Tektronix®

F7523A1 MOD WQ

Distortion Test Set

TS-4353/U

OPERATORS

Tektronix®
COMMITTED TO EXCELLENCE

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F7523A1 MOD WQ

Distortion Test Set

TS-4353/U

OPERATORS

Contract Number: M67854-89-D-0030
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Tektronix, Inc.
P.O. Box 500
Beaverton, Oregon 97077

Serial Number ____________________

070-7813-01
Product Group 75

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INSTRUMENT SERIAL NUMBERS

Each instrument manufactured by Tektronix has a serial number pm a panel insert, tag, or stamped on the chassis. The letter at the beginning of the serial number designates the country of manufacture. The last five digits of the serial number are assigned sequentially and are unique to each instrument. Those manufactured in the United States have six unique digits. The country of manufacture is identified as follows:

B010000 – Tektronix, Inc. Beaverton, Oregon, USA
G100000 – Tektronix Guernsey, Ltd., Channel Islands
E200000 – Tektronix United Kingdom, Ltd., London
J300000 – Sony/Tektronix, Japan
H700000 – Tektronix Holland, NV, Heerenveen, The Netherlands

Instruments manufactured for Tektronix by external vendors outside the United States are assigned a two digit alpha code to identify the country of manufacture (e.g., JP for Japan, HK for Hong Kong, IL for Israel, etc.)

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Tektronix warrants that the products that it manufactures and sells, of the types listed below, will be free from defects in materials and workmanship for a period of one (1) year from the date of shipment. If any such product proves defective during this warranty period, Tektronix, at its option, either will repair the defective product without charge for parts and labor, or will provide a replacement in exchange for the defective product.

In order to obtain service under this warranty, Customer must notify Tektronix of the defect before the expiration of the warranty period and make suitable arrangements for the performance of service. Customer shall be responsible for packaging and shipping the defective product to the service center designated by Tektronix, with shipping charges prepaid. Tektronix shall pay for the return of the product to Customer if the shipment is to a location within the country in which the Tektronix service center is located. Customer shall be responsible for paying all shipping charges, duties, taxes, and any other charges for products returned to any other locations.

This warranty shall not apply to any defect, failure or damage caused by improper use or improper or inadequate maintenance and care. Tektronix shall not be obligated to furnish service under this warranty a) to repair damage resulting from attempts by personnel other than Tektronix representatives to install, repair or service the product; b) to repair damage resulting from improper use or connection to incompatible equipment; or c) to service a product that has been modified or integrated with other products when the effect of such modification or integration increases the time or difficulty of servicing the product.

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OPERATORS SAFETY SUMMARY

The general safety information in this part of the summary is for both operating and servicing personnel. Specific warnings and cautions will be found throughout the manual where they apply, but may not appear in this summary.

TERMS

In This Manual

CAUTION statements identify conditions or practices that could result in damage to the equipment or other property.

WARNING statements identify conditions or practices that could result in personal injury or loss of life.

As Marked on Equipment

CAUTION indicates a personal injury hazard not immediately accessible as one reads the marking, or a hazard to property including the equipment itself.

DANGER indicates a personal injury hazard immediately accessible as one reads the marking.

SYMBOLS

In This Manual

This symbol indicates where applicable cautionary or other information is to be found.

As Marked on Equipment

DANGER – High voltage.

Protective ground (earth) terminal.

ATTENTION – Refer to manual.

Refer to manual.

Power Source

This product is intended to operate in a power module connected to a power source that will not apply more than 250 volts rms between the supply conductors or between either supply conductor and ground. A protective ground connection by way of the grounding conductor in the power cord is essential for safe operation.

Grounding the Product

This product is grounded through the grounding conductor of the power module power cord. To avoid electrical shock, plug the power cord into a properly wired receptacle before connecting to the product input or output terminals. A protective ground connection by way of the grounding conductor in the power cord is essential for safe operation.

Danger Arising From Loss of Ground

Upon loss of the protective-ground connection, all accessible conductive parts (including knobs and controls that may appear to be insulating) can render an electric shock.

Use The Proper Fuse

To avoid fire hazard, use only the fuse specified in the parts list for your product, and which is identical in type, voltage rating and current rating.

Refer fuse replacement to qualified service personnel.

Do Not Operate in Explosive Atmospheres

To avoid explosion, do not operate this product in an explosive atmosphere unless it has been specifically certified for such operation.

Do Not Operate Plug-In Unit Without Covers

To avoid personal injury, do not operate this product without covers or panels installed. Do not apply power to the plug-in via a plug-in extender.

Section 1
System Overview

TEST SET DESCRIPTION

F7523AI Mod WQ is a compact portable distortion test set. The test set is comprised of a test set transmitter and receiver. The test set transmitter provides a low distortion signal source and an intermodulation distortion 1:1 twin-tone signal source. The test set receiver provides a fully automatic distortion analyzer

The test set transmitter is comprised of a SG 505 Mod WQ Oscillator and a SG 505 Mod WR Oscillator coupled together internally via the power module mainframe. The test set receiver is comprised of the AA 501A Mod WQ Distortion Analyzer. The test set transmitter and receiver are installed in the TM 504A Mod WQ Power Module mainframe. Refer to Fig. 1.1.1.

The test set transmitter generates custom twin-tone frequencies from 2kHz to 100 kHz and single tone frequencies of choice between 10 Hz and 100 kHz. The twin-tone frequencies are generated by mixing the two oscillators in a 1:1 ratio using the internal function or externally in any desired ratio to produce the desired difference frequencies. The test set receiver provides measurement functions for LEVEL (VOLTS, dBm, dB RATIO), total harmonic distortion, SPMTE/DIN, and CCIF IMD. See Section 2, Part 2 for a discussion of these measurement functions.

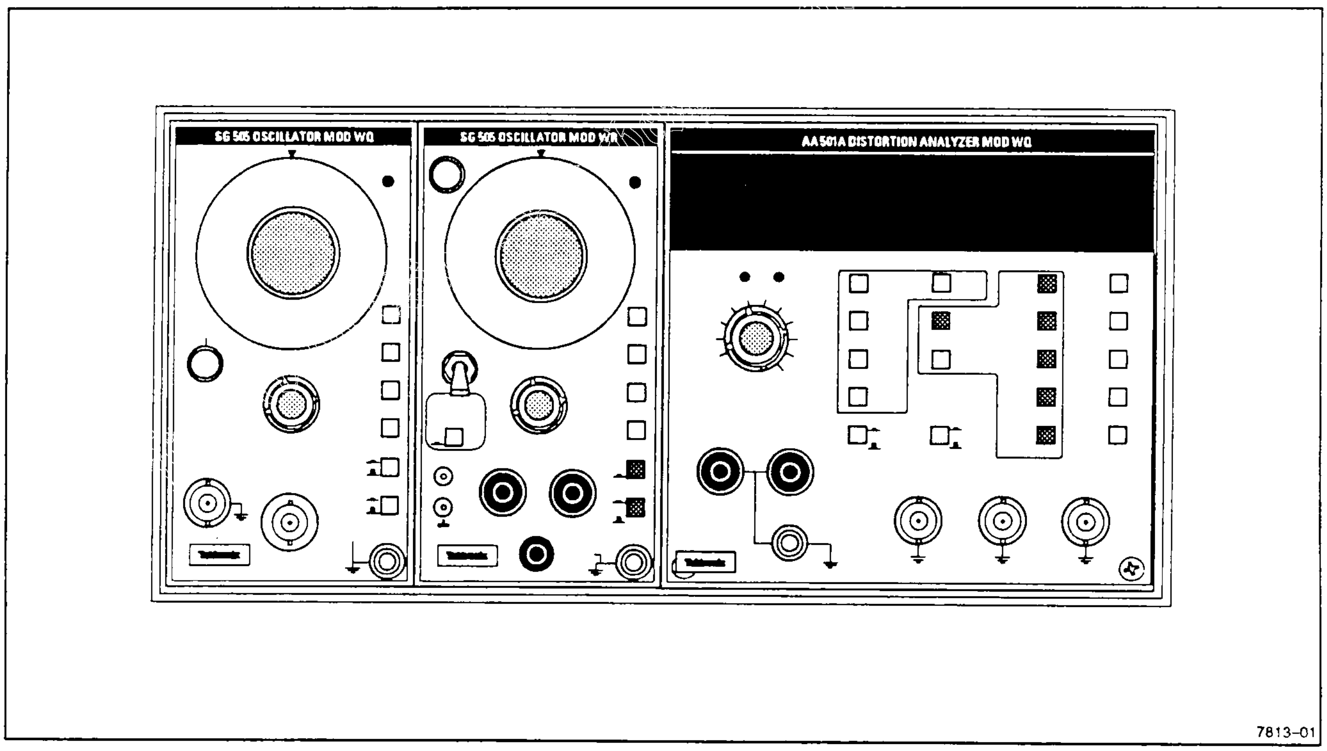

Fig. 1.1.1. F7523A1 Mod WQ.

MAJOR COMPONENTS AND ACCESSORIES

The F7523A1 Mod WQ includes the following:

Major Components

Quantity	Description
1	AA501A Mod WQ Distortion Analyzer.
1	SG 505 Mod WQ Test Signal Oscillator.
1	SG 505 Mod WR Test Signal Oscillator.
1	TM 504A Mod WQ Power Module.

Furnished Accessories

Quantity	Description
1	Cable Assembly, RF: 50 Ω Coax, 20.0 L (BNC to tip-jack cable). Tektronix Part Number 175-1178-00.
1	Power cord for TM 504A Mod WQ.
2	BNC female to dual banana adapters. Tektronix Part Number 103-0090-00.

Additional *User-Supplied* Items Needed for Operation and Use

Quantity	Description
2	Coaxial cables or twisted-wire pairs to connect system to device being tested.

SYSTEM SPECIFICATION

(In addition to separate specifications for individual instruments)

Table 1.1.1
ELECTRICAL CHARACTERISTICS

Characteristics	Performance Requirements	Supplemental Information
TWIN-TONE MODE Relative Amplitude Match	1:1 +0.5 dB	
Thd of individual signals		≤0.1%
SYSTEM TOTAL HARMONIC DISTORTION PLUS NOISE FUNCTION Residual THD + N (V_{in} ≥ 250 mV) 10 HZ – 50 kHz, no filter	≤0.01% rms Response (-80 dB)	
50 kHz – 100 kHz, no filter	≤0.10% rms Response (-60 dB)	
SYSTEM INTERMODULATION Twin-Tone Residual IMD	≤-90 dB	
POWER REQUIREMENTS Voltage Ranges		Selectable 100V, 110V, 120V 200V, 220V, and 240V nominal line, ± 10%
Frequency Range		48 to 440 Hz
Power Consumption		≤ 75 watts

Table 1.1.2
ENVIRONMENTAL CHARACTERISTICS

Characteristics	Supplemental Information
Overall	Meets or exceeds MIL-T-28800D, Class 5 requirements.
Temperature	
Operating	0°C to +50°C.
Non-operating	-55°C to +75°C.
Humidity	90-95% RH for 5 days cycled to +50°C.
Altitude	
Operating	4.6 km (15,000 ft).
Non-operating	15 km (50,000 ft).
Vibration	0.38 mm (0.013"), 5 Hz to 55 Hz, 75 minutes.
Shock	40 g's (terminal sawtooth), 11 ms, 18 shocks.
Bench handling	45°, 4", or equilibrium, whichever occurs first.
Transportation	Qualified under National Safe Transit Association Preshipment Test Procedures 1A-B-1 and 1A-B-2.

PHYSICAL CHARACTERISTICS

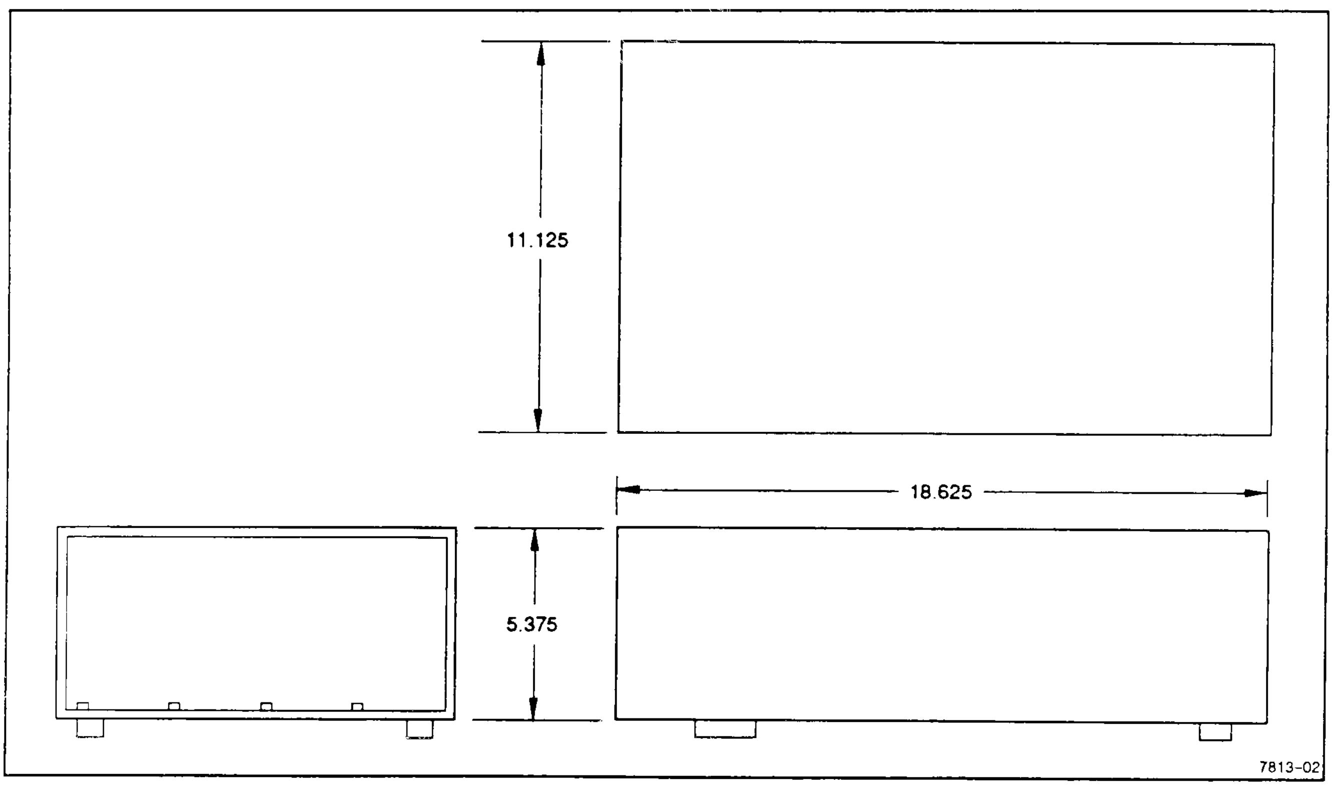

Fig 1.1.2. F7523A1 System Outline Drawing.

