Analog Signal And Testing Overview

ANALOG SIGNAL OVERVIEW

Analog signals are signals where amplitude or frequency vary in a continuous manner. This type of signal includes voice-frequency (voice or data) signals. This section discusses the analog signal in terms of the following:

- Signal transmission
- Transmission components
- Carrier multiplexing
- Pulse code modulation and quantization.

Signal Transmission

There are three major characteristics of analog signal transmission: pass band, transmission mode, and transmission media.

Pass Band

To limit unwanted noise, circuits that carry telephone transmissions pass only certain frequencies. The upper limit of the pass band is the frequency above the center of the pass band with 3 dB loss; the lower limit of the pass band is the frequency below the center of the pass band with 3 dB loss. The difference between the upper and lower limits of the pass band, or message channel, is the channel bandwidth. The three grades of voice-frequency pass bands are: narrowband (0 to 300 Hz), voice band (300 to 3300 Hz), and wideband (greater than 3300 Hz).

Narrowband is a subvoice channel. This channel allows low-speed data transmission (for example, telegraph, teletype and other similar equipment). Transmission speeds for analog signals within this grade range from 45 through 300 bps (bits per second). Voice grade transmission is not possible over narrowband channels.

Voice band supports the transmission of speech and data. Transmission speeds for most voice grade networks range from 75 through 9600 bps. Voice band is the most commonly used passband for analog transmission. The two types of voice band lines are dial-up (switched or public) and leased (dedicated or private).

Wideband supports the transmission of several voice channels within one group or program. This bundling of channels increases the efficiency of the transmission medium. Transmission speeds also increase (50 kbps or greater).

Transmission Modes

Three terms are often used to describe transmission modes: simplex, half-duplex, and full-duplex.

Simplex transmission between two stations occurs in one direction. An input terminal can only receive. An output terminal can only transmit. Since this mode does not allow for the transmissions of error or control signals, simplex is not widely used.

Half-duplex transmission between two stations occurs in either direction, but in only one direction at a time.

Full-duplex transmission between two stations occurs in either direction. Each of these stations can simultaneously transmit and receive.

Transmission Media

Transmission media refers to the physical means of transmitting a signal. Analog carrier facilities may operate over twisted-wire, coaxial cable, microwave radio, and satellite links. Most transmission activity uses twisted-wire between the subscriber loop and the local central office.

Two-wire and 4-wire are two types of twisted-wire circuits in common use. Two-wire operation occurs when oppositely directed portions of a single telephone conversation occur over the same wire pair. Two-wire circuits typically exist in the subscriber loop between the telephone set and the local telephone exchange (serving central office) on dial-up lines. Four-wire operation occurs when one 2-wire pair operates as a transmit path, and a second 2-wire pair operates as a receive path. Four-wire carrier equivalent circuits usually exist between serving central offices.

Four-wire loops accept greater gain, have less noise, allow better balance, and permit more signaling types. For this reason, 4-wire circuits are better choices for long distance services. Two-wire circuits, on the other hand, are more cost effective for local loops and terminations.

Transmission Components

To better understand the importance of analog testing, let's examine some of the components of the analog line and how they may impair data transmission.

Bridged Taps. An installer makes a bridged tap when he bridges a cable wire-pair to bring it into a customer facility. When this connection is no longer needed, the customer loop is cut, often leaving loose ends still

bridged across the cable pair. Several loose ends can have enough capacitance to cause noticeable phase distortion within a network.

Load Coils. At frequencies up to about 3500 Hz, load coils make attenuation more nearly constant over the voice-frequency range. (Beyond 3500 Hz, load coils actually increase signal attenuation.) Load coils are present on most circuits greater than three to six miles (for example, 88 mH inductance spaced every 6000 feet).

Voice Frequency Repeaters. Repeaters are amplifiers that adjust for signal attenuation. They are placed in series with a 2-wire circuit wherever signal power decreases by a factor of 100 (20 dB). The maximum number of tandem repeaters is usually two. This limits singing and other oscillations.

Switches. Electro-mechanical switches are the most common sources of impulse noise. Each time a switch changes position, a momentary signal spike occurs. This is due to the release of an energized relay coil. This release can generate up to 2500 volt spikes for durations of up to 10 milliseconds. These spikes cause impulse noise. During telephone conversations impulse noise sounds like crackles, clicks, and pops. While these spikes may be merely annoying during voice transmission, they can cause serious errors during data transmission. This is especially true at higher data rates.

Compandors. When repeaters amplify a signal, strong signals may overload the amplifier. Weak signals may get lost in the amplified noise. Instantaneous compandors correct this by adjusting the amplitude of low-level signals, while leaving high-level signals unaffected. This provides a nearly constant signal-to-noise ratio. For voice-frequency transmissions, syllabic compandors additionally introduce loss during quiet intervals. This reduces noise and further improves the signal-to-noise ratio.

Equalizers. Equalizers are special circuits added to voice grade lines to adjust attenuation and delay distortion. They equalize the response across a channel's bandwidth. Conditioned lines usually have equalizers. Some modems for dial-up lines have built-in equalizers that match average line conditions.

Hybrids. Hybrids serve as an interface between standard 2-wire subscriber loops and 4-wire trunks between central offices. (See Figure 2-1.) Two of the wire pair connections on a hybrid belong to the 4-wire path. This path consists of a transmit pair and a receive pair. A third connection is a 2-wire link to the subscriber. A fourth wire pair connects the hybrid to a resistance-capacitance balancing network. This network electrically balances the hybrid with the 2-wire subscriber. Ideally, signal power from the receive side of the 4-wire facility divides equally between the balancing network and the 2-wire subscriber. In practice, the match is never perfect. A portion of the original signal returns as an echo on the transmit side of the 4-wire facility.

Echo Suppressors. Echo suppressors typically exist on switched long-distance circuits. These suppressors insert loss (35 dB or more) into the return path. This prevents echos from looping back to the talker. During full-duplex transmission, these suppressors may cause signal loss in both directions. When using dial-up lines in full-duplex situations, the

modem must be able to turn off echo suppressors at the beginning of a conversation.

Echo Cancelers. Echo cancelers use the received signal to derive a signal that is a replica of the echo. Subtracting this replica from the transmit signal cancels the echo, while allowing normal communications to continue undisturbed.

Carrier Multiplexing

Carrier multiplexing combines several communications channels for transmission over a common broadband channel. This makes efficient use of a transmission facility's bandwidth. It also achieves a low per-channel transmission cost. The two main multiplexing methods are Frequency Division Multiplexing (FDM) and Time Division Multiplexing (TDM).

OFFICE A   OFFICE Z

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Figure 2-1. Hybrid Interface Between 2-Wire and 4-Wire Facilities

Frequency Division Multiplexing

> Frequency Division Multiplexing (FDM) simultaneously places several discrete signals onto one circuit. Each analog signal, occupying a frequency range of 300 through 3300 Hz, modulates a carrier of much higher frequency. This increases the signal frequency to nearly that of the carrier. Other high carrier frequencies, typically stepped 4 kHz apart, similarly increase other analog signals. Figure 2-2 shows 12 voice band channels multiplexed over a bandwidth of 48 kHz.

Time Division Multiplexing

> Time Division Multiplexing (TDM) takes representative samples of several signals. It then sequentially sends the samples on the circuit. Figure 2-3 shows five signals multiplexed by time division onto one output channel. Each of the signals contains six code elements (five information and one synchronization). The duration of each code element divides into five time slots (since there are five signals to sample).

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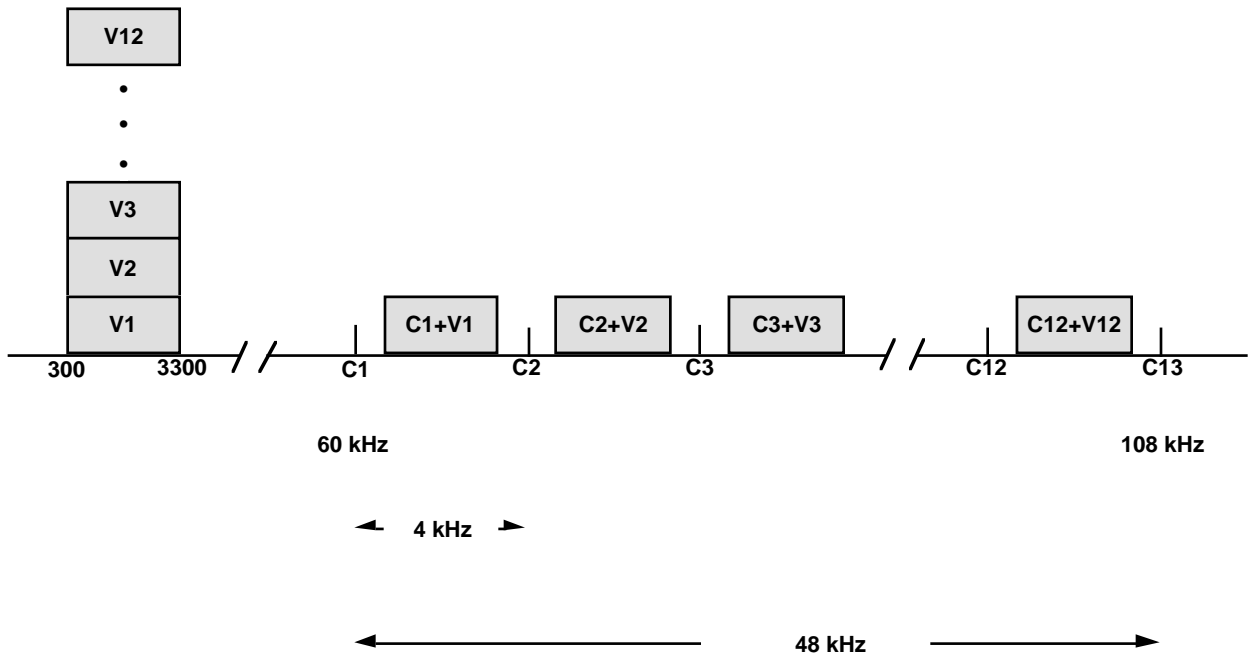
Figure 2-2. Frequency Division Multiplexing

During the first time slot, input channel A is sampled; a signal (voltage, frequency, current, etc.) is detected; and a corresponding signal element is placed on the output channel. During the second time slot, input channel B is sampled; a signal is again detected; and a similar signal element is placed on the output channel. During the third time slot, channel C does not contain a signal; therefore, no signal element is placed on the output channel.

