSION

Table II summarizes the forms of crosstalk and lists ways of coping with them. Reduction of R_{ON} is helpful in all three cases. While T_{BRK} should be minimized as much as possible, it is important that no two channels are ON at the same time. In some cases, T_{BRK} is chosen such that even over temperature extremes, the break-before-make feature is maintained. Since all three components of crosstalk are present in a dynamic multiplexer, the "careful circuit board layout" is important even though it is not listed in the ACCT section.

Table 2. How to Handle Crosstalk

Crosstalk Component	Variation with f_{SIG}	Ways to Minimize Effects
Static	**6dB/octave**	• **Minimize R_{ON}** • **Reduce stray capacitance (C_{EO}) by careful circuit board layout.**
Dynamic	**6dB/octave**	• **Minimize R_{ON}** • **Minimize f_{CLK}** • **Minimize T_{BRK}, but $T_{BRK} > 0$ is needed to prevent shorting channels together.** • **Minimize R_L** • **Reduce stray capacitance (C_{EO}) by careful circuit board layout.**
Adjacent Channel	**NONE**	• **Minimize R_{ON}** • **Minimize f_{CLK}** • **Minimize T_{BRK}, but $T_{BRK} > 0$ is needed to prevent shorting channels together.** • **Minimize R_L and C_L** • **WAIT before allowing sample/hold or DEMUX to measure MUX output.**

This paper has pointed out the fact that static crosstalk (given on multiplexer data sheets) is only **one** of the **three** components of crosstalk. The models for static and dynamic crosstalk are relatively simple and were discussed to show how they are related. The most troublesome component of crosstalk (adjacent channel crosstalk) was shown not to be quite so straight-forward. For one thing, adjacent channel crosstalk (ACCT) is **not signal frequency dependent** as are CT and DCT. The mechanism which governs this form of crosstalk is stored charge on the MUX node. While CT and DCT must be minimized by careful layout and once present in the multiplexer cannot be reduced, such is not the case with ACCT. Even though ACCT is present in the multiplexer, the proper timing of demultiplexer or sample/hold commands can effectively eliminate ACCT from the total system.