MEASUREMENT BASICS

Measurement Fundamentals

Much of the special vocabulary used by audio and communications workers relates to the dB (decibel). Since level measurements are common from several tens of volts on down to microvolts, the industry long ago standardized on using dB to express both absolute levels and ratios of signals.

In the broadcasting, recording, and satellite/microwave/telephone industries, absolute levels are also referred to in dB rather than volts or watts. The most common reference is one milliwatt. Levels referred to one milliwatt are expressed in dBm. Watts are clearly a power unit, but most level-measuring instruments are voltmeters (not wattmeters) and are not sensitive to circuit impedance. They must be calibrated for some particular value of impedance if they are to display dBm (power) even though they really measure voltage; 600 ohms is the most common circuit impedance in broadcasting and recording (150 ohms is also frequently used). Most of the other special terminology is in the area of standard industry specifications. SMPTE is the Society of Motion Picture and Television Engineers. DIN is the Deutsches Institut fur Normalung, German standards. CCIR, CCIF, and CCITT are all French initials for International Radio Consultative Committee, International Telephone Consultative Committee, and International Telegragh Consultative Committee, all European standards. IEC is the International Electrotechnical Commission. IHF is the Institute of High Fidelity Manufacturers and EIA is the Electronic Industries Association. SINAD stands for the ratio of (signal + noise + distortion) to (noise + distortion).

Most measurements in the audio and communication world are made below 100 kHz and fall into two broad categories: level and non-linearity. Level measurements include frequency response, gain/loss, noise level or signal-to-noise (S/N) ratio, power, and cross-talk/separation/isolation. Nonlinearity measurements include total harmonic distortion (THD), THD plus noise (THD + N), individual harmonic distortion, intermodulation distortion (IMD; standards include SMPTE, DIN, CCIF, and Twin-Tone).

Communications and audio equipment under ideal conditions faithfully reproduces an input signal at its output. When this signal is not faithfully reproduced, it is said to be distorted. Nonlinearity in system circuits causes harmonic and intermodulation distortion to be present. This distortion consists of frequency components present in the output signal that are not contained in the input signal. This will appear to the user as poor sound quality, noise or channel cross-talk. Harmonic distortion is the result of undesired harmonic related frequencies being generated from a pure tone stimulus (input signal). Intermodulation distortion is the result of undesired intermodulation being generated from a pure two tone stimulus. Harmonic distortion and intermodulation distortion are merely two different techniques to measure the results of nonlinearities. Which technique is most appropriate depends upon several factors, most importantly on whether the device being tested is wideband or has a sharp upper frequency cutoff.

Harmonic distortion tests are the most common test for amplifiers. A 1 kHz signal is the standard test tone. Harmonics can then be predicted for the 2nd harmonic at 2 kHz, 3rd harmonic at 3 kHz, etc. Therefore, harmonic distortion test aren't very useful above a frequency equal to one-third to one-half the upper band of the device under test (DUT). SMPTE/DIN is a better test for HI-Fidelity devices; while the CCIF method is more appropriate for sharp upper frequency cutoff as in voice grade communications links or recorders.

The total of these frequency components present in the signal, in addition to the fundamental frequency, can be measured quickly with a distortion analyzer. A distortion analyzer with the use of appropriate filters, tunes out the fundamental frequency and measures the amplitude of the remaining frequency components. Refer to Section 6 for an Application Note on Common Audio Frequency Measurements.

Most audio measurements are stimulus/response measurements; that is, a suitable stimulus is applied to the input of the device- under-test and the measurement is then made at the output. The F7523A1 Mod WQ distortion test set provides this capability.

Filters in Audio Measurements

Distortion analyzers, audio voltmeters, and other audio test equipment often have built-in, selectable filters. How to use them, what to expect from them, and what to avoid are complex issues. The major filter types in distortion analyzers are filters for noise measurements, filters for distortion analysis, low-pass filters, high-pass filters, and notch filters.

Filters in Noise Measurements

For an audio-frequency unit or system, the goal of noise measurements is quantifying the noise level or the ratio of the normal signal level to the noise level. The measurement equipment is either a wideband audio voltmeter or a distortion analyzer's LEVEL section. For noise measurements in audio systems that people listen to, components beyond 20 kHz are probably irrelevant.

Human hearing sensitivity is not constant from 20 Hz to 20 kHz. For a given loudness, midband frequencies require less power than low or high frequencies. Because of this varying response, a flat-response voltmeter noise measurement doesn't correlate well with the noise that people hear.

To improve the correlation, weighting filters have been developed. Their response curves approximate the inverse of the ear's sensitivity curves. In the United States, "A" weighting is used more than other noise-weighting curves.The 'C' MSG filter is another standard that is often used in communications.

Filters in Distortion Analysis

Distortion analyzers measure the affects of all harmonics plus noise by first using a notch-filter to remove the fundamental frequency of a test tone and then measuring the RMS (or the average) sum of the remaining signals.

The remaining signals may include these elements:

- Harmonics of test tone generated by nonlinearities in the test devices.
- Broadband noise.
- Interfering signals such as a stereo pilot tone in an FM stereo system.

Low-Pass Filters

Todays better audio equipment typically has low levels of distortion. Accurate measurement of the actual harmonic distortion may be restricted by the broadband noise of the device under test and by the distortion analyzer itself.

Distortion analyzers often include low-pass (band-limiting) filters to reduce the noise seen by the detector. This reduction permits harmonic measurements at even lower amplitudes. Typically, these filters are an 80 kHz low-pass filter and a 30 kHz low-pass filter.

None of these filters attenuate any of the standard 1 kHz test signal's important harmonics. However, selecting the 30 kHz low-pass filter would be inappropriate for THD measurements at any fundamental frequency above 15 kHz, because all harmonics would be attenuated. Even with a 10 kHz fundamental, the 30 kHz low-pass filter significantly attenuates (3 dB) the third harmonic.

The combination of the fundamental frequency and selected filter should not attenuate the second or third harmonics, and perhaps not the fourth and fifth harmonics. If 3 dB attenuation of the fifth harmonic is the criterion, 6 kHz is the highest test oscillator frequency appropriate for 30 kHz low-pass filter use. The 80 kHz low-pass filter could be used with oscillator frequencies up to 18 kHz.

High-Pass and Notch Filters

Broadband noise is the most common distortion measurement limitation. Hum introduced in a test unit by a poorly filtered power supply or by poor shielding may also set a floor under harmonic distortion measurements. Using filters within the audio band can produce more impressive measurements. They an also obscure problems in the tested equipment.

Most distortion analyzers contains a 400 Hz high-pass filter which can be used to reduce the effects of hum in measurements of total harmonic distortion with 1 kHz or higher fundamentals. Because the filter would attenuate the tone itself, it cannot be used with fundamentals below 1 kHz.

Using a filter in the test equipment to reject the effects of audible hum may not be appropriate. Unless the audio system uses loudspeakers that reject most of the hum at the power-mains frequencies, the hum will be audible even though it was eliminated from distortion measurements by use of a filter in the analyzer.

Distortion measurements in stereo FM transmitters, tuners, and receivers are a special case. Commonly used systems have a 19 kHz pilot tone. Because most adults can't hear this frequency, most tuners provide little rejection of it. However, the distortion analyzer can "hear" the 19 kHz pilot tone. A high level 19 kHz pilot tone may prevent the distortion analyzer from measuring significant harmonics of a 1 kHz test tone. An external 19 kHz notch filter solves the problem.

Distortion Measurements

Distortion is a measure of signal impurity. It is usually expressed as a percentage of dB ratio of the undesired components to the desired components. Harmonic distortion is simply the presence of harmonically related or integral multiples of a single pure tone called the fundamental, and can be expressed for each particular harmonic. Total harmonic distortion, or THD, expresses the ratio of the total power in all significant harmonics to that in the fundamental.

The transfer (input vs output) characteristics of a typical device is shown in Fig. 1.1.3. Ideally this is a straight line. A change in the input produces a proportional change in the output. Since the actual transfer characteristic is non-linear, a distorted version of the input waveshape appears at the output. The output waveform is the projection of the input sine wave on the device transfer characteristic as shown in Fig. 1.1.4. The output waveform is no longer sinusoidal, due to the nonlinearity of the transfer characteristic. Using Fourier analysis it can be shown that the output waveform consists of the original input sine wave, plus sine waves at integer multiples of the input frequency. These harmonics represent nonlinearity in the device under test. Their amplitudes are related to the degree of nonlinearity.

A total harmonic distortion measurement inevitably includes effects from noise to hum. The term THD + N has been recommended[1] to distinguish distortion measurements made with a distortion analyzer from those made with a spectrum analyzer.

[1] **IHF-A-202 1978, Standard Methods of Measurement for Audio Amplifiers, The Institute of High Fidelity, Inc., 489 Fifth Avenue, New York, N.Y. 10017**

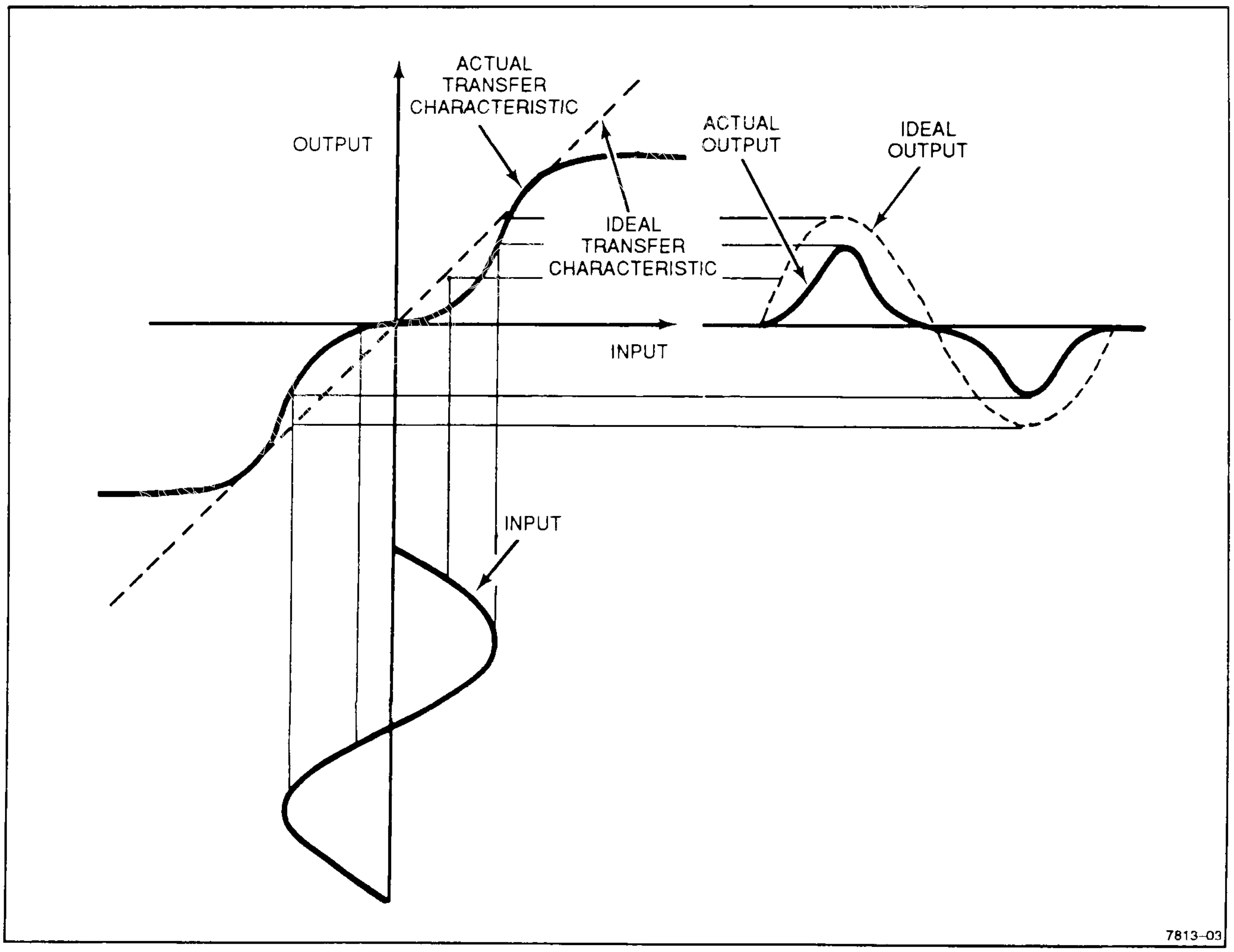

Fig. 1.1.3. Typical device transfer characteristics.

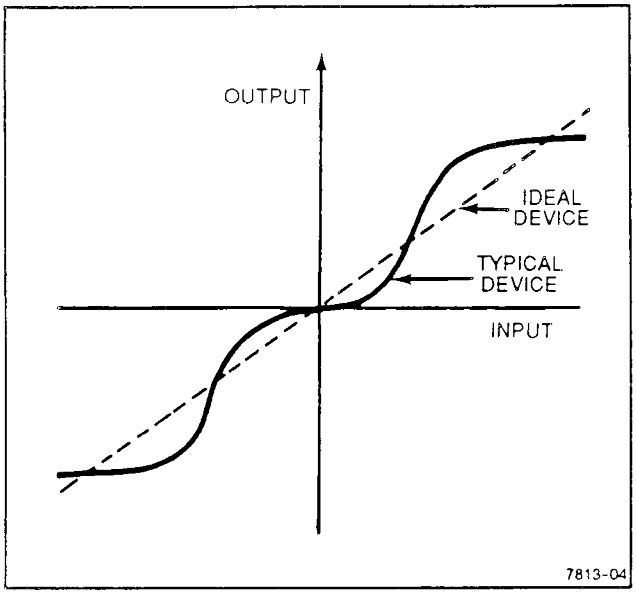

Fig. 1.1.4. Transfer characteristics of an audio device.