By the end of the first code element, samples of all five input signals have been placed on the output channel. The sampling rate must be high enough to sample each channel during each code-element duration.

You can also think of time division multiplexing as a parallel-to-serial conversion. In this process, samples of several parallel (or simultaneous) signals are sent sequentially on a single high-speed circuit. A small amount of time is allotted for transmission of a sample from each input signal or channel. The samples are sent in sequence until all input signals are sampled. The cycle then repeats. For the resultant sample to be accurate for analog signals, the sampling cycle must be at least twice as fast as its highest frequency.
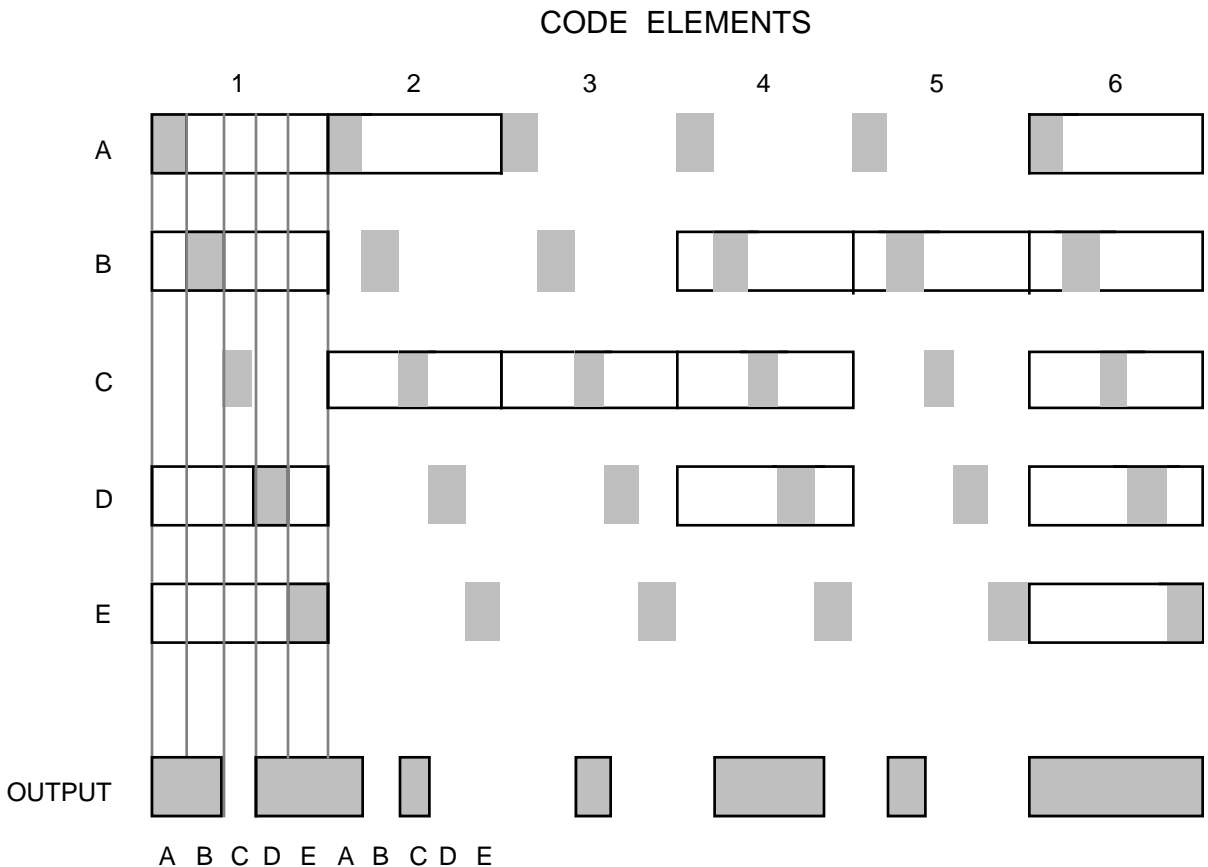

Figure 2-3. Time Division Multiplexing

Pulse Code Modulation and Quantization

Pulse Code Modulation (PCM) uses TDM to sample the incoming signal. The amplitude at the instant of sampling is quantized into digital pulses. The value depends on the amplitude of the analog signal. The size of the PCM quantization step is non-linear. This means low amplitude signals reproduce as accurately as high-amplitude signals.

After coding, you can amplify and regenerate PCM signals. The repeater detects the presence of pulses. It then regenerates them as clean pulses with proper timing. Since only the presence of a pulse (not its shape) is significant, PCM systems are relatively insensitive to transmission impairments.

ANALOG TESTING OVERVIEW

This section provides an overview of analog testing with the REACT System. It covers the following topics:

- Introduction to analog testing
- Test parameters
- Test resources
- Circuit access configurations.

Introduction to Analog Testing

Analog test resources enable you to test voice-frequency (voice or data) circuits at metallic access points in a network. You can access these circuits through the following resources:

- Hekimian Metallic Test Access Unit (MTAU)
- AT&T's Switched Maintenance Access System (SMAS)
- Model 3570 Small Office Integrated Test System

Test Parameters

The following paragraphs describe several parameters you can measure during analog circuit testing. These parameters differentiate several possible circuit impairments.

Basic Analog Measurements

Attenuation Distortion. Attenuation distortion results from a less than perfect amplitude versus frequency response. The attenuation distortion test measures the point-to-point loss or gain over a voice-frequency channel. To determine loss or gain at a receiving terminal, measure the received power and subtract the expected level. This measurement examines the loss on the line at one frequency with respect to another frequency. This test checks all frequencies in the required bandwidth with respect to the reference frequency of 1004 Hz.

Echo Return Loss (ERL). Echo return loss measurements show how well input and output impedances match throughout a circuit. This measurement is a weighted average of the power difference of frequencies between 600 Hz and 2200 Hz incident upon a transmission system discontinuity to the power reflected from that discontinuity. This measurement is particularly useful for mixed 2-wire and 4-wire systems providing two-way transmission.

Envelope Delay Distortion (EDD). (IEEE applications only)

or

Group Delay Distortion (GDD). (ITU-T [formerly CCITT] applications only)

The envelope delay or group delay test measures the finite time it takes a signal to pass through the total extension of a voice channel. Some frequencies of a complex signal are delayed more than others during transmission. This delay is equivalent to signal phase shift. If the phase shift is non-linear with respect to frequency, the output signal will be distorted from that of the input.

EDD uses a separate reference path except in loop-around measurements which uses the original modulation source as the reference (see Figure 3-1); GDD uses an alternate measure-reference carrier frequency to time-share the measure and reference carriers which does not require a separate reference channel.

FORWARD REFERENCE MODE

Forward Path

(Nominally 1804 Hz) Fixed Frequency

Originating
Near-End

Remodulation
Far-End

Repeat
Mode

Return
Path
Relative
Delay

Variable Frequency

300 Hz to 3500 Hz

RETURN REFERENCE MODE

300 Hz to 3500 Hz

Variable Frequency

Originating
Near-End

Remodulation
Far-End

Repeat
Mode

Return
Path
Relative
Delay

(Nominally 1804 Hz) Fixed Frequency

Return Path

3614

Figure 3-1. Envelope Delay Distortion

Noise. Noise is a transmission impairment characterized by unwanted disturbances superimposed upon a useful signal. It results from several factors:

- Thermal susceptibility of network components
- Opening and closing of switch contacts
- Presence of crosstalk
- Miscellaneous external sources.

To measure noise on a voice channel, place a quiet termination of either 600 or 900 ohms impedance on one end. Place a weighted measuring element on the other end. This element may be any of several filters designed to help isolate the noise frequency. Received noise levels appear in units of dBrn and dBm. (See Table 3-1.) For C-Message or C-Notch frequency weighting, noise levels appear as units of dBrnC (dB with respect to C-weighted noise for IEEE); for ITU-T psophometric or
P-Notch frequency weighting, noise levels appear as units of and dBm for ITU-T.

For practical comparison purposes, the psophometer reading in dBM is equal to a C-Message noise reading in dBrn. For example, one milliwatt of white noise in the 300 to 3400 Hz band measured by both a ITU-T psophometric weighting and C-Message weighting produces the following results:

        -2.0 dBm — ITU-T psophometric weighting
        88 dBrn — IEEE C-Message weighting

Note that the psophometric weighting uses a 800-Hz reference frequency and C-Message weighting uses a 1000-Hz reference frequency; this conversion includes the effect of the difference between the reference frequencies used by the two types of noise meters.

C-Message. The C-Message filter measures background noise present on a channel in the absence of a signal. It provides a -5 dB passband (0 dBm referenced at 1000 Hz) between 600 Hz and 3200 Hz. It also sharply attenuates low frequency components, such as 60 Hz and its harmonics, and high frequency components above 3200 Hz.