A spectrum analyzer allows direct measurement of each harmonic. The spectrum analyzer technique involves making a narrow-band measurement of each harmonic, and then performing a root-mean-square summation of the harmonics to produce a THD number uninfluenced by broadband noise and other components such as ac hum or interference. However, it is relatively complex, time consuming, and requires interpretation of a graphic display.

An appealing feature of the THD + N (total harmonic distortion plus noise) measuring technique is that the meter presents one number integrating harmonics, broadband white noise, hum, and specific interfering signals.

Distortion analyzers can quantify the nonlinearity of a device or system. A distortion analyzer removes the fundamental of the signal investigated and measures the remainder. See Fig. 1.1.5. Because of the notch filter response, any signal other than the fundamental influences the measurement.

Many audio devices and systems contain internal filters that the user cannot control. Digital audio tape and compact disc players have sharp cut-off filters slightly above 20 kHz. Many telephone voice channels and two-way radio transmitters cut off around 3 kHz. AM radio transmitters may roll off between 5 kHz and 10 kHz. Stereo FM transmitters must roll off below 19 kHz.

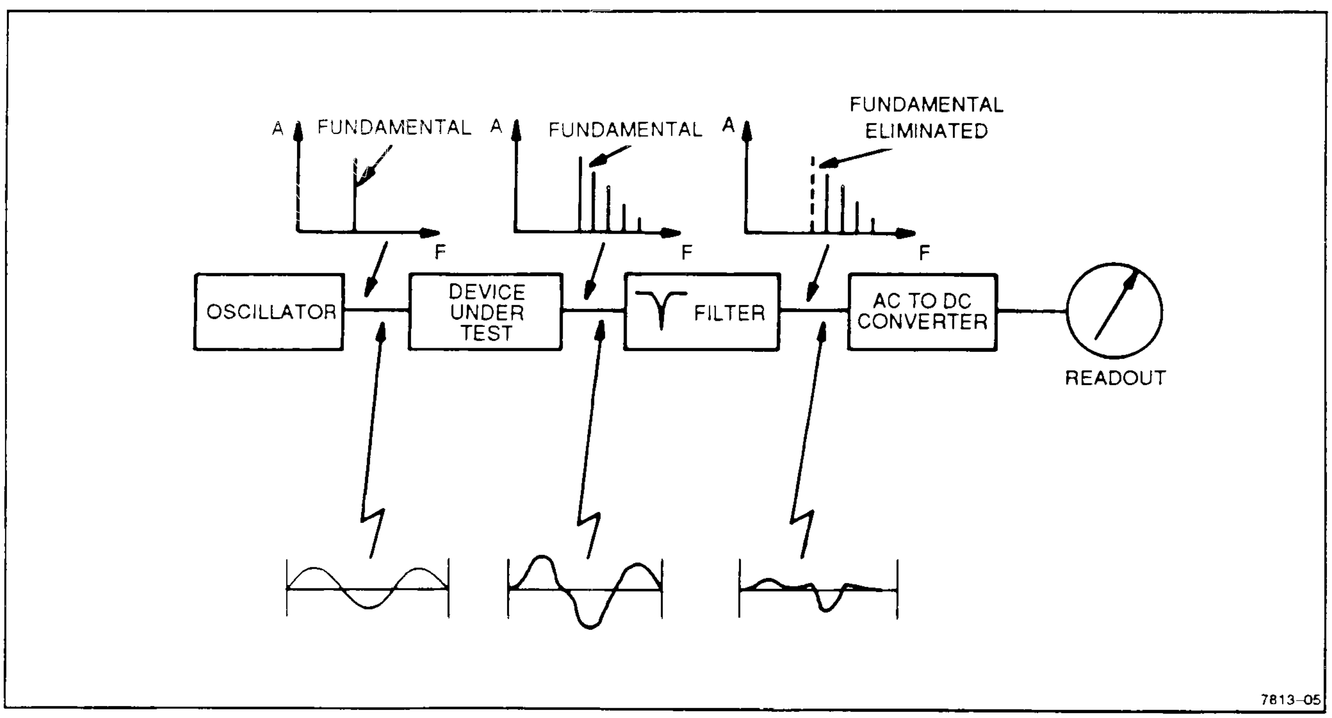

Fig. 1.1.5. Block diagram of a basic harmonic distortion analyzer.

Given those conditions, THD measurements are meaningless between 10 kHz and 20 kHz in a digital audio system that has a 20 kHz internal filter. Also, no third harmonic information can be obtained with fundamentals above 6.7 kHz. The only way to determine a band-limited system's linearity in the top one or two octaves is with intermodulation testing.

IM Distortion Measurements

Another measurement of distortion investigates the interaction of two or more signals. Nonlinearities in the device under test cause the sine waves to cross modulate. The amplitude ratio of low to high frequencies should be between 4:1 and 1:1. Many tests have been devised to measure this interaction. Four common standards are SMPTE, DIN, CCIF and Twin-Tone.

To measure intermodulation distortion (IMD), according to SMPTE, DIN or CCIF standards, the device under test is excited with a low frequency and high frequency signal simultaneously (Fig. 1.1.6).

As shown in Fig. 1.1.7, when this composite signal is applied to the device, the output waveform is distorted. As the high frequency tone is moved along the transfer characteristic by the low frequency tone, its amplitude changes. This results in low frequency amplitude modulation of the high frequency tone. This modulation is apparent in the frequency domain as sidebands around the high frequency tone. The power in these sidebands represents nonlinearity in the device under test.

The output signal is high-pass filtered to remove the low frequency component. The high frequency tone is then demodulated, as an AM radio signal. The demodulator output is low-pass filtered to remove the residual carrier (high frequency) components. The amplitude of the low frequency modulation is displayed as a percentage of the high frequency level. See Fig. 1.1.8.

The SMPTE standard test frequencies are 60 Hz and 7 kHz. The DIN standard is virtually identical to the SMPTE standard except for the two frequencies used. They may be any pair of octave band center frequencies, with the upper at least eight times as high as the lower (250 Hz and 8 kHz are most common).

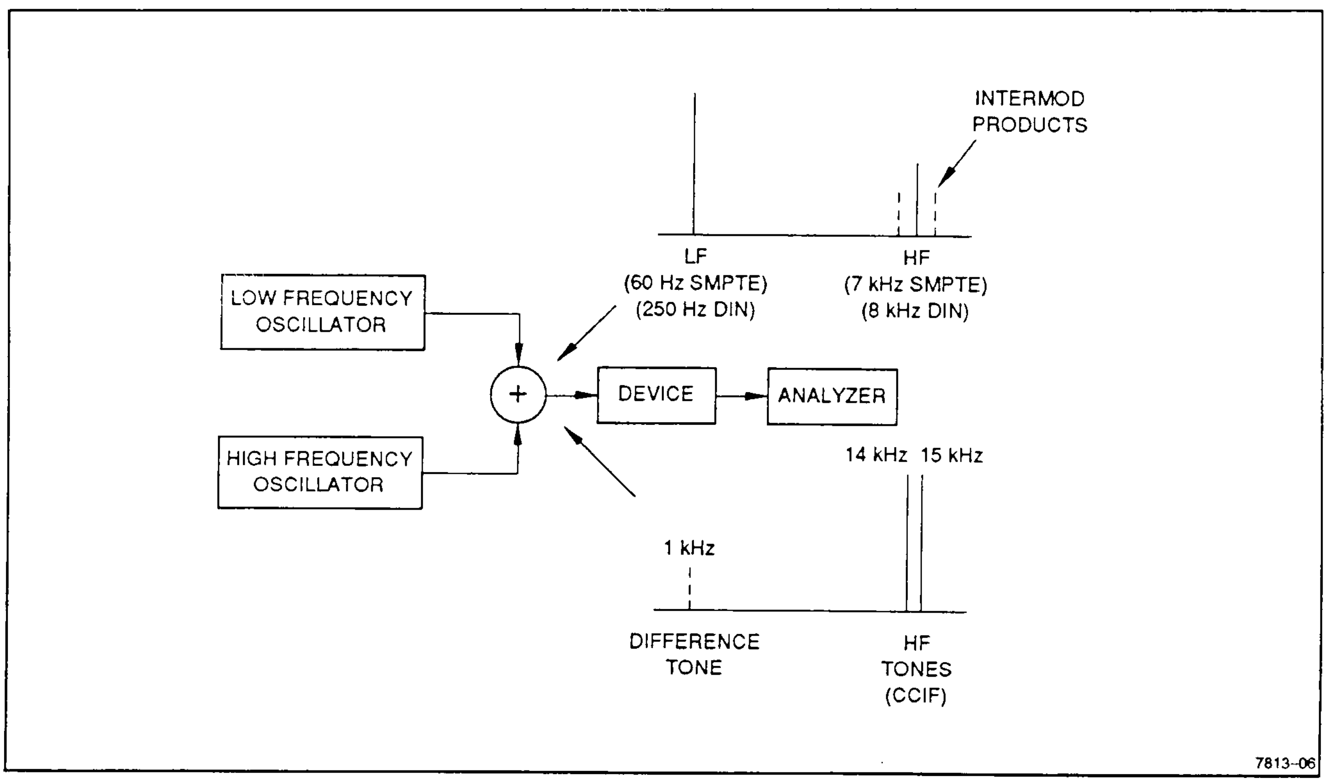

Fig. 1.1.6. SMPTE, DIN or CCIF Intermod Test.

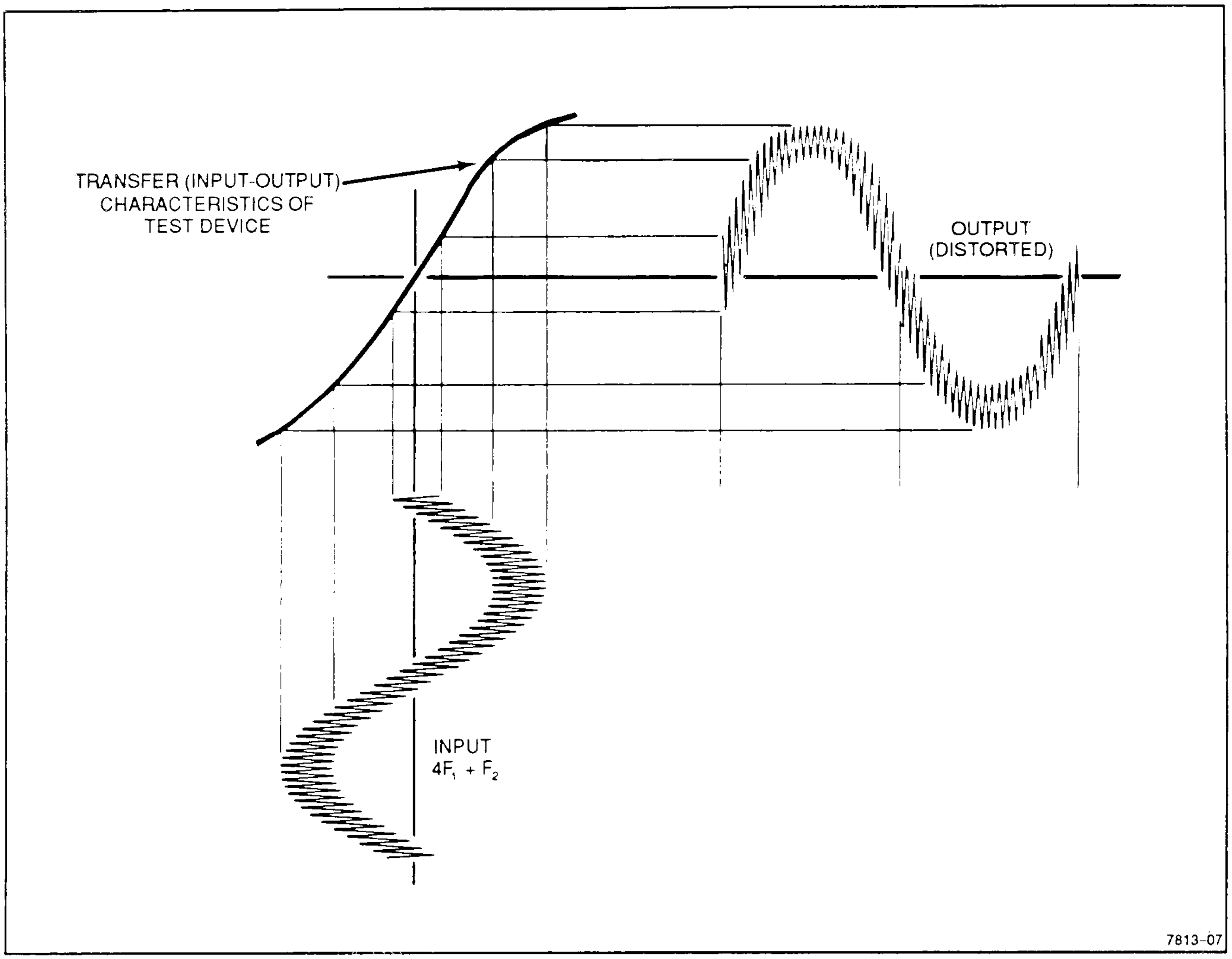

Fig. 1.1.7. IM test of transfer characteristics in time and frequency domain.

To measure twin-tone difference frequency distortion, the device is excited with two input signals as described above. The output of the device is low-pass filtered to remove the two test tones and extract the difference frequency product. The level of this component is expressed as a percentage of the high frequency signals. The AA 501A CCIF difference frequency mode will accept any pair of input frequencies which are within limits as listed in the Specification section. The amplitudes of the two signals should be equal.