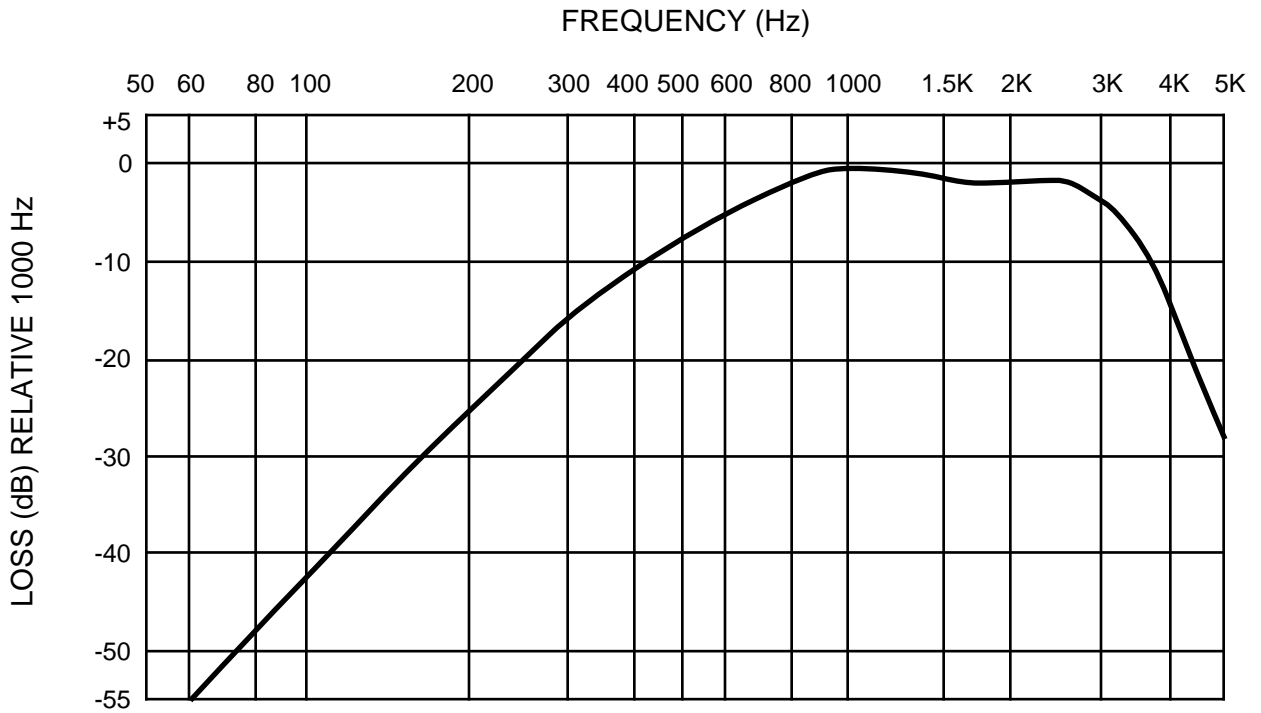   *NOTE: ITU-T measurements use a psophometer.*

Figure 3-2 shows an ideal C-Message filter response. Table 3-2 compares the relative weights and frequencies of a C-Message weighting response and a psophometric weighting response.

C-Notch. Elements in a network which are only active while sending a tone can generate noise. To test this noise, transmit a 1004-Hz test tone. To measure just the resultant noise, use a notch filter to remove the test tone. The C-Notch filter takes the C-Message filter and adds a -50 dB stop band (or notch) between 995 Hz and 1025 Hz. Figure 3-3 shows an ideal C-Notch filter response.

> *NOTE: ITU-T measurements use a P-Notch filter, psophometric with a 1010-Hz filter.*

Table 3-1. Noise Conversion

LEVEL dBm	NOISE dBrnco (IEEE)	NOISE dBm (ITU-T)
0	90	90
-10	80	80
-20	70	70
-30	60	60
-40	50	50
-50	40	40
-60	30	30
-70	20	20
-80	10	10
-90	0	0

FREQUENCY (Hz)

Figure 3-2. C-Message Filter Response

Program. The Program filter allows you to measure weighted noise on voice-frequency channels. The broadcast industry uses this filter between studios and transmitters. This filter provides 0 to 7 dB of gain to noise frequencies between 1 kHz and 9 kHz. Figure 3-4 shows an ideal Program filter response.

3-kHz Flat. The 3-kHz Flat filter allows you to measure low frequency noise, like power induction. The response for this filter has a Butterworth shape, with roll-off at 12 dB/octave. Figure 3-5 shows an ideal 3-kHz Flat filter response.

15-kHz Flat. The 15-kHz Flat filter allows you to measure unweighted noise on program circuits. The response for this filter has a Butterworth shape, with roll-off at 12 dB/octave. Figure 3-6 shows an ideal 15-kHz Flat filter response.

50-Kilobit. The 50-Kilobit filter measures noise on facilities assigned to 56-kilobit data service. It provides a -5 dB pass band between 40 Hz and 35 kHz, with less than 1 dB of attenuation between 80 Hz and 15 kHz. Figure 3-7 shows an ideal 50-Kilobit filter response.

Table 3-2. C-Message and Psophometric Weighting Comparison

FREQUENCY (HZ)	C-MESSAGE RELATIVE WEIGHT (dB)	PSOPHOMETRIC RELATIVE WEIGHT (dB)
100	-42.5	-41.0
200	-25.1	-21.0
300	-16.3	-10.6
400	-11.2	-6.3
500	-7.7	-3.6
600	-5.0	-2.0
700	-2.8	-0.9
800	-1.3	0.0
900	-0.3	+0.6
1000	-0.0	+1.0
1200	-0.4	0.0
1800	-1.3	-2.4
2000	-1.1	-3.0
2500	-1.1	-4.2
3000	-3.0	-5.6
3500	-7.1	-8.5
4000	-14.6	-15.0
4500	-22.3	-25.0
5000	-28.7	-36.0

FREQUENCY (Hz)
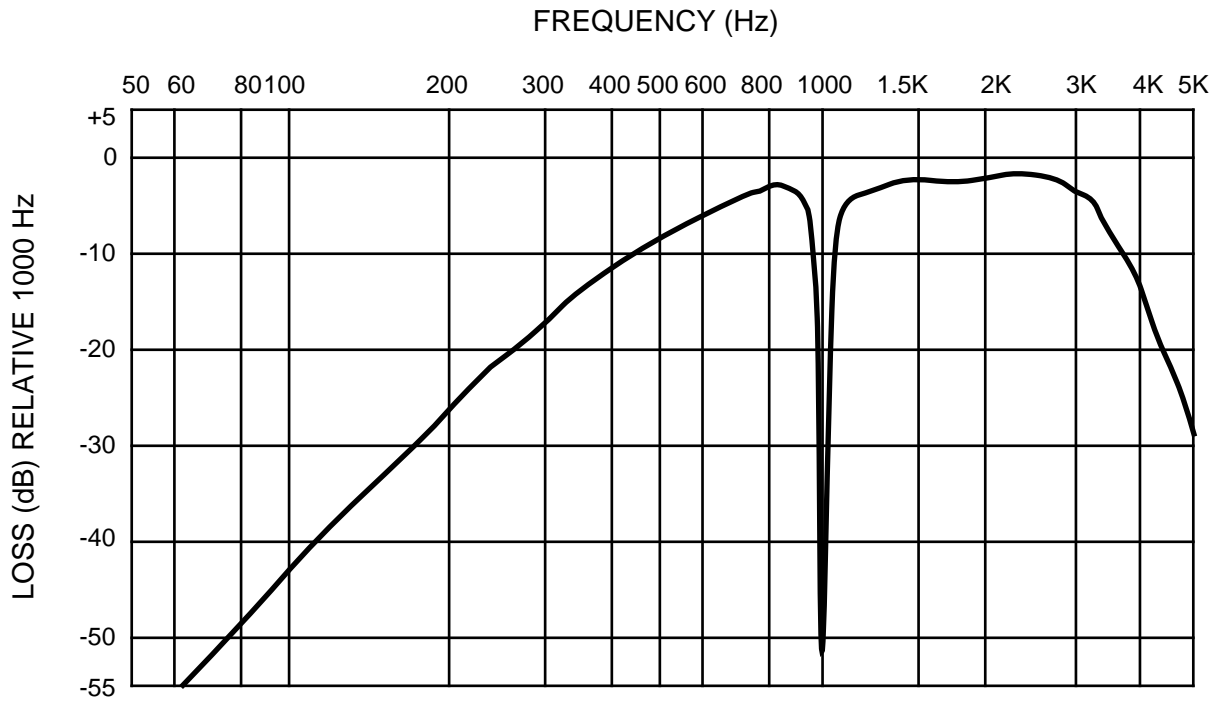
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Figure 3-3. C-Notch Filter Response
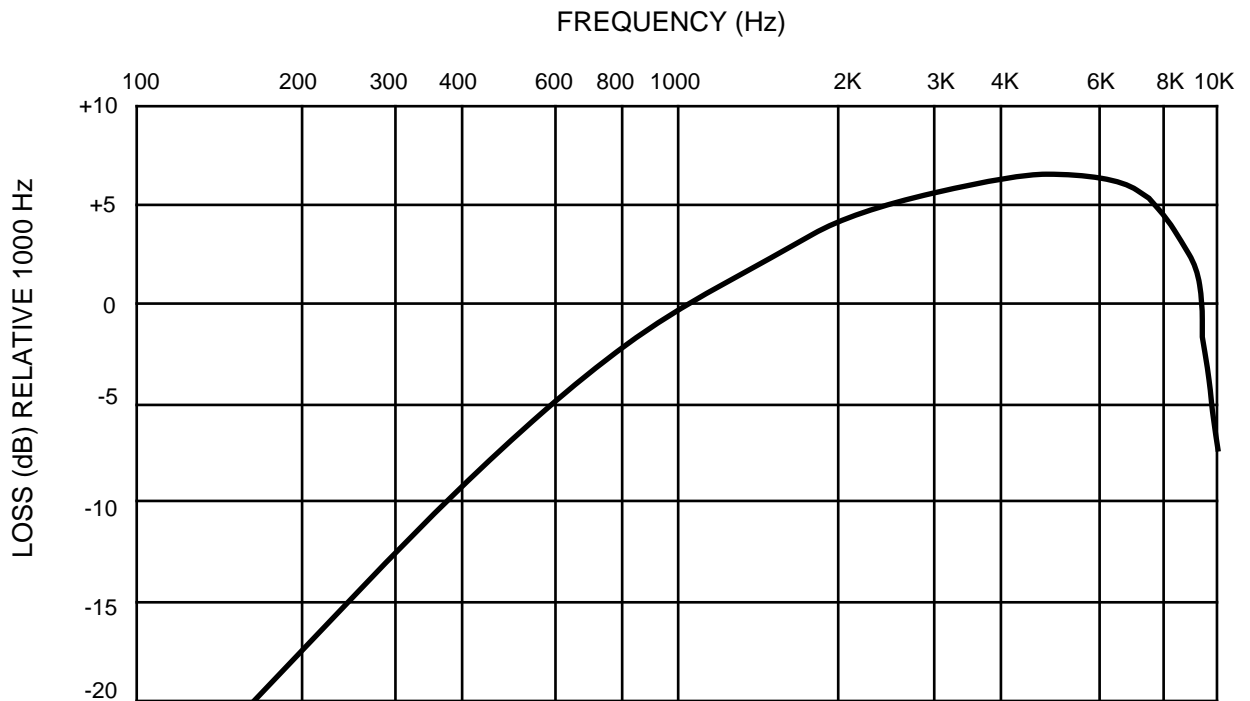
FREQUENCY (Hz)