The AA 501A Mod WQ is capable of measuring THD + N and automatically selecting and performing all three IMD tests. The AA 501A Mod WQ can accept a wide of test frequencies and any pair of test frequencies which are within the limits as listed in the Specification section.

Monitoring

The AA 501A Mod WQ has facilities for monitoring of the input signal and the distortion components after removal of the fundamental frequency.

The input signal may be monitored on an oscilloscope for evidence of clipping. Monitoring the input signal with a spectrum analyzer during twin-tone measurements provides information on the harmonics other than the difference frequency.

The monitoring of the distortion components with an oscilloscope can help determine their composition. Triggering the oscilloscope on the same line frequency as the DUT will result in a stable display of the line frequency related components. Monitoring of the frequency components with a spectrum analyzer will provide information on harmonic amplitudes.

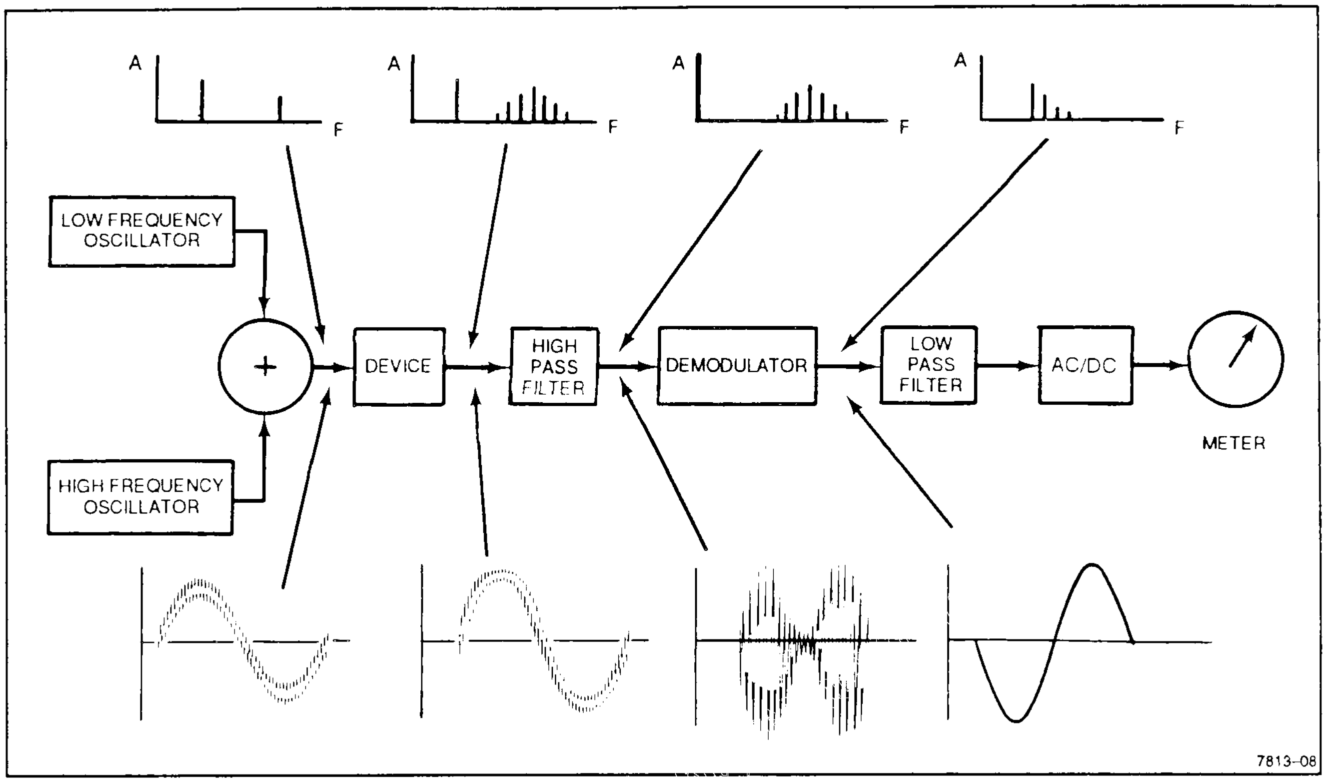

Fig. 1.1.8. Block diagram of basic IM analyzer.

OPERATING INSTRUCTIONS

F7523A1 Mod WQ is easily operated. Both oscillators in the transmitter section have a frequency range of 10 Hz to 100 kHz. Each oscillator may be used independently or together to produce an IMD test signal. The distortion analyzer of the receiver section may be used as an ac voltmeter, dBm level meter, dB ratio meter, or distortion analyzer.

Fundamental frequency oscillator, SG 505 Mod WR, has a dual female banana output connector. The modulating frequency oscillator is internally connected to the fundamental oscillator. The OUTPUT ON/OFF push button on the modulating oscillator disconnects the signal from its output connector. The two tone test signal 1:1 push button on the fundamental oscillator must be pushed in for two tone testing. See Fig. 1.1.9 for a typical configuration for distortion testing.

The complete operating instructions for each instrument comprising the F7523A1 Mod WQ is provided in its respective section of this manual. The operator should review these sections before proceeding.

Twin-Tone Measurements

Twin-Tone testing is done to measure the effect of device nonlinearity. Two equal-amplitude, closely spaced signals are fed to the device under test. If asymmetric nonlinearities exist, a second order difference product will be produced at the low frequency signal equal to their spacing. To make this measurement requires a low-pass filter followed by a voltmeter, as provided by the AA 501A Mod WQ.

Two SG 505 Oscillators are required to generate the test signal. The two oscillators are combined internally and their amplitudes are set for a 1:1 ratio. The AA 501A Mod WQ will automatically measure the amplitude of the difference tone.

Twin-Tone measurements are made by adjusting the output of the test set transmitter to the recommended test level on the test set receiver. After the required reference is set, the test set transmitter is connected to the device under test (DUT). The output of the DUT is connected to the test set receiver and the distortion measured.

To adjust the output of the test set transmitter, connect the output of the fundamental oscillator, SG 505 Mod WR, to the test set receiver, AA 501A Mod WQ. Select the test frequencies on both the fundamental and modulating oscillators. Activate the 1:1 two tone push button on the fundamental oscillator. Select the LEVEL FUNCTION mode of the test set receiver and the appropriate Input Level Range on AUTO RANGE. Push the OUTPUT ON/OFF push button on the fundamental oscillator to the ON position. Adjust the OUTPUT LEVEL of the fundamental oscillator to obtain the required signal level on the test set receiver.

CAUTION

If the GNDED/FLTG switch on either of the oscillators in the transmitter is set to GNDED, the OUTPUT connector outer conductor (shield) will be connected to chassis ground through a low impedance.

Disconnect the fundamental oscillator from the test set receiver and connect to the DUT. The output of the DUT is connected to the test set receiver. The receiver has several filters available which may be selected for the measurement. With the test set receiver in the LEVEL FUNCTION mode, adjust the INPUT RANGE control until the DECREASE RANGE and INCREASE RANGE lights extinguish or select AUTO RANGE FUNCTION. Select the appropriate percent of distortion range and type of distortion measurement; THD + N for harmonic distortion plus noise measurements or IMD for SMPTE/DIN, CCIF, and Twin-Tone measurements. The percent of distortion is now indicated on the test set receiver.

For two tone testing when other than a 1:1 ratio is required, connect the two oscillators outputs together externally. Adjust the oscillators' frequency and output level to the required levels and proceed as described above.

For totally automatic distortion measurements, select the desired filter, type of distortion measurement and then select the AUTO RANGE FUNCTION. The percent of distortion will automatically be displayed.

Distortion Measurements

The total harmonic distortion plus noise (THD + N) method of testing a DUT involves using a single pure tone stimulus. Nonlinearities in the DUT will produce harmonics. The relative strength of the harmonics plus noise is an indicator of DUT linearity.

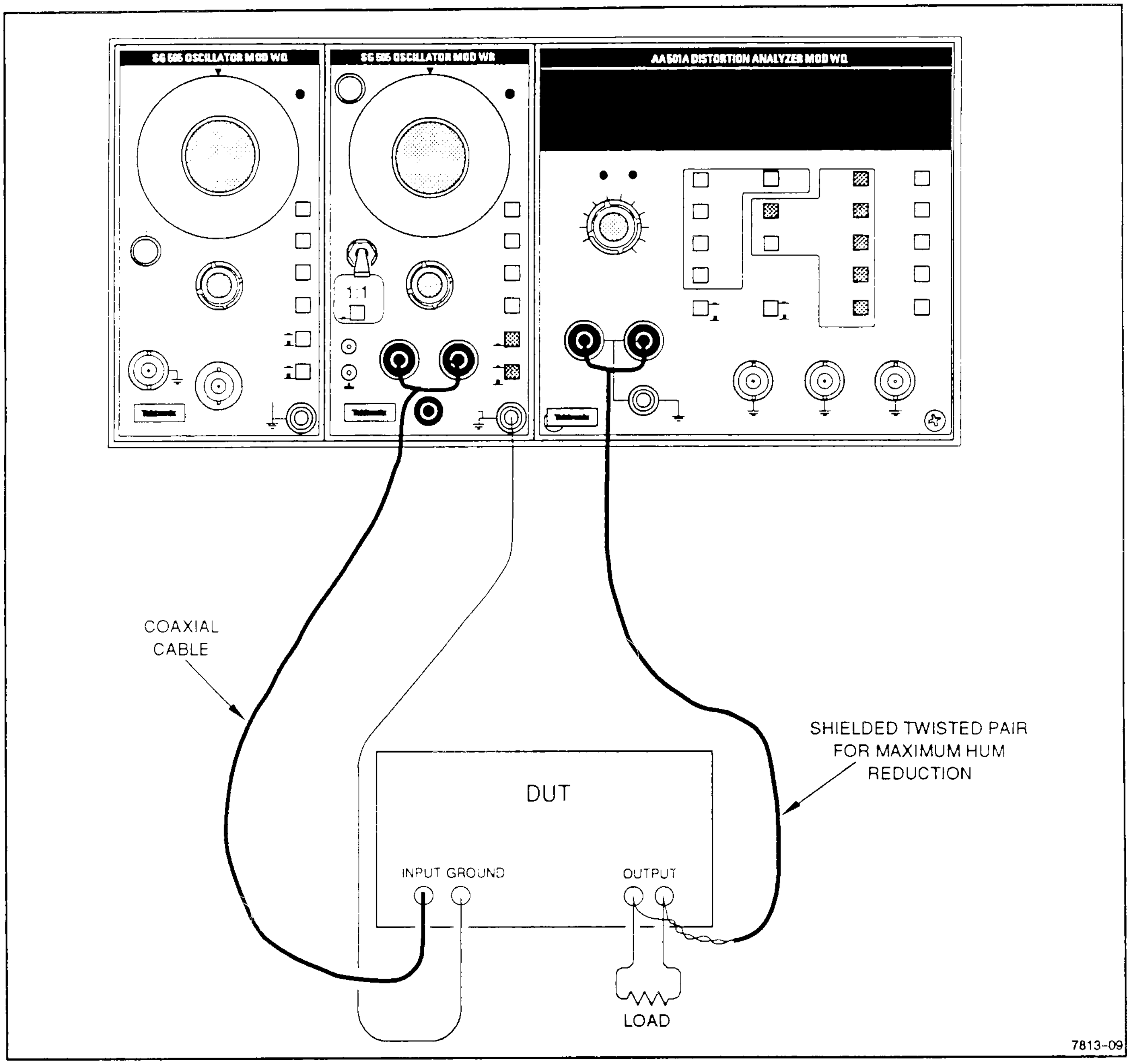

Fig. 1.1.9. Typical connections for distortion measurements.

THD + N measurements with the F7523A1 Mod WQ are easy. The controls have been automated and provide the operator with the flexibility of choosing auto or manual modes of operation.

To make a THD + N measurement, set the test oscillator (one of the SG 505) to the desired test frequency and output level. The AA 501A Mod WQ LEVEL FUNCTION may be used to establish the output level.

Connect the test oscillator to the DUT input. Connect the output DUT to the AA 501A Mod WQ input with a shielded cable. In manual operation, adjust the INPUT RANGE control until the range LEDs are extinguished. Select THD + N and the highest distortion range (20%), then adjust the distortion range to the range that provides an onscale reading. For auto operation, select THD + N and AUTO RANGE for INPUT RANGE and distortion. The RMS position of the RESPONSE button should be used.

Level Measurements

Level measurements can easily be accomplished using the AA 501A Mod WQ. Select the LEVEL function and the desired readout units button; VOLTS, dBm 600 OHMS, or dB RATIO. Set the INPUT RANGE to AUTO RANGE for auto operation or adjust the range manually.

When measuring signal to noise ratio or making noise level measurement, it is often desirable to employ a frequency dependent weighting network. For most noise-level measurements use the 'C' MSG weighting filter: select LEVEL mode, VOLTS, or dBm, and read the display.

For signal-to-noise measurements, do not have the weighting filter selected when you set up the signal (tone) reference level to which noise will be compared. Unless the reference frequency is exactly at the weighting filter response curve's 0.0 dB gain point, the filter causes errors in the reference-tone level set up. So, disengage the filter, establish the reference tone frequency with the test oscillator, and adjust the oscillator for the specified level.

- Select dB RATIO and press the PUSH TO SET 0 dB REF button.
- Remove the test oscillator and back terminate (replace the oscillator with a resistor equal to the oscillator output characteristic impedance). With the Tektronix SG 505 Oscillator, you can do this step simply by pressing the OFF button.
- Engage the weighting filter and read the weighted signal-to-noise ratio.

Repackaging Information

If the Tektronix instrument is to be shipped to a Tektronix Service Center for service or repair, attach a tag showing the owner (with address) and the name of an individual at your location that can be contacted. Include the complete instrument serial number and a description of the service required.

Save and reuse the package in which your instrument was shipped. If the original packaging is unfit for use or not available, repackage the instrument as follows:

Surround the instrument with polyethylene sheeting to protect the finish of the instrument. Obtain a carton of corrugated cardboard of the correct carton strength and having inside dimensions of no less than six inches more than the instrument dimensions. Cushion the instrument by tightly packing three inches of dunnage or urethane foam between carton and instrument on all sides. Seal the carton with shipping tape or an industrial stapler.