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Figure 3-4. Program Filter Response
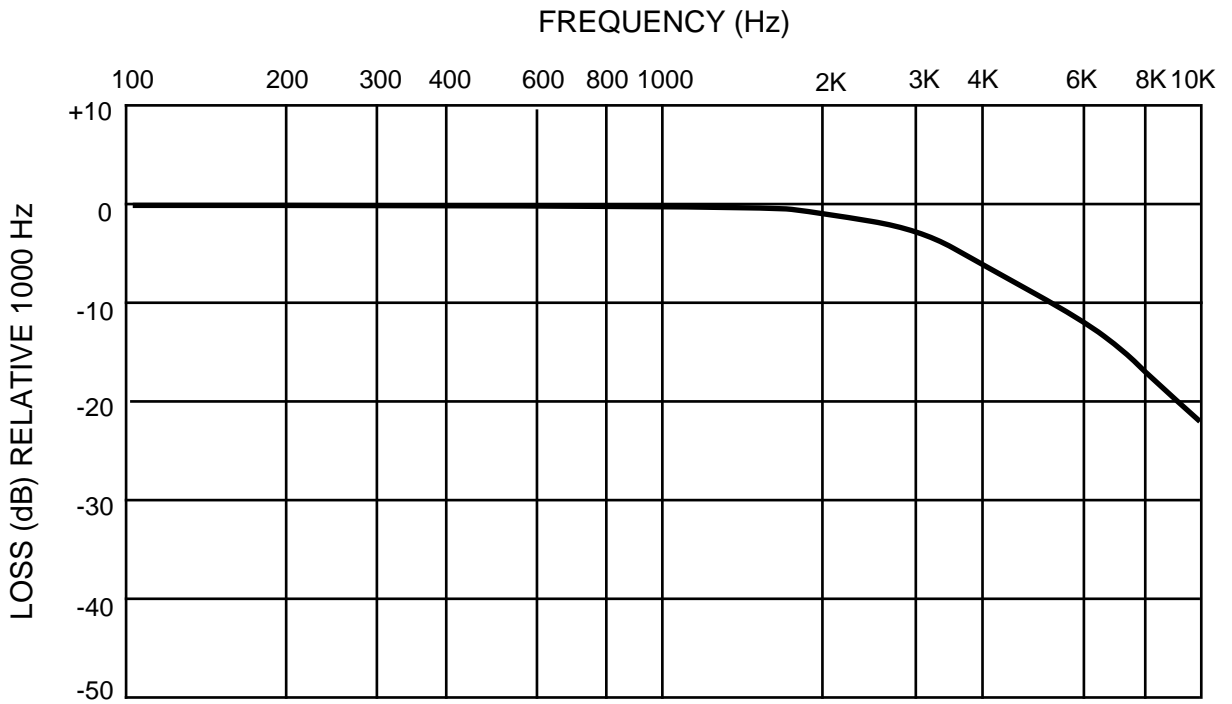
Figure 3-5. 3-kHz Flat Filter Response
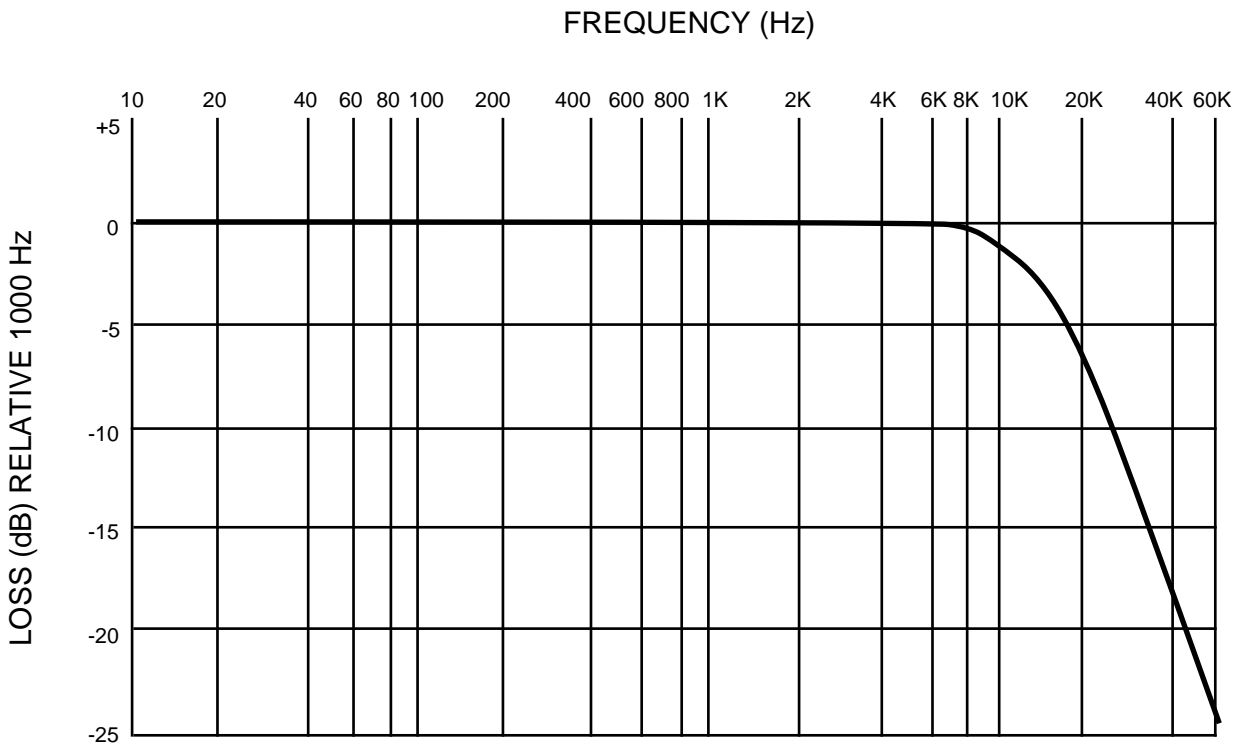
Figure 3-6. 15-kHz Flat Filter Response
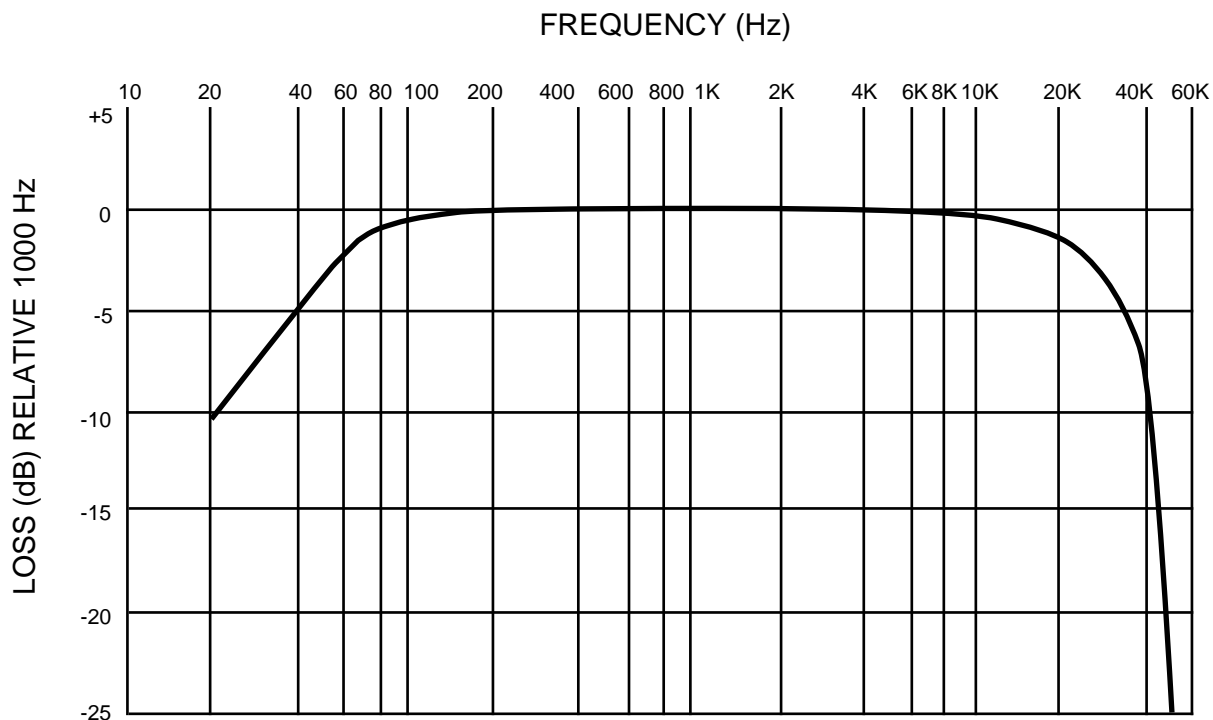
FREQUENCY (Hz)

Figure 3-7. 50-Kilobit Filter Response

Gain Slope. A gain slope (3-tone slope) test shows line loss at one frequency with respect to another frequency. Excessive loss at the lower frequencies causes the voice to sound tinny. Loss at the higher frequencies makes the voice signal unintelligible. To determine the gain slope, compare the difference between the received levels at 404 Hz and 1004 Hz to the difference between levels at 1004 Hz and 2804 Hz. The 4-Hz offset avoids measurement errors caused by test frequencies which are multiples of the carrier sampling rate.