The carton test strength for this instrument is 200 pounds per square inch.

Storage Information

1. After repackaging store in a clean, dry, environment.
2. In a high humidity environment protect the system from temperature variations that could cause internal condensation.
3. Outdoor storage is not recommended.
4. Environment: Store within the following environmental limits.

Temperature	-40 to 71 °C
Altitude	≤ 4570 m (15,000 feet)
Relative Humidity	95% @ 30° to 60 °C

5. No ventilation or preservation required.

Section 2
AA 501A Mod WQ
Distortion Analyzer

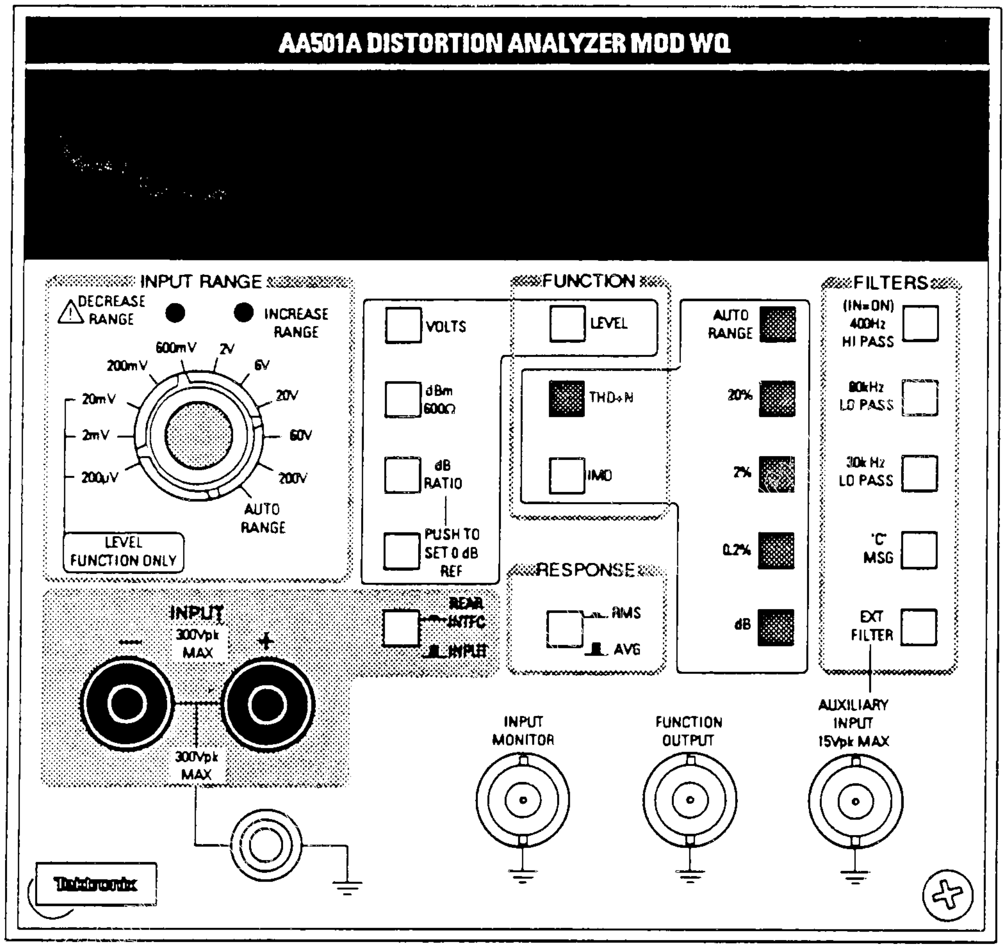

Figure 2.1.1. AA501A Mod WQ Distortion Analyzer.

SPECIFICATION

Instrument Description

The AA 501A Mod WQ is a fully automatic distortion analyzer packaged as a two-wide TM 500 plug-in. Total harmonic distortion can be measured with the AA 501A Mod WQ as well as SMPTE/DIN intermodulation distortion and CCIF two-tone difference frequency distortion.

Distortion set level, frequency tuning and nulling are fully automatic, requiring no operator adjustment. Input level range and distortion measurement range selections are fully automatic or may be manually selected. Distortion readout is provided in percent or dB.

The AA 501A Mod WQ is also a high sensitivity, autoranging, audio frequency voltmeter. Readings may be in volts, dBm, or dB relative to any arbitrary reference.

Filters are included which allow measurement of noise to IHF and FCC specifications. A hum rejection filter is provided as are provisions for external filters.

All readings are displayed on a 3 1/2 digit readout. An uncalibrated analog readout is also provided to aid in nulling and peaking applications.

Ac to dc conversion is either average or true rms responding, allowing conformance with most standards.

Ac input and output connections are available on both the front panel and the rear interface. Dc signals, corresponding to the displayed reading, are available through the rear interface. This allows flexibility in interconnection with other instruments such as filters, chart recorders, spectrum analyzers, oscilloscopes, etc.

Performance Conditions

The electrical characteristics in this specification are valid only if the AA 501A Mod WQ has been adjusted at an ambient temperature between +20 degrees C and +30 degrees C. The instrument must be in a non-condensing environment whose limits are described under the environment section. Allow twenty minutes warm-up time for operation to specified accuracy; sixty minutes after exposure to or storage in a high humidity (condensing) environment. Any conditions that are unique to a particular characteristic are expressly stated as part of that characteristic.

The electrical and environmental performance limits, together with their related validation procedures, comprise a complete statement of the electrical and environmental performance of a calibrated instrument.

Items listed in the Performance Requirements column of the Electrical Characteristics are verified by completing the Performance Check in the Calibration section of this manual. Items listed in the Supplemental Information column are not verified in this manual.

Table 2.1.1
ELECTRICAL CHARACTERISTICS

Characteristics	Performance Requirements		Supplemental Information
INPUT (all functions)			
Impedance	100 kΩ ±2%, each side to ground.		Full differential. Each side ac coupled through 1 μF and shunted to ground by approximately 200 pF. Dual banana jack connectors at 0.750 inch spacing with ground connector additionally provided.
Input ranges	200 μV to 200 V in 10 steps.		2–6 sequence from 200 μV to 200 V Range selection is manual or automatic. Autoranging time is typically <1 second. Separate increase range and decrease range indicators illuminate whenever input level does not fall within optimum window for selected range. For specified instrument performance both indicators must be extinguished.
Maximum input voltage			300 V peak, 200 V rms either input to ground or differentially. Will recover without damage from overloads of 120 V rms continuously or 200 V rms for 30 minutes on all ranges. For linear response, peak input voltage must not exceed 3 times INPUT LEVEL RANGE setting.
Common mode rejection (inputs shorted)	≥ 50 dB at 50 or 60 Hz for common mode signals up to one-half of selected input range or 50 mV, whichever is greater.		Typically ≥ 40 dB to 300 kHz.
LEVEL FUNCTION			
Modes			Volts, dBm (600 Ω), or dB ratio with push to set 0 dB reference. Input range determines display range. Single effective range in dB modes with 0.1 dB resolution. Stored 0 dB reference is unaffected by subsequent changes in mode or function.
Accuracy V_{in} in ≥100 μV (-78 dBm) with level ranging indicators extinguished. (T ≤ +40°C)	VOLTS.	dBm OR dB RATIO.	
20 Hz to 20 kHz	Within ±(2% + 1 count).	±0.3 dB.	
10 Hz to 20 Hz and 20	Within ±(4% +2 count).	±0.5 dB.	

Table 2.1.1 (cont)

Characteristics	Performance Requirements	Supplemental Information
LEVEL FUNCTION (cont)		
Bandwidth (no filters selected)	At least 300 kHz.	
Residual noise (Inputs shorted, T ≤ +40°C)	≤3.0 μV (−108 dBm) with 80 kHz, 400 Hz filters.	
TOTAL HARMONIC DISTORTION PLUS NOISE FUNCTIONS		
Fundamental frequency range	10 Hz to 100 kHz.	Fully automatic tuning and nulling. For proper tuning THD + N ≤10%. After initial tuning THD + N can degrade to 30% without loss of lock for SINAD testing. Typical nulling time is less than 5 s above 20 Hz.
Distortion ranges		Auto range, 20%, 2%, 0.2%, and dB. dB is internally autoranging with single effective display range. Auto range allows measurements above 20%.
Accuracy (THD ≤ 30% and reading ≥4% of selected distortion range).		Accuracy is limited by residual THD + N and filter selection. 100% reference level is total input signal amplitude including distortion and noise components.
20 Hz to 20 kHz	Within ±10% (±1 dB) for harmonics ≤100 kHz.	
10 Hz to 100 kHz	Within +10% −20% (+1 dB, −2 dB) for harmonics ≤ 300 kHz.	
Residual THD + N (V_{in} ≥ 250 mV, all distortion, noise, and nulling error sources combined, T ≤ 40°C)		Measured with SG 505 oscillator.
10 Hz to 50 kHz, no filter	≤0.0071% rms Response (−83 dB).	
50 kHz to 100 kHz, no filter	<0.010% rms Response (−80 dB).	
Typical fundamental rejection		At least 10 dB below specified residual THD + N or the actual signal THD, whichever is greater.

Table 2.1.1 (cont)

Characteristics	Performance Requirements	Supplemental Information
INTERMODULATION DISTORTION FUNCTION		
Operation		Fully automatic SMPTE, DIN, or CCIF difference tone tests depending upon actual input signal whenever respective IMD ≤ 20%. Distortion ranges are same as THD + N function. Internal jumper selects Automatic, CCIF, or SMPTE/DIN.
SMPTE/DIN tests		
Lower frequency range		50 Hz to 250 Hz.
Upper frequency range		Usable from 2 kHz to 160 kHz.
Level ratio range		1:1 to 4:1, lower:upper.
Residual IMD V_{in} ≥ 250 mV, 60 Hz, and 8 kHz, 4:1 amplitude ratio, T ≤ +40°C		Measured with SG 505 pair. ≤ -90 dB.
CCIF difference tone test		
Frequency range		Usable from 2 kHz to 160 kHz.
Difference frequency range		40 Hz to 1 kHz.
Minimum input level	60 mV(-22 dBm).	
Residual IMD V_{in} ≥ 250 mV, 2 kHz and 2.5 kHz, T ≤ +40°C	Measured with SG 505 pair. ≤ -90 dB.	
Accuracy (IMD ≤ 20% and reading ≥ 4% of selected distortion range)	Within ±10% (±1 dB) for IM components ≤1 kHz (Accuracy is limited by residual IMD and filter selection.)	
FILTERS		
400 Hz high pass	-3 dB at 400 Hz ±5%; at least -40 dB rejection at 60 Hz.	Three pole Butterworth response.
80 kHz low pass	-3 dB at 80 kHz ±5%.	Three pole Butterworth response.
30 kHz low pass	-3 dB at 30 kHz ±5%.	Three pole Butterworth response.
"C" message weighting		Within recommendation of IEEE standard 743-1984.
External filter	Selects front panel AUXILIARY INPUT allowing connection of external filter between it and FUNCTION OUTPUT.	

Table 2.1.1 (cont)

Characteristics	Performance Requirements	Supplemental Information
FRONT PANEL SIGNALS		
Input Monitor		
$V_{in} \geq 50$ mV	1 V rms ±10% (10 Hz to 100 kHz).	Constant amplitude (average response) version of differential input signal. THD is typically ≤ 0.0010% (-100 dB) from 20 Hz to 20 kHz. Setting time is ≤1.5 seconds.
$V_{in} \leq 50$ mV		Approximately 20 times input signal.
Function Output		
Signal	1 V, ±3%, for 1000 count volts or % display.	Selected and filtered ac signal actually measured.
Impedance	1 kΩ, ±5%.	
Auxiliary Input		
Sensitivity	1 V, ±3%, for 1000 count volts or % display.	Loop through accuracy from FUNCTION OUTPUT is ±3%.
Maximum Input Voltage		15 V peak, 6 V peak for linear response.
Impedance	100 kΩ, ±5%.	Ac coupled.
REAR INTERFACE		
Rear interface input		Pins 28B(+), 28A(-), 27B and 27A (common) are front panel selectable and independent of main front panel input. All characteristics are the same as main INPUT except maximum input voltage is limited to 42 V peak, 30 V rms. Due to potential crosstalk at the rear interface, noise and distortion performance may be degraded.
Input monitor		Pins 24A and 23A (gnd) same as front panel INPUT MONITOR.
Function output		Pins 23B and 24B (gnd) same as front panel FUNCTION OUTPUT.
Auxiliary input		Pins 25B and 26B (gnd) same as front panel AUXILIARY INPUT. Maximum input voltage is 15 V peak, 6 V peak for linear operation.
Ac/dc converter output		Pins 20A and 19A (gnd). Dc output of the selected ac to dc converter. 1 V ±5% for 1000 count display with 500 Ω ±5% source resistance.

Table 2.1.1 (cont)

Characteristics	Performance Requirements	Supplemental Information
REAR INTERFACE (cont)		
dB converter output		Pins 19B and 20B (gnd). Dc output of the logarithmic dB converter. 10 mV ±5% equals 1 dB of display with 1 kΩ ±5% source resistance. Changes in level or distortion range will cause brief ac transients.
DETECTORS AND DISPLAYS		
Detectors (Response)		
RMS		True rms detection.
AVG		Average detection, rms calibrated for sinewaves. Typically reads 1 to 2 dB lower than true rms detection for noise, THD+N, and IMD measurements.
Displays		
Digital	3½ digit, 2000 count LED. Overrange indication is 1, blank, blank, blank.	
Analog bar graph	10 segment LED intensity modulated bar graph display of digital readout. Segments are logarithmically activated with approximately 2.5 dB/segment.	
MISCELLANEOUS		
Power consumption		Approximately 24 watts.
Internal power supplies		
+15		Nominally +15.1 V ±3%.
-15		Nominally -15.1 V ±5%.
+5		Nominally +5.25 V ±5%.
Fuse Data		
F4060		3 AG, 1 A, 250 V, fast blow.
F4061		3 AG, 1 A, 250 V, fast blow.
F4062		3 AG, 1.5 A, 250 V, fast blow.
Recommended adjustment interval		1000 hours or 6 months, whichever occurs first.
Warm-up time		20 minutes; 60 minutes after storage in high humidity environment.