Intermodulation Distortion (IMD). Amplifier and mixer stages using high gain transistors can generate intermodulation products (second and third harmonics). This results from beats between the components of a desired signal. The effect is equal to the addition of low amplitude signals. The frequencies of these signals equals the sums and differences of integral multiples of the two or more component frequencies present in the input waveform. These products interfere with the desired signal in the same manner as does noise.

Peak-to-Average Ratio (P/AR). The peak-to-average ratio test measures channel dispersion of a P/AR test signal. The shape of a P/AR test signal represents a data modulated voice-frequency signal. The center of its spectrum is about 1650 Hz, with 12 dB points at 100 Hz and 2400 Hz. The P/AR rating is a weighted measure of total attenuation, phase distortion, and noise. This rating provides a relatively good indication of the general quality of a voice band channel. If the received P/AR signal is entirely undistorted, the P/AR rating is 100.

Phase Jitter (PJ). Phase jitter is unwanted phase (or frequency) modulation. A signal may acquire jitter as it traverses a communications channel. Ripple in the dc power supply of the master oscillator of long-haul carriers is the usual cause. Some phase jitter can also occur in short haul systems from incomplete filtering of image sidebands. The most common frequency components of phase jitter are 20 Hz (ringing current), 60 Hz (commercial power), and their second and third harmonics. You measure phase jitter by sending a 1004-Hz holding tone at the data level. Use a test set at the receiving end to measure the phase deviation. To do this, establish a phase reference loop. Carrier standards for phase jitter are no more than 10 degrees between 20 and 300 Hz, and no more than 15 degrees between 4 and 300 Hz. Phase jitter rarely occurs above 300 Hz. When it does occur, jitter accompanies it below 300 Hz. This makes it easy to detect.

Signal-to-Noise Ratio (S/N). A signal-to-noise ratio test measures C-Notch or C-Message noise in dB. This is the amount by which the level of a 1004-Hz test tone exceeds the level of measured noise-with-tone on the line. To test the C-Notch noise, transmit a 1004-Hz test tone. To measure the resultant noise alone, use a notch filter to remove the test tone. The C-Notch filter takes the C-Message filter and adds a -50 dB stop band or notch between 995 Hz and 1025 Hz.

Singing Return Loss (SRL Low/High). Singing return loss results from sustained oscillations due to positive feedback in network amplifiers or amplifier circuits. Low singing return loss (SRL Low) is a weighted average of loss between 200 Hz and 600 Hz. High singing return loss (SRL High) is a weighted average of loss between 2200 Hz and 3400 Hz.

Transients

Transients are sudden changes in a received signal level or frequency. Analog testing is concerned primarily with four types of transient impairments:

- Dropouts
- Gain hits
- Impulse noise
- Phase hits.

Dropouts (DO). Dropouts are sudden decreases of 12 dB or greater in the received signal level. Communication links fail during a dropout. This means the receiving equipment must re-synchronize itself to the carrier signal before communication can resume. Like phase and gain hits, you measure dropouts by monitoring a holding tone. Then count the number of events that exceed a threshold during a specified time interval.

Gain Hits (GH). Gain hits are sudden changes in the received signal level ($\pm$ 1 through 10 dB). Gain hits create errors by appearing like information transmitted on an amplitude modulated carrier. You can measure gain hits by monitoring a holding tone. Then count the number of events that exceed selectable thresholds during a specified time interval.

Impulse Noise (LOW MD HI). Starting and stopping calls activates and releases switches. This can cause noise spikes from the associated electrical transients. These spikes have a low value of energy per pulse. However, because of their short time duration and high peak amplitude, they can interfere with the signal. A noise spike is impulse noise if it lasts less than 4 milliseconds. To measure the impulse noise, compare the number of spikes that exceed the low, mid, and high threshold levels.

> *NOTE: ITU-T applications use impulse noise specifications per ITU-T Recommendation O.71.*

Phase Hits (PH). Phase hits are sudden changes in the received signal phase or frequency ($\pm$ 5 through 45). The phase of the received signal may return to its original value in a short time, or remain indefinitely at a changed value. Phase hits create errors by appearing like information transmitted on a phase or frequency modulated carrier. You can measure phase hits by monitoring a holding tone. Then count the number of events that exceed selectable thresholds during a specified time interval.

Test Resources

An analog circuit test node includes two types of equipment: circuit access (switching) equipment and circuit test equipment. (See Figure 3-8.) The following paragraphs describe the access and test equipment that may exist at the test resource nodes in your network.

Access Equipment

Hekimian Model 3200 Metallic Test Access Unit (MTAU). Although user configurations may vary, the basic MTAU includes an access control shelf and a line relay shelf. The MTAU provides switched access for voice-frequency facility testing. It removes the need for test board jack fields. This increases test personnel productivity by permitting remote circuit access and testing.

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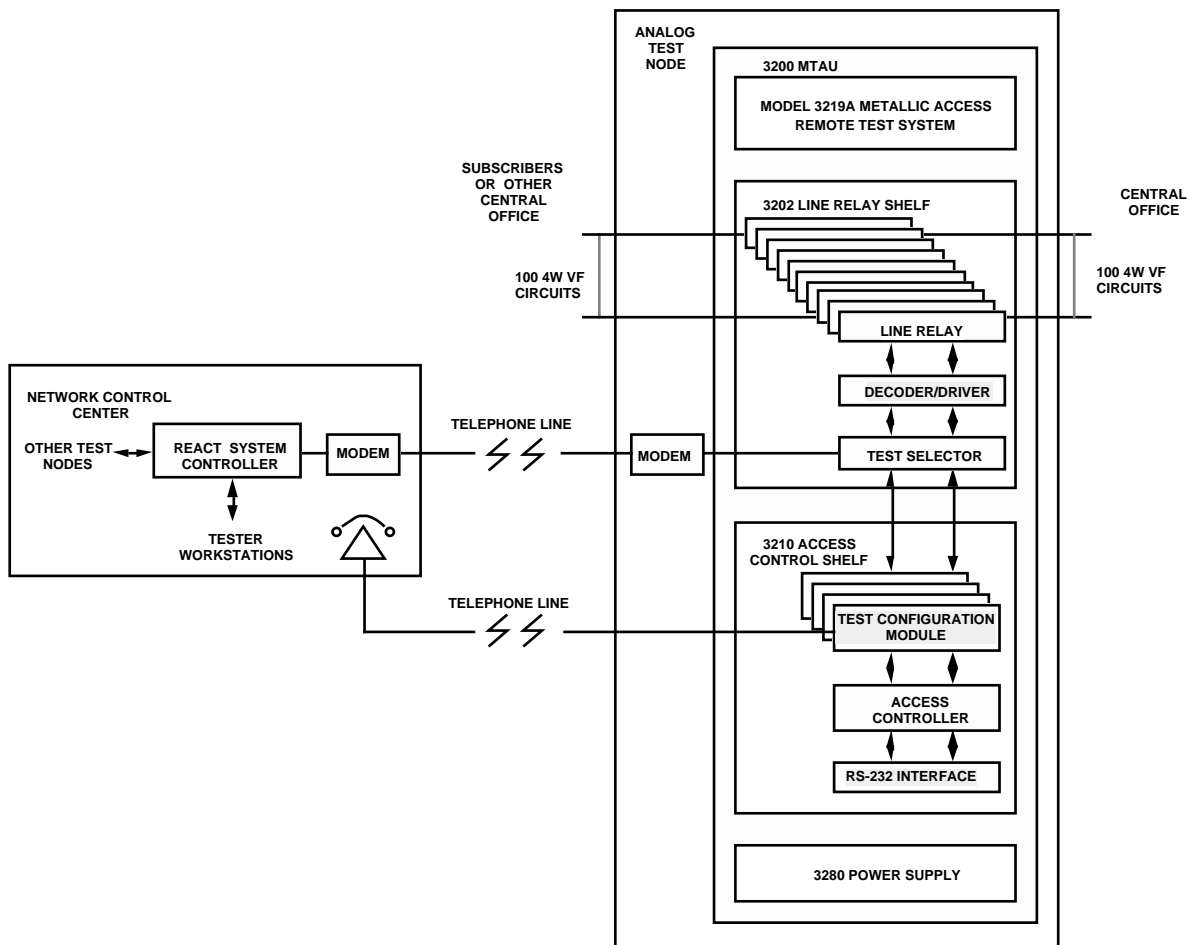
Figure 3-8. Typical Analog Circuit Test Node

Model 3200 Operating Characteristics

The operating characteristics of the Model 3200 support the following user requirements:

- Bridge and split access switching
- 2W, 4W, 6W, and 8W circuit capability
- RS-232 test position control
- Local and remote (unattended) control
- Transmission, signal, and cable testing
- Built-in system diagnostics.

Bridge and Split. Bridge and split access switching uses state-of-the-art telephone relay technology. In addition to featuring a gold over silver-palladium surface, all relay contacts associated with the bridging and splitting functions receive a sealing signal. This sealing enhances contact reliability. It also detects any open or improperly mated contacts.