Table 2.1.2
ENVIRONMENTAL CHARACTERISTICS

Characteristics	Description	
Temperature		Meets MIL-T-28800C, Class 5.
Operating	0°C to +50°C.	
Non-Operating	-40°C to +75°C.	
Humidity	95% RH, 0 to +30°C. 75% RH, to +40°C. 45% RH, to +50°C.	Meets MIL-T-28800C, Class 5.
Altitude		Exceeds MIL-T-28800C, Class 5.
Operating	4.6 km (15,000 ft).	
Non-Operating	15 km (50,000 ft).	
Vibration	0.38 mm (0.015") peak to peak, 5 Hz to 55 Hz, 75 minutes.	Meets MIL-T-28800C, Class 5.
Shock	30 g's (1/2 sine), 11 ms duration, 3 shocks in each direction along 3 major axes, 18 total shocks.	Meets MIL-T-28800C, Class 5.
Bench Handling (plug-in only)	12 drops from 45°, 4" or equilibrium, whichever occurs first.	Meets MIL-T-28800C, Class 5.
Package Product Vibration and Shock (plug-in only)	Qualified under National Safe Transit Association Preshipment Test Procedures 1A-B-1 and 1A-B-2.	
Electromagnetic Susceptibility	Within limits of MIL-STD-461B (April 1, 1980) Class B.	
Electromagnetic Interference	Within limits of F.C.C. Regulations, Part 15, Subpart J. Class A; VDE 0871 category B, VDE 0875; and MIL-STD-461B (April 1, 1980) Class B.	
Electrostatic Immunity	At least 15 kV discharge from 500 pF in series with 100 Ω to instrument case or any front panel connector without damage or permanent performance degradation (input terminals limited to 10 kV).	

Table 2.1.3
PHYSICAL CHARACTERISTICS

Characteristics	Description
Maximum Overall Dimensions	
Height	126.0 mm (4.96 inches).
Width	131.2 mm (5.16 inches).
Length	285.5 mm (11.24 inches).
Net Weight	Approximately equal to 2.04 kg (4.5 lbs.).
Finish	
Front Panel	Plastic-aluminum laminate.
Chassis	Anodized aluminum.

OPERATING INSTRUCTIONS

Controls, Connectors, and Indicators

All controls, connectors and indicators (except for the rear interface connector) required for operation of the AA 501A are located on the front panel. Fig. 2.2.1 provides a brief description of all front panel controls, connectors, and indicators.

(1) **INPUT RANGE**
Selects input voltage range or AUTORANGE. The three most sensitive ranges operate in the LEVEL FUNCTION only.

(2) **DECREASE RANGE** ⚠
When this light is illuminated, reduce the INPUT LEVEL RANGE until the light goes out. If the FUNCTION selected is THD + N or IMD a flashing light indicates insufficient input signal level for distortion measurements.

(3) **INCREASE RANGE**
When this light is illuminated, increase the INPUT LEVEL RANGE until the light goes out.

(4) **+ INPUT**
Differential input terminal. Positive going input signal provides positive going output signal at INPUT MONITOR.

(5) **- INPUT**
Differential input terminal. Negative going input signal provides positive going output at INPUT MONITOR.

(6) **RELEASE LATCH**

(7) **LEVEL**
Button in selects input level measuring function.

(8) **VOLTS**
Button in selects voltage units for level function.

(9) **dBm 600 Ω**
Button in selects dBm units for level function. 0 dB reference is 0.7746 V corresponding to 1 mW into 600 Ω.

(10) **dB RATIO**
Button in selects dB ratio, with respect to preset level, as units for level function.

(11) **PUSH TO SET 0 dB REF**
Push button to set display to 0 with input signal applied to INPUT terminals in LEVEL FUNCTION. dB RATIO and LEVEL push buttons must be in for this feature to operate.

(12) **REAR INTFC-INPUT**
Button in selects rear interface input; button out selects front panel input.

(13) **RESPONSE**
Button in gives RMS detection (responds to the rms value of the input waveform). Button out gives average detection or calibrated for sine waves.

(14) **THD + N**
Button in selects total harmonic distortion function.

(15) **IMD**
Button in selects intermodulation distortion function.

(16) **AUTO RANGE**
Button in selects automatic distortion range selection (0.2% to 100% full scale).

(17) **20%**
Button in selects full scale distortion readout of 20% with 0.01% resolution.

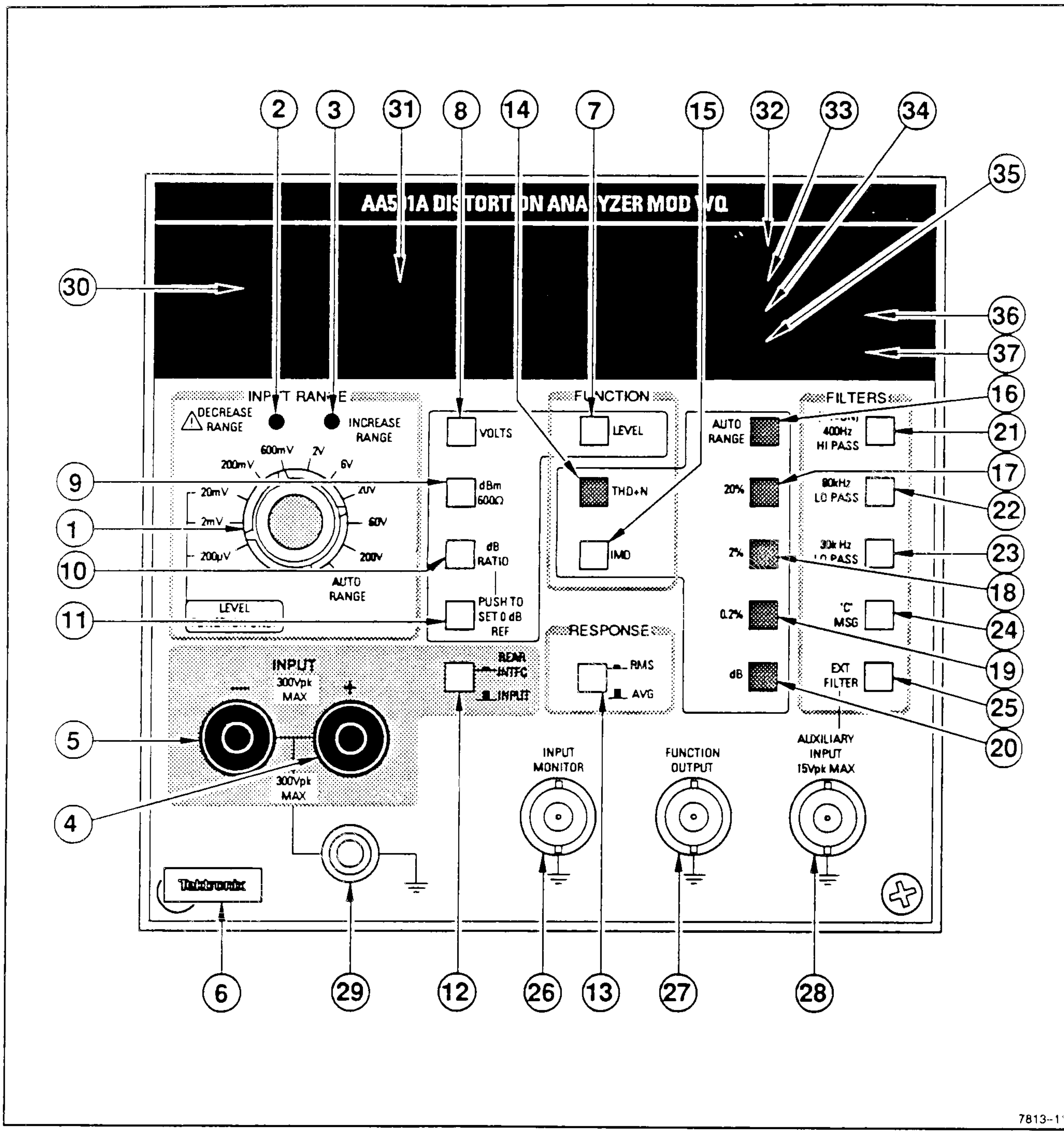

Fig. 2.2.1. Front Panel Controls and Connectors.

(18) **2%**
Button in selects full scale distortion readout of 2% with 0.001% resolution.

(19) **0.2%**
Button in selects full scale distortion readout of 0.2% with 0.0001% resolution.

(20) **dB**
Selects single equivalent 0 dB to −100 dB distortion display range with 0.1 dB resolution.

(21) **400 Hz HI PASS**
Button in connects filter before detector circuit in all function.

(22) **80 kHz LO PASS**
Button in connects filter before detector circuit in all functions.

(23) **30 kHz LO PASS**
Button in connects filter before detector circuit in all functions.

(24) **'C MSG' WTG FILTER**
Button in connects filter before detector circuit in all functions.

(25) **EXT FILTER**
Button in allows connection of external filter between FUNCTION OUTPUT and AUXILIARY INPUT in all functions.

(26) **INPUT MONITOR**
Provides a buffered sample of the input signal.

(27) **FUNCTION OUTPUT**
Provides a sample of the selected FUNCTION signal additionally processed by selected filters.

(28) **AUXILIARY INPUT**
Provides input to the detector circuit when the EXT FILTER button is pressed.

(29) **GROUND**
Provides front panel chassis ground connection.

(30) **LED BAR GRAPH**
Provides approximate analog display of the digital display for nulling and peaking. Each segment represents approximately 2.5 dB.

(31) **DIGITAL DISPLAY**
3½ digits. Overrange indication is a blanked display with the numeral 1 in the most significant digit position.

(32) **V**
Illuminated when display units are volts.

(33) **mV**
Illuminated when display units are millivolts.

(34) **μV**
Illuminated when display units are microvolts.

(35) **%**
Illuminated when display units are percent.

(36) **dBm**
Illuminated when display units are dB.

(37) **dB**
Illuminated when display units are dB.

Instrument Connections

To make connections to the AA 501A Mod WQ, refer to Fig. 2.2.2. Connections can be made to the rear interface connector. However, low level or distortion measurements made through the rear interface may be degraded due to cross talk. To measure signals connected to the front panel make certain the INPUT push button is out. To select the rear interface signal input, press the INPUT push button.

CAUTION

Maximum front panel input voltage is 300 V peak, 200 V rms either input to ground or differentially. Maximum rear interface input is 42 V peak and 30 V rms.

The AA 501A Mod WQ input circuitry is protected against accidental overloading. This circuitry will recover without damage from continuous 120 V rms (30 minutes at 200 V rms) overloads in any INPUT RANGE setting.

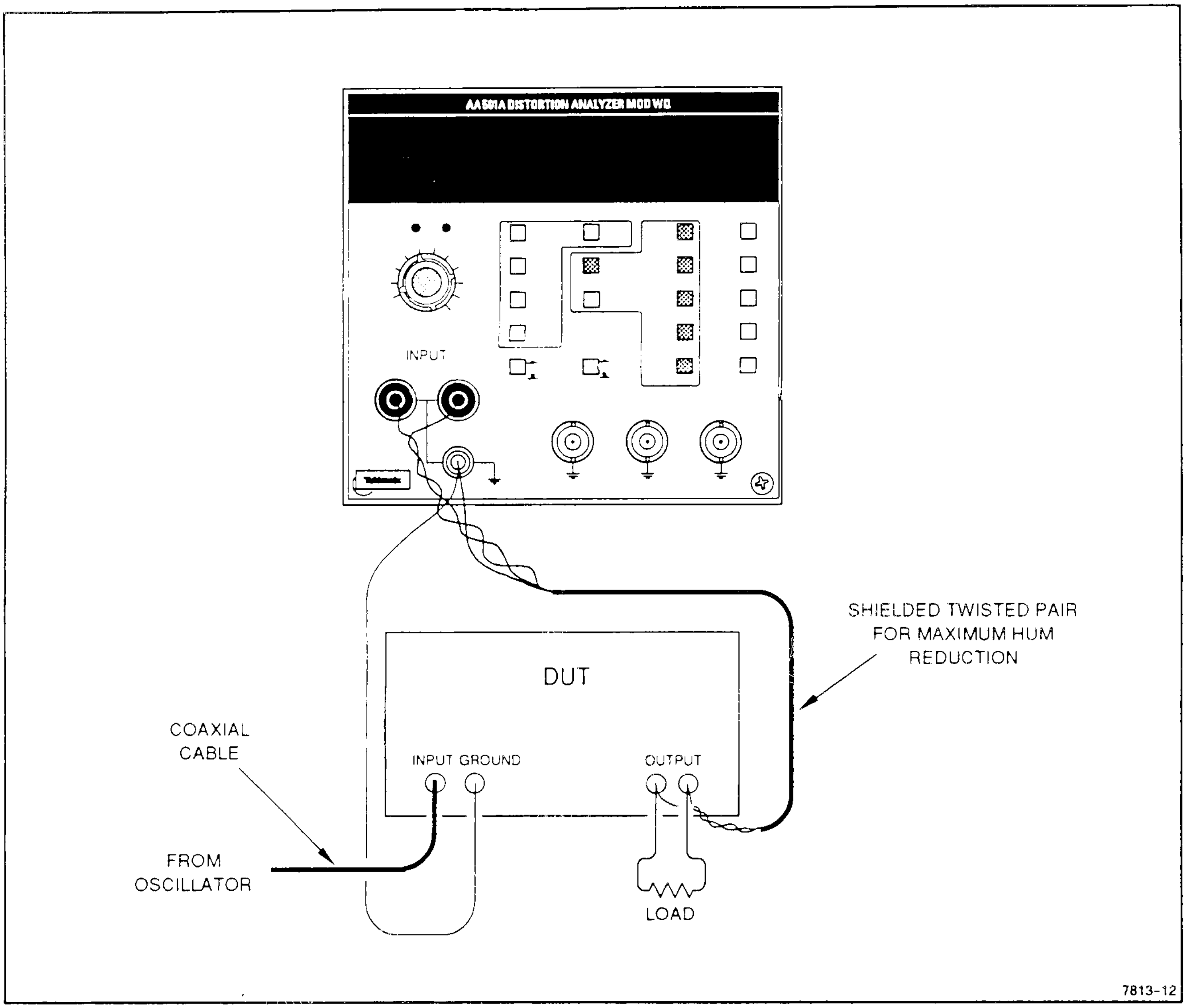

Fig. 2.2.2. Typical connections for distortion measurements.