2W, 4W, 6W, and 8W Circuit Capabilities. The basic switch design accommodates 2-wire, 4-wire, 6-wire, and 8-wire circuits. You can intermix circuit configurations. You can address individual pairs without disturbing the full circuit. Additional test position switching is available to configure the line under test to a "ready to test" condition.

RS-232 Test Resource Control. You can control test resources through any RS-232 compatible terminal. This allows you to use the test system in stand-alone applications as well as computer-controlled local and remote test systems.

Local and Remote (Unattended) Control. Local control is available by connecting an RS-232 compatible terminal to the RS-232 control port. Remote control is available by connecting a modem to an RS-232 control port. This provides remote (unattended) control without any additional hardware options or modifications.

Transmission, Signal, and Cable Testing. You can connect test equipment with an RS-232 control port to the test position test line appearance. This allows remote-controlled test instruments to operate through the remote control (unattended) modem facility used for switch control. This test capability is fully compatible with Hekimian's line of cable, signaling, and transmission testing instrumentation.

Built-in System Diagnostics. All systems have built-in diagnostics. In addition to a variety of system alarm indicators, diagnostics show system status and clear system faults. They also perform system tasks such as automatically resealing all or part of the circuits in the system.

Model 3200 Basic Units

Model 3202-01 Line Relay Shelf. Each line relay shelf within the MTAU system contains a maximum of 10 line relay cards. These cards have bridging and splitting relays for up to 50 8-wire circuit groups. You can intermix circuits for a maximum capacity of 200 2-wire circuits, 100 4-wire circuits, or 50 6- or 8-wire circuits. This shelf provides line and equipment connections via standard 25-pair telephone cables. It contains all necessary relay, test bus, and control circuitry. Each shelf has a test selector card and decoder/driver card. The test selector card connects a selected circuit to one of four available test buses per the line relay shelf. The decoder/driver card interfaces the line relay shelf to the access control shelf.

Model 3210-01 Access Control Shelf. This shelf includes an access control processor, an RS-232-C interface card, and a maximum of four optional test configuration modules. The access control processor is a 16-bit microprocessor. It processes serial commands from the system test resources to access a circuit. The interface card provides the communications link between the MTAU, peripheral devices, and test resources. Each optional test configuration module controls the selection of a test line and equipment test direction. This module also controls other test line appearance functions between the test bus and its test line appearance ports.

Model 3280 Power Supply. This power supply provides power for the access control shelf and all line relay shelves. It also powers the communications test system.

Test Equipment

Model 3703 Communications Test System. The basic Model 3703 CTS can perform 40 Hz to 20 kHz level, noise, frequency, and return loss measurements. A multiple function signal generator, and a flexible 2W/4W line interface are also available. The 2W/4W line interface includes independent send/receive impedance selection of 135 ohms, 600 ohms, 900 ohms, or 1200 ohms (bridged or terminated receive). It also includes send/receive line reversal, dual hold circuits, and an internal dial capability.

Among the standard features of the Model 3703 are a programmable transmission level point (TLP) and noise mode. Also included are a C-Notch filter and a frequency counter with 1-Hz resolution. The programmable TLP allows extended low-level measurements of level and noise. C-Message and 3-kHz noise weighting filters are standard. The 15-kHz Flat and Program, or 15-kHz Flat and 50-Kilobit weighting filters are available as options. Other available measurement capabilities include:

- Signal-to-noise ratio
- 2W and 4W return loss
- 3-level impulse noise
- Intermodulation distortion
- Envelope delay
- Phase and amplitude jitter
- Hits
- P/AR
- Master-slave
- Responders.

For more details, refer to the Model 3700 Communications Test Systems User's Manual.

Hekimian Model 3901 Communications Test System (CTS). The Model 3901 CTS basic unit combines 40 Hz to 20 kHz level, noise, frequency, and return loss measurements. This unit also features a multiple function signal generator and a flexible 2W/4W line interface. The 2W/4W line interface includes send/receive line reversal, and dual-hold circuits. There is also a versatile dial-talk arrangement that provides local talk battery in the 4-wire mode. Standard features include a C-Notch filter, programmable transmission level point (TLP) and noise mode with 0.1-dB adjustment resolution, and a frequency counter with 0.1-Hz resolution for high accuracy frequency offsets. You can configure up to eight single-width, plug-in measurement modules to match your needs. Several available measurement capabilities include:

- 2W and 4W return loss
- 3-level impulse noise
- Non-linear distortion
- Envelope delay
- Phase and amplitude jitter
- Hits
- P/AR
- Master-slave
- Responders
- Remote VOM/CAP.

For more details, refer to the Model 3900-series Communications Test System Operating Manual.

Hekimian Model 3219 SMAS Access Controller. The Model 3219 SMAS Access Controller can control the following systems of metallic access equipment: AT&T's Switched Maintenance Access System (SMAS) or Hekimian's Metallic Test Access Unit (MTAU). It provides a plug-for-plug replacement for the Remote Test System (RTS)-5A controller and allows direct interface and control of SMAS 5A/5B components through TL1 commands. The Model 3219 supports up to 20 simultaneous tests of analog circuits using Model 3708 System Test Shelves. The Model 3708s can be configured to run enhanced analog tests or data impairment tests.

For more details, refer to the Model 3219 SMAS Access Controller System Installation, Operation, and Maintenance Manual.

Hekimian Model 3219A Metallic Access Remote Test System (MARTS). The Model 3219A MARTS controls existing AT&T Switched Maintenance Access System (SMAS) network elements through TL1 commands and provides special services testing. Designed as a plug-for-plug replacement for a complete AT&T Remote Test System (RTS)-5A, MARTS replaces the RTS-5A controller, remote test port panels, and test enhancement shelf. The Model 3219A is also capable of bringing up an MTAU access. MARTS provides a full selection of signaling and supervision in the test and nontest direction. Signaling capabilities include:

- Loop signaling (2-wire and 4-wire)
- DX signaling (2-wire and 4-wire)
- E&M 1, 2, 3, 4, and 5 signaling
- SF signaling
- No-Test Trunk interface.

Several available measurement capabilities include:

- Level and frequency
- Noise
- Return loss
- Phase/amplitude jitter
- Transients (phase hits, gain hits, and dropouts)
- Intermodulation distortion
- Impulse noise
- P/AR
- Voltage (ac and dc)
- Current (ac and dc)
- Resistance
- Capacitance
- Simplex voltage and resistance.

For more details, refer to the Model 3219A Metallic Access Remote Test System Installation, Operation, and Maintenance Manual.

Hekimian Model 3509 CCITT Metallic Access Remote Test System (MARTS). The Model 3509 CCITT MARTS controls new or existing MTAU network elements through TL1 commands and provides special services testing. Testing capabilities include basic noise, level, frequency, multimeter, signaling, and enhanced data parameter testing for VF and analog data circuits. The Model 3509 uses an MTAU for circuit access. Additional functions include the following:

- Executes far-end access and testing functions
- Provides remote diagnostics
- Allows remote downloading of software
- Provides No-Test Trunk interface.

For more details, refer to the Model 3509 CCITT Metallic Access Remote Test System Installation, Operation, and Maintenance Manual.

Hekimian Model 3560 Digital Loop Carrier Remote Test Unit (DLC RTU). The Model 3560 DLC RTU provides comprehensive special services testing capabilities for metallic circuits in the subscriber loop. Special services testing capabilities include analog voice and analog data testing on 2-wire, 4-wire, and 6-wire access points toward the customer drop or the central office terminal. The Model 3560 uses DSC Communication Corporation's Litespan-2000 system for circuit access.

For more details, refer to the Model 3560 Digital Loop Carrier Remote Test Unit Installation, Operation, and Maintenance Manual.

Hekimian Model 3570 Small Office Integrated Test System. The Model 3570 Small Office Integrated Test System provides small office analog and DDS metallic and/or DCS access and testing. Testing capabilities include VF, analog data, multimeter, DDS, and DS1. The Model 3570 provides up to two metallic analog or DDS accesses, and as many as three DCS access. DCS access can be channelized, DDS, or DS1. DDS DS0A/DS0B testing is supported from both the metallic and the DCS testing sides of the system.

For more details, refer to the Model 3570 Small Office Integrated Test System Installation, Operation, and Maintenance Manual.

Circuit Access Configurations

The following paragraphs describe circuit access configurations that are available for analog circuit testing. These configurations consist of the following:

- No signaling (NONE)
- Single Frequency (SF)
- Duplex (DX)
- E&M I, E&M II, E&M III, E&M IV, and E&M V
- Loop
- Dual access.

No Signaling (NONE) Type Circuit Configurations

No signaling (NONE) type circuits are data (sub-voice) circuits that have no signaling or supervisory requirements. In REACT, these signaling types are NONE(4W) and NONE2W. These configurations do not provide for analog voice transmission.

Single Frequency (SF) Type Circuit Configurations

Single Frequency (SF) systems are compatible with loop type and E&M type signaling interfaces. SF signaling uses the presence or absence of a 2600-Hz tone to determine the onhook/offhook status of the line. A typical application is on a 4-wire carrier system with origination from either end. One major difference between SF type signaling systems and dc signaling systems is that SF signaling systems interrupt the voice path during and after transitions between onhook and offhook.

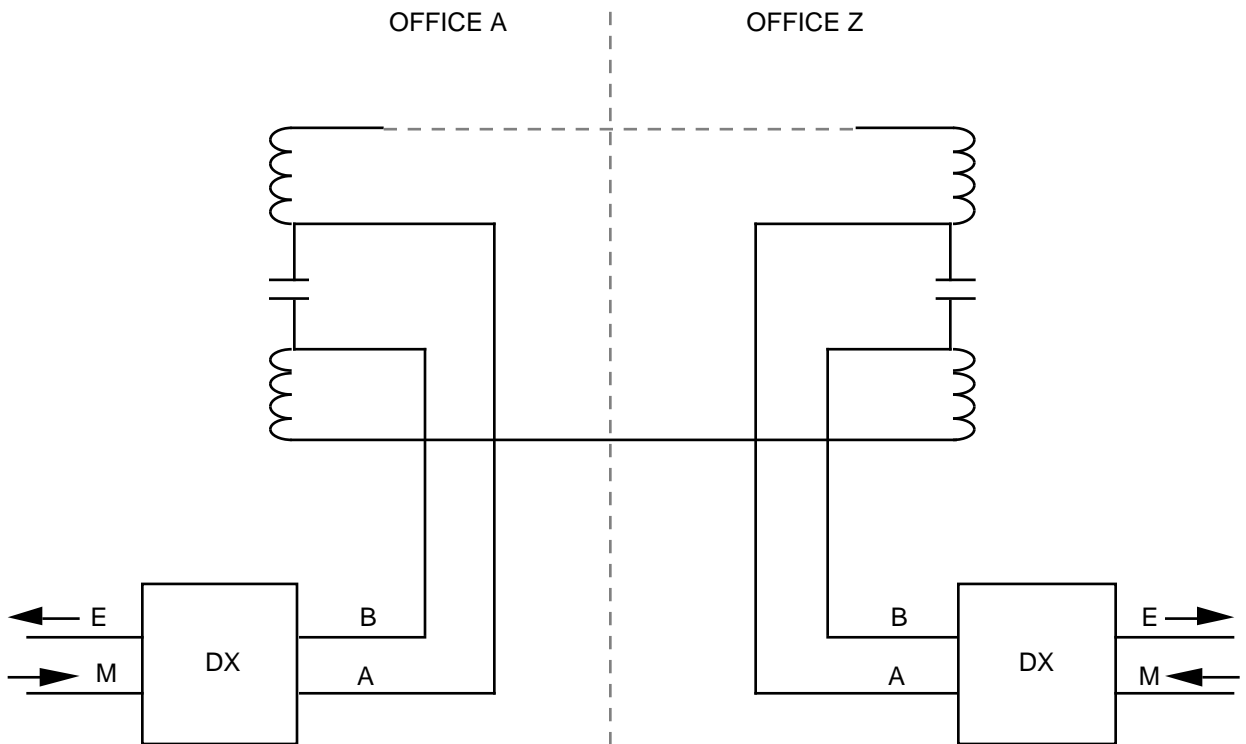### Duplex (DX) Type Circuit Configurations

Duplex (DX) type circuits provide simultaneous two-way signaling. This is based upon a balanced and symmetrical circuit that is the same at both ends. (See Figure 3-9.) Duplex signaling is restricted to 2-wire (DX2W) and 4-wire (DX4W) line facilities. In the idle or onhook state, no current flows into the system. If either end becomes busy or goes offhook, the system becomes unbalanced. A current detector at the opposite end senses the resulting current flow. This type of circuit may extend E&M type circuit leads beyond their normal limitations.

E&M Type Circuit Configurations

> E&M type signaling systems traditionally use one lead for each direction of transmission between switching equipment and signaling equipment. They share a common ground return. E&M systems derive their name from historical designations of the signaling leads. The E lead carries signals from the signaling equipment to the switching (trunk) equipment. The M lead carries signals from the switching (trunk) equipment to the signaling equipment.

Type I E&M Circuit

> Figure 3-10 shows a 2-wire Type I E&M interface. The dc conditions (onhook/offhook) for the E lead are such that ground is presented to the E lead for a FACILITY OFFHOOK state (E lead contact closed). For FACILITY ONHOOK (E lead contact open) an open circuit (battery) is presented to the E lead.

1161A

Figure 3-9. Typical Duplex (DX) Circuit Configuration

The dc conditions for the M lead are such that battery is presented for an EQUIPMENT OFFHOOK state (M lead contact closed). During the offhook state, a current limiting device should exist in series with the battery feed. Resistance should not be more than 60 ohms while under a load of 85 milliamps, plus any internal equipment load current. Also, the drop between battery supply and the M lead should not be greater than 5 V. For an EQUIPMENT ONHOOK state (M lead contact open), the potential drop between the M lead and local ground should not exceed 1 V.

For an equipment originated call, the M lead changes from ground to battery. This sends offhook signaling toward the facility. When the facility answers (goes offhook), the E lead changes from open circuit (E lead contact open) to ground (E lead contact closed). Both equipment and facility are offhook. A link exists between the two. For a facility originated call, the E lead changes from an open circuit (E lead contact open) to ground (E lead contact closed). This causes offhook signaling toward the equipment side. When the equipment answers by going offhook, the M lead changes from ground (M lead contact open) to battery (M lead contact closed).
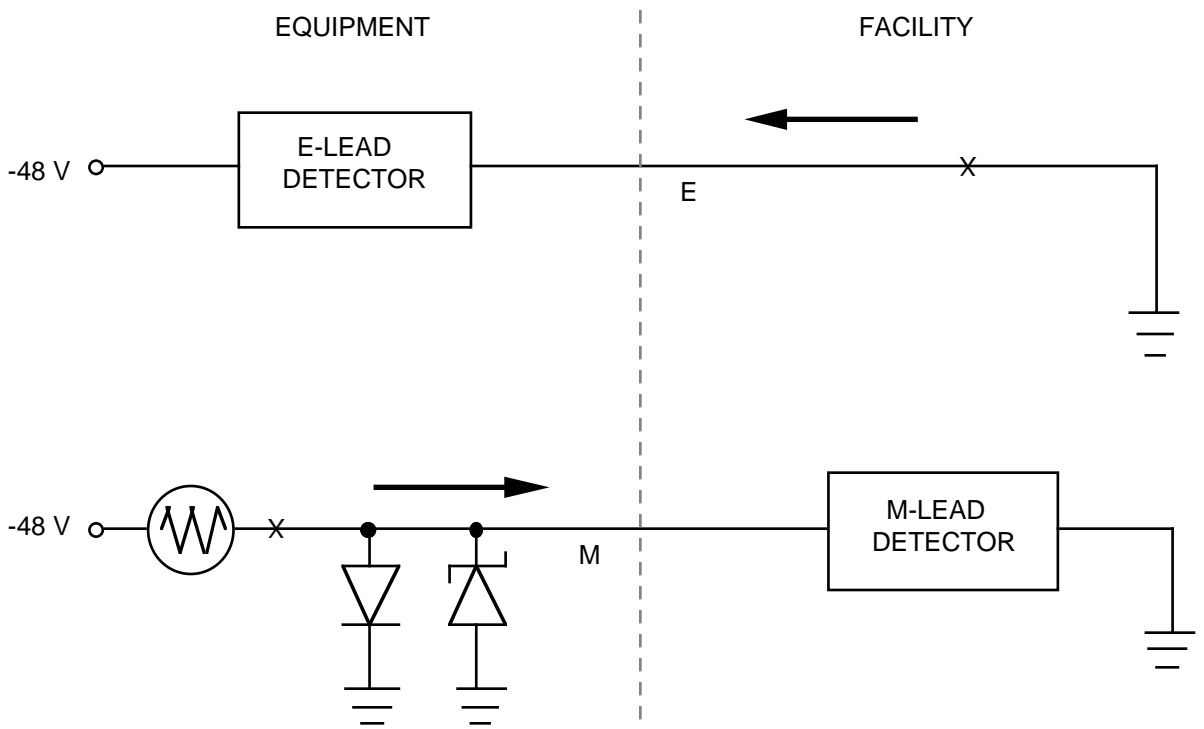

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Figure 3-10. Type I E&M Circuit Configuration

Type II E&M Circuit

Figure 3-11 shows a 4-wire Type II E&M interface. For EQUIPMENT OFFHOOK (M lead contact closed), battery is presented to the M lead. For EQUIPMENT ONHOOK (M lead contact open), the M lead appears as an open circuit (high input impedance). In the offhook state, the potential drop from the M lead to the SB lead should not exceed 2 V.

For FACILITY OFFHOOK (E lead contact closed) ground is presented to the E lead. For FACILITY ONHOOK (E lead contact open), an open circuit (battery) is presented to the E lead.

To initiate an equipment originated call, close the loop across the M and SB leads. This sends offhook signaling toward the facility. The facility answers (goes offhook) by closing the path across the E and SG leads. To initiate a facility originated call, close the loop across the E and SG leads. This sends offhook signaling toward the equipment. The equipment answers (goes offhook) by closing the path across the M and SB leads.
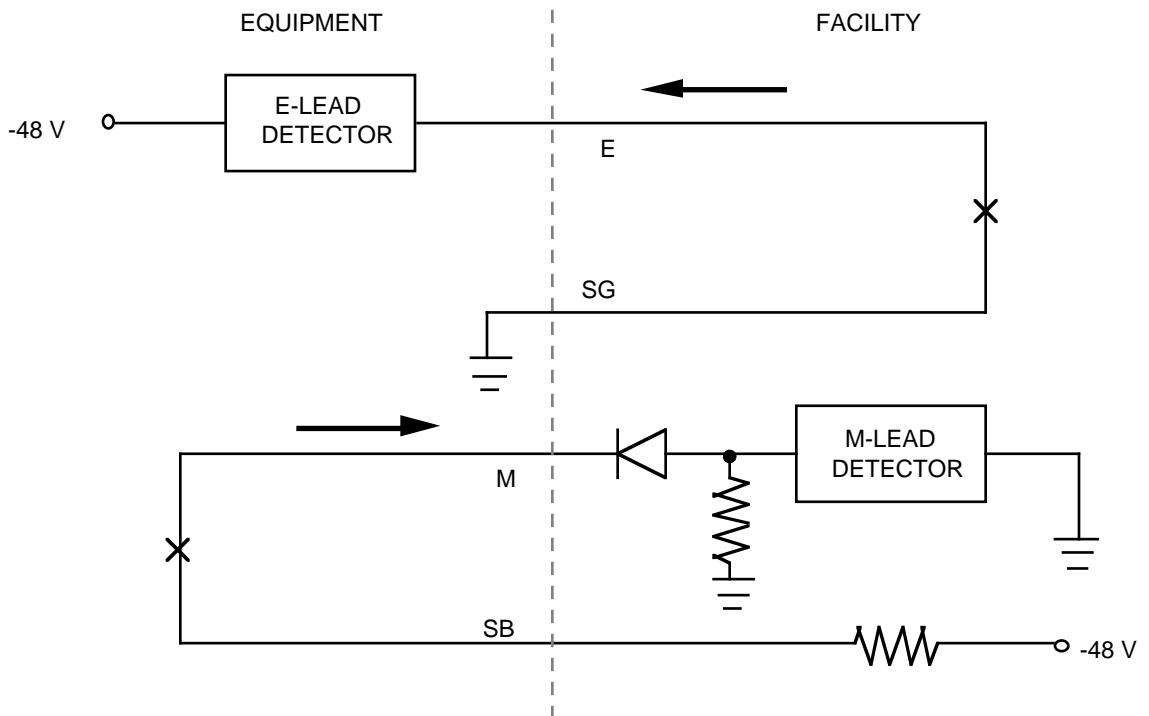
Type III E&M Circuit