In most cases, for maximum hum rejection, follow the cabling and grounding as shown in the figure. Shielded, twisted pair offers maximum hum and radio frequency interference rejection. Cable shielding, If used, should be grounded only at the AA 501A Mod WQ front panel ground post. Use shielded cable to connect the output of an oscillator, external to the device under test, to the input of the device. Generally, to avoid possible ground loops, if the device under test has one side of the input grounded, float the output of the external oscillator. If the input to the device under test is floating (not chassis grounded) select the grounded mode for the output of the oscillator. Terminate the output of the device under test in Its recommended load impedance, or the load impedance specified in the appropriate standard.

Level Measurements

In the LEVEL function the AA 501A Mod WQ operates as a wide band ac voltmeter. The Specification section of this manual contains the operating parameters. The meter is rms calibrated and either rms or average responding, depending on the position of the RESPONSE push button.

Press the FUNCTION LEVEL push button. The top three buttons to the left of the FUNCTION push buttons select readout units as VOLTS, dBm 600 Ω, or dB RATIO. For example, to measure voltage, press the VOLTS push button. If the INCREASE RANGE LED is illuminated, adjust the INPUT LEVEL RANGE control to the higher ranges until the LED goes out. If the DECREASE RANGE LED is illuminated, turn the INPUT RANGE control counterclockwise until the DECREASE RANGE LED goes out. Readings are useable as long as the display is not overranged; however, for specified accuracy, the DECREASE RANGE LED must also be off Overrange is indicated by a blank display with the numeral 1 in the most significant digit slot.

If the INPUT LEVEL RANGE switch is placed in the AUTO RANGE position, the input level is adjusted automatically. The LEDs (VOLTS, mVOLTS or μVOLTS) automatically illuminate showing the proper display units. Notice that the three most sensitive ranges on the INPUT LEVEL RANGE control operate in the LEVEL FUNCTION only.

When the dBm 600 Ω push button is pressed, the LED opposite dBm on the display indicates the display units. The reference level for this measurement, 0 dBm, is 0.7746 V corresponding to 1 mW dissipated in 600 Ω. The INPUT LEVEL RANGE switch operate as previously described.

The dB RATIO mode permits direct amplitude ratio measurements of two input signals. When the dB RATIO push button is pressed, the LED opposite the dB nomenclature on the display illuminates. To use this feature, press the dB RATIO push button. To establish the input signal as 0 dB reference, push the PUSH TO SET 0 dB REF push button and notice that the display reads all zeros.

Release the 0 dB REF push button. As the amplitude of the signal is changed, the display reads the dB ratio of the input signal to the reference signal amplitudes.

There are many useful applications for the dB RATIO mode in measurements of gain-loss, frequency response, S/N ratio, etc. For example, the corner frequency of a filter may be quickly checked. Set the test frequency to some midband value and set the zero dB reference. Adjust the test frequency until the display reads -3 dB; this is the corner frequency of the filter.

Gain measurements may be simplified by using this feature. Set the device to be tested as desired and connect the AA 501A Mod WQ input to the input of the device under test. Press the PUSH TO SET 0 dB REF push button. Then connect the input of the AA 501A Mod WQ to the device output and read the gain or loss directly from the display.

When measuring signal to noise ratio or making noise level measurement, it is often desirable to employ a frequency dependent weighting network. The AA 501A MOD WQ provides several internal filters, as well as facilities for connecting external filters. For information on their operation and use, see the text under Filter in this section of this manual.

Distortion Measurements

Distortion is a measure of signal impurity. It is usually expressed as a percentage of dB ratio of the undesired components to the desired components. Harmonic distortion is simply the presence of harmonically related or integral multiples of a single pure tone called the fundamental, and can be expressed for each particular harmonic. Total harmonic distortion, or THD, expresses the ratio of the total power in all significant harmonics to that in the fundamental.

The transfer (input vs output) characteristics of a typical device is shown in Fig. 2.2.3. Ideally this is a straight line. A change in the input produces a proportional change in the output. Since the actual transfer characteristic is nonlinear, a distorted version of the input waveshape appears at the output. The output waveform is the projection of the input sine wave on the device transfer characteristic as shown in Fig. 2.2.4. The output waveform is no longer sinusoidal, due to the nonlinearity of the transfer characteristic. Using Fourier analysis it can be shown that the output waveform consists of the ordinal input sine wave, plus sine waves at integer multiples of the input frequency. These harmonics represent nonlinearity in the device under test. Their amplitudes are related to the degree of nonlinearity.

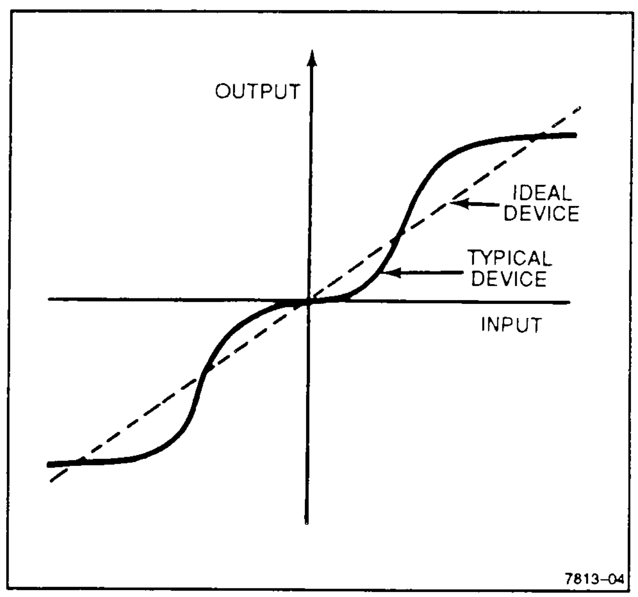

Fig. 2.2.3. Transfer characteristics of an audio device.

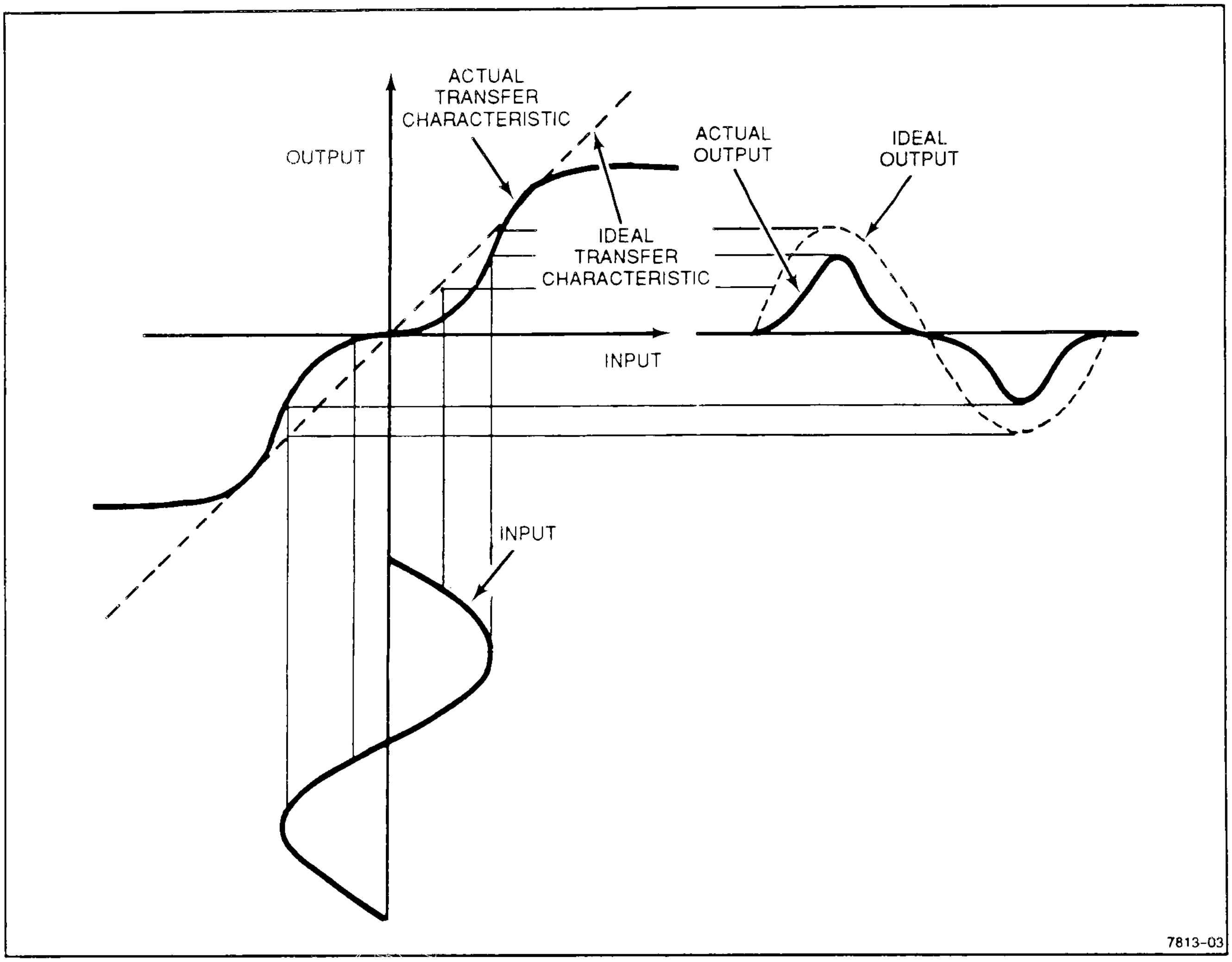

Fig. 2.2.4. THD test of transfer characteristics.

A total harmonic distortion measurement inevitably includes effects from noise to hum. The term THD + N has been recommended[1] to distinguish distortion measurements made with a distortion analyzer from those made with a spectrum analyzer.

A spectrum analyzer allows direct measurement of each harmonic. The spectrum analyzer technique involves making a narrow-band measurement of each harmonic, and then performing a root-mean-square summation of the harmonics to produce a THD number uninfluenced by broadband noise and other components such as ac hum or interference. However, it is relatively complex, time consuming, and requires interpretation of a graphic display.

[1] **IHF-A-202 1978, Standard Methods of Measurement for Audio Amplifiers, The Institute of High Fidelity, Inc., 489 Fifth Avenue, New York, N.Y. 10017.**

An appealing feature of the THD + N (total harmonic distortion plus noise) measuring technique is that the meter presents one number integrating harmonics, broadband white noise, hum, and specific interfering signals.

Distortion analyzers can quantify the nonlinearity of a device or system. A distortion analyzer removes the fundamental of the signal investigated and measures the remainder. See Fig. 2.2.5. Because of the notch filter response, any signal other than the fundamental influences the measurement.

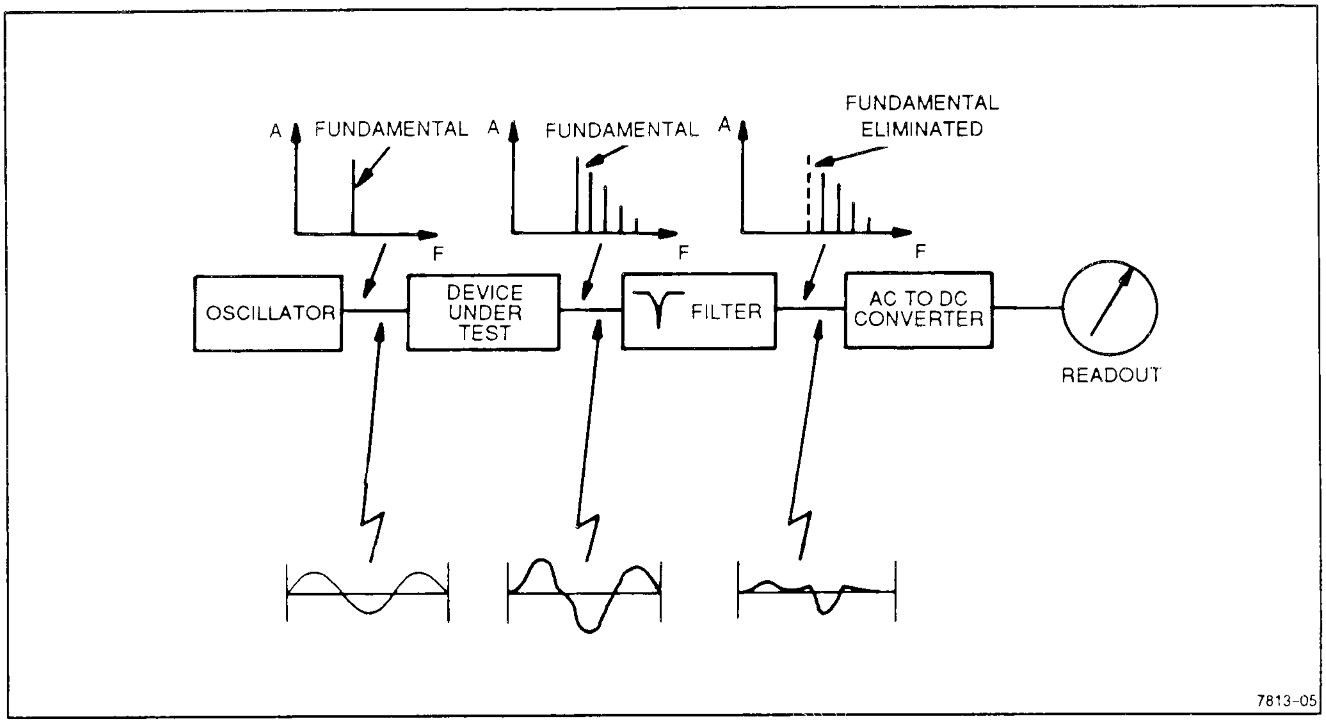

Fig. 2.2.5. Block diagram of a basic harmonic distortion analyzer.