Figure 3-12 shows a 4-wire Type III E&M interface. For EQUIPMENT ONHOOK (M lead contact open), the M lead appears as ground. The dc requirements say that the M lead should have less than a 2 V potential drop to ground. For EQUIPMENT OFFHOOK (M lead contact closed), the M lead detects battery. For FACILITY ONHOOK (E lead contact open), the E lead detects an open circuit (battery). For FACILITY OFFHOOK (E lead contact closed), the E lead detects ground.

Type IV E&M Circuit

Figure 3-13 shows a 4-wire Type IV E&M interface. This interface is a symmetrical, 4-wire looped E&M arrangement. Signaling from the equipment to the signaling facility is through opens and closures across the M (ONHOOK) and SB (OFFHOOK) leads; signaling in the reverse direction is across E and SG leads. Since the equipment grounds the SG lead and the signaling facility grounds the SB lead, the signaling over both E&M leads is by open for onhook and ground for offhook.
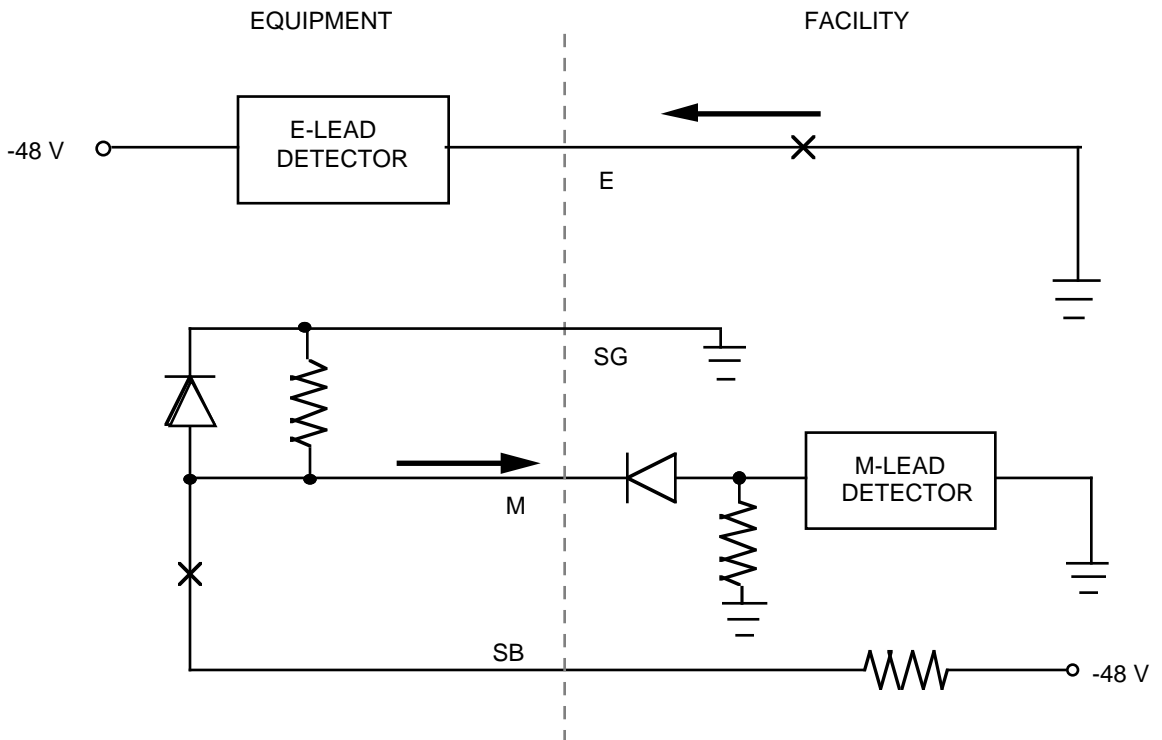
Type V E&M Circuit

Figure 3-14 shows a 2-wire Type V E&M interface. This interface is a symmetrical 2-wire E&M arrangement that signals in both directions–open for onhook and ground for offhook. Signaling from the equipment to the signaling facility is over the M lead; signaling in the reverse direction is over the E lead. The Type V E&M interface uses local ground for offhook (unlike the Type IV E&M interface in which ground is obtained over the SB or SG lead).
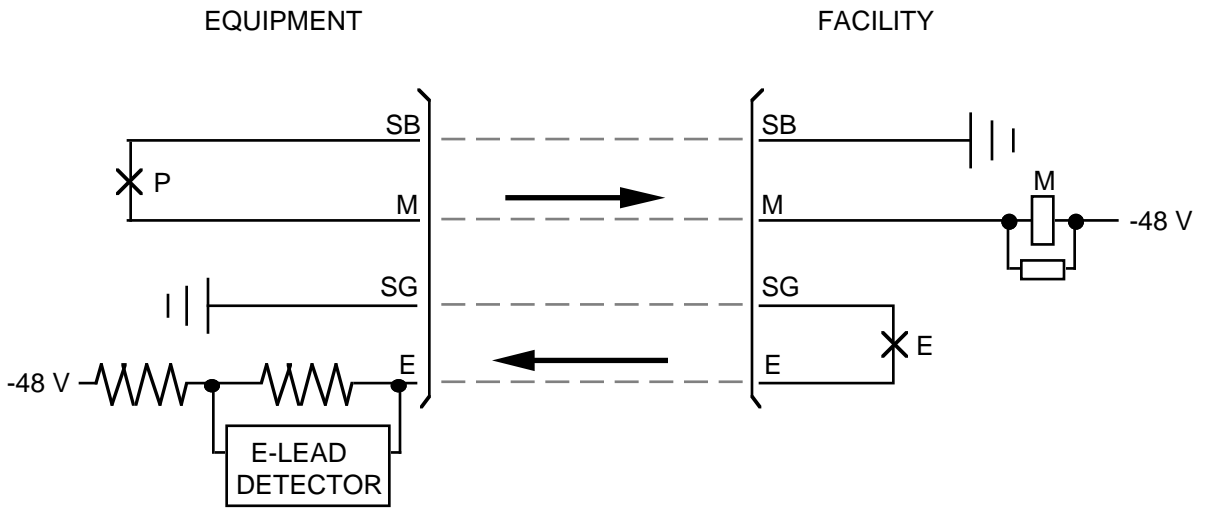
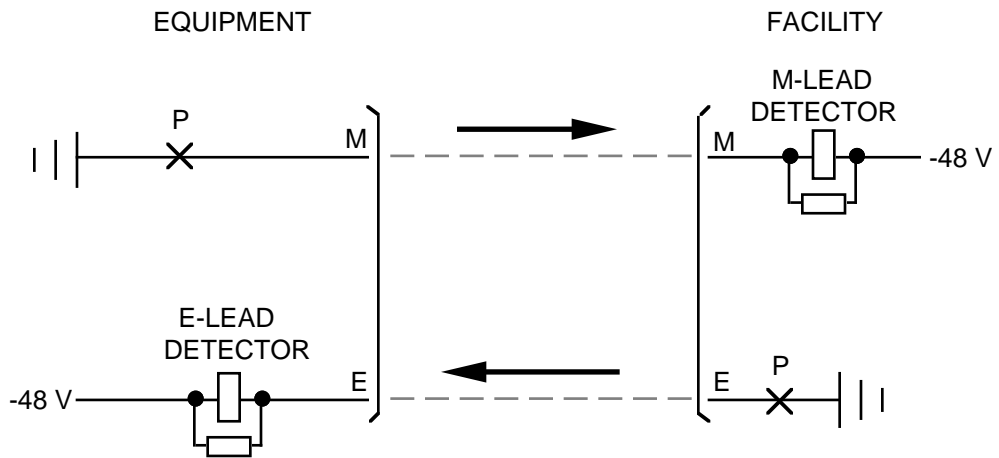1163A

Figure 3-11. Type II E&M Circuit Configuration

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Figure 3-12. Type III E&M Circuit Configuration

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Figure 3-13. Type IV E&M Circuit Configuration

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Figure 3-14. Type V E&M Circuit Configuration

Loop Type Circuit Configurations

> Loop signaling provides continuous application of a dc voltage between a caller's terminal equipment and either a carrier central office or remote terminal. Current sensing equipment at the central office or remote terminal recognizes one signaling state when the caller's equipment is onhook (no current flowing). It recognizes a second signaling state when the caller's equipment is offhook (current flow in loop). It recognizes a third signaling state by reversing the direction or changing the magnitude of the current in the loop. This circuit configuration includes 2-wire loop (LP2W) and 4-wire loop (LP4W) circuit types.

Dual-Access Test Configurations

> Dual-access or office-to-office testing allows you to access a circuit at two points simultaneously. This method allows you to test in either direction. This testing uses the full capabilities of the test equipment at each node.