Distortion Measurement Procedure

All of the controls found on a traditional distortion analyzer are automated on the AA 501A Mod WQ. It is only necessary to connect to the DUT and set the INPUT RANGE and DISTORTION RANGE switches to AUTO RANGE. Press THD + N and wait briefly for a reading.

Minimum input signal amplitude for valid distortion measurements is 60 mV. To provide greater flexibility the instrument may be manually operated as described in the following paragraphs.

Adjustment of the input level range control is the same as for level measurements. Manually setting the INPUT RANGE control to the correct scale ensures that the input is within the 10 to 12 dB range of the internal auto set-level circuitry. The range LEDs must be extinguished to make readings to specified accuracy. The 200 µV, 2 mV and 20 mV ranges do not operate in the distortion function and a flashing Decrease Range LED indicates insufficient input signal level for distortion measurements.

To manually select a distortion range, press the THD + N button and the desired range button. Selection of AUTO RANGE causes the instrument to autorange the distortion readout. The remaining range push buttons cause the instrument to stay in these ranges without autoranging. This may reduce the measurement time slightly if the approximate reading is already known. This is useful in production line testing or in the testing of low distortion equipment. The dB display is effectively a single range; however, internal instrument operation is identical to AUTO RANGE.

When making distortion measurements, the RESPONSE button should normally be in the RMS position. Current distortion measurement standards require the use of rms reading instruments by specifying power summation of each of the components. The AVG response may be used when making comparisons with readings taken with older distortion analyzers. However, it may read up to 25% (2 dB) lower than rms response when noise is significant and even lower with high crest factor distortion signals (characteristic of crossover or hard-clipping nonlinearities).

For frequencies below 20 kHz, the residual wideband noise in the measurement may be reduced by activating the 80 kHz LO PASS filter. If hum (line related components) are Interfering with the measurement, they may be reduced with the 400 Hz HI PASS filter. This filter should not be employed with fundamental frequencies below approximately 400 Hz because of additional error due to rolloff. For more information, see text under Filters section of this manual.

High Distortion Measurement Limitations

NOTE

Care must be taken to ensure proper locking for input signals with 10% or greater noise or non-harmonic components, because the AA 501A Mod WQ automatically tunes and nulls out the fundamental frequency prior to making a THD + N measurement.

In those applications which require higher THD + N measurements (for example, SINAD[2] testing) the internal circuitry will remain locked to noise levels of approximately 30%, after it is initially given a clean signal. To perform a SINAD test, the receiver under test is first given a high level modulated rf input. The AA 501A Mod WQ will lock onto the audio signal at the demodulated output. The rf level feeding the receiver is then reduced until a -12 dB (25%) THD + N reading is obtained on the AA 501A Mod WQ and becomes a measure of the receiver's sensitivity.

2 Defined in Electronic Industries Association Standard No. RS 204A, July 1972, Electronic Industries Association, Engineering Department, 2001 Eye St. N. W., Washington, D.C. 20006.

IM Distortion Measurements

Another measurement of distortion investigates the interaction of two or more signals. Many tests have been devised to measure this interaction. Four common standards are SMPTE[3], DIN[4], CCIF[5], and Twin-Tone. The AA 501A Mod WQ is capable of automatically selecting and performing all three tests.

To measure intermodulation distortion (IMD), according to SMPTE and DIN standards, the device under test is excited with a low frequency and high frequency signal simultaneously (Fig. 2.2.6). The output signal is high-pass filtered to remove the low frequency component. The high frequency tone is then demodulated, as an AM radio signal. The demodulator output is low-pass filtered to remove the residual carrier (high frequency) components. The amplitude of the low frequency modulation is displayed as a percentage of the high frequency level.

3 Society of Motion Picture and Television Engineers, Standard No. TH 22.51, 862 Scarsdale Avenue, Scarsdale, N.Y. 10583.
4 Deutsches Institut fur Normung e V, No. 45403 Blatt 3 and 4, January 1975, Beuth Verlag GmbH, Berlin 30 and Koln 1.
5 International Telephone Consultative Committee.

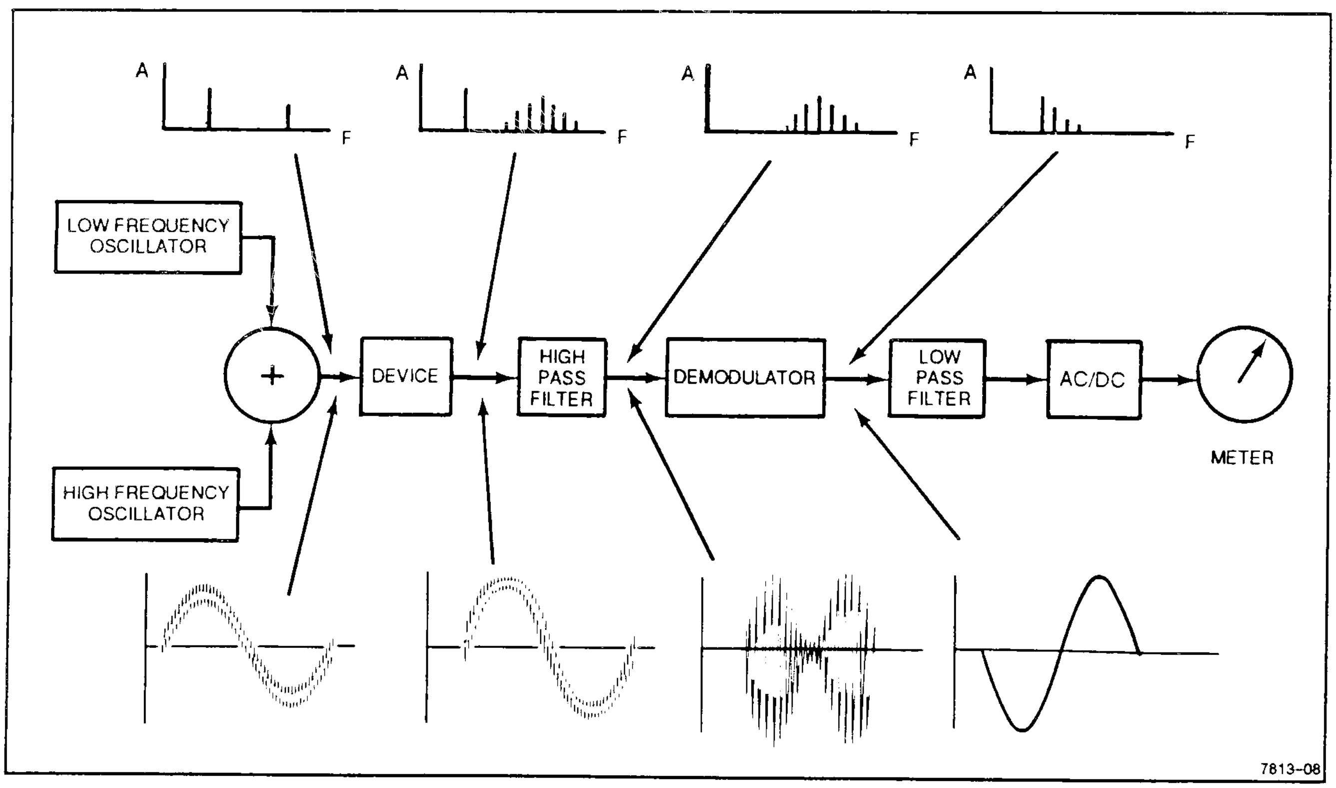

Fig. 2.2.6. Block diagram of basic IM analyzer.

As shown in Fig. 2.2.7 when this composite signal is applied to the device, the output waveform is distorted. As the high frequency tone is moved along the transfer characteristic by the low frequency tone, its amplitude changes. This results in low frequency amplitude modulation of the high frequency tone. This modulation is apparent in the frequency domain as sidebands around the high frequency tone. The power in these sidebands represents nonlinearity in the device under test.

The amplitude ratio of low to high frequencies should be between 4:1 and 1:1. The AA 501A Mod WQ circuitry automatically adjusts calibration to compensate for the selected test signal ratio. Some additional range is provided in this circuitry to enable measurement of devices with nonflat frequency response.

SMPTE standard test frequencies are 60 Hz and 7 kHz. The DIN standard is virtually identical to the SMPTE standard except for the two frequencies used. They may be any pair of octave band center frequencies, with the upper at least eight times as high as the lower (250 Hz and 8 kHz are most common). The AA 501A Mod WQ can accept a wide range of test frequencies as shown in the Specifications section.

CCIF difference frequency distortion is measured with two high frequency sine waves driving the device under test. Both are of equal level and closely spaced in frequency. Nonlinearities in the device under test cause the sine waves to cross modulate. This creates new signals at various sum and difference frequencies from the inputs. For example, the commonly used 14 kHz and 15 kHz test frequencies produce 1 kHz, 13 kHz, 14 kHz, 15 kHz, 16 kHz, 28 kHz, etc.

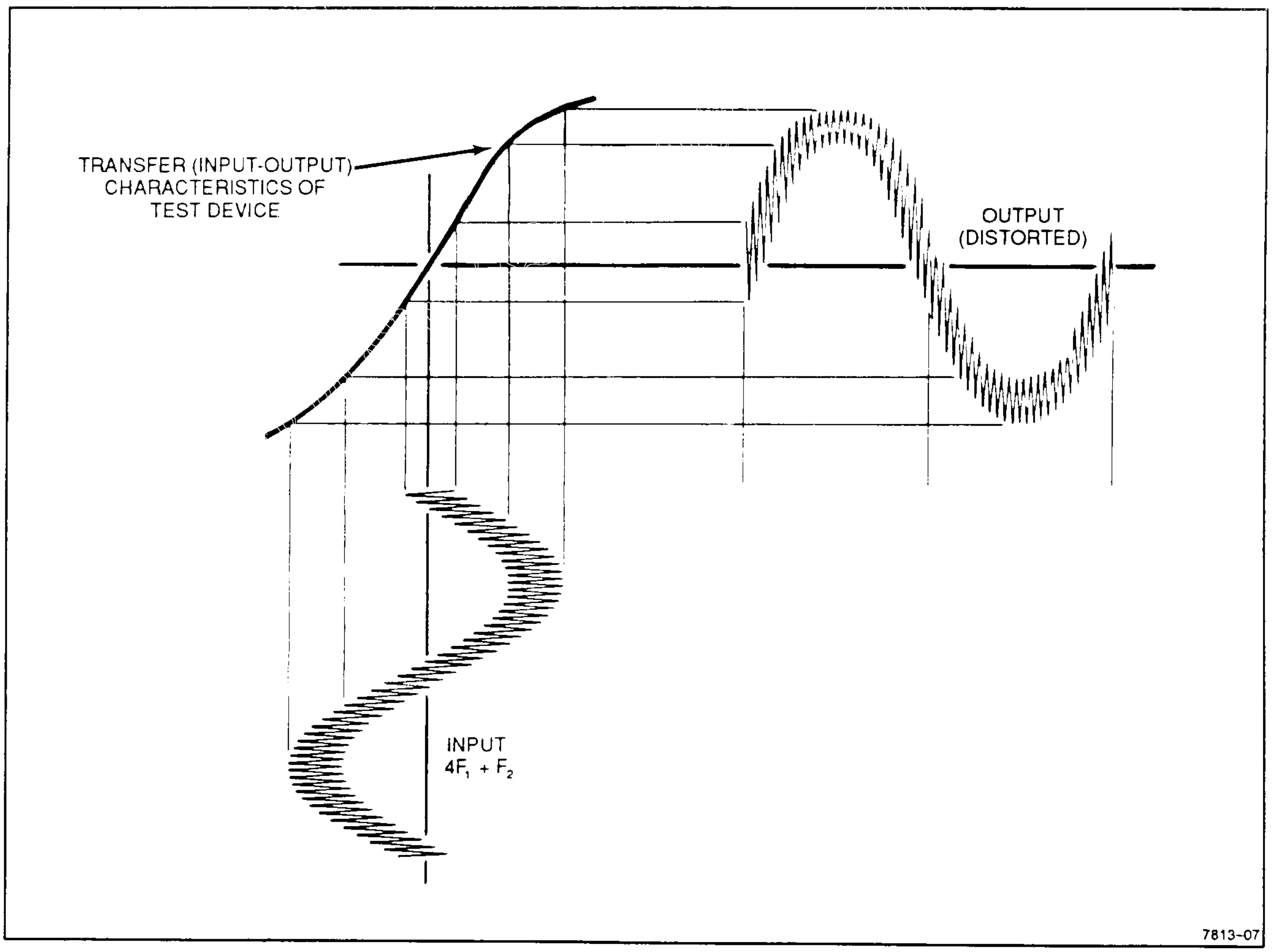

Fig. 2.2.7. IM test of transfer characteristics in time and frequency domain.

The user could measure each new component with a tunable filter such as a spectrum analyzer; however, this is usually limited to an 80 dB dynamic range and is very tedious. In many systems and especially those with asymmetric non-linearities, a good measure of this distortion may be obtained by investigating only the difference frequency (in this example 1 kHz). If only the low frequency component is measured, it is called a CCIF second order difference frequency distortion test.

To measure two tone difference frequency distortion, the device is excited with two input signals as described above. The output of the device is low-pass filtered to remove the two test tones and extract the difference frequency product. The level of this component is expressed as a percentage of the high frequency signals. The AA 501A Mod WQ CCIF difference frequency mode will accept any pair of input frequencies which are within limits as listed in the Specification section. The amplitudes of the two signals should be equal.

IM Distortion Measurement Procedure

Intermodulation and THD testing are similar, using the AA 501A Mod WQ. After connecting the appropriate signal source to the DUT, set the INPUT RANGE as described in the THD section. Press the IMD FUNCTION button and select a distortion range. Selecting AUTO RANGE or dB provides automatic ranging. The AA 501A Mod WQ accepts SMPTE, DIN, CCIF, and Twin-Tone difference frequency test signals. The AA 501A Mod WQ circuitry automatically adjusts calibration to compensate for the selected test signal ratio. Some additional range is provided in this circuitry to enable measurement of devices with nonflat frequency response. Selection between the necessary analyzing circuits is accomplished automatically for IMD levels less than 20%, based upon the spectral content of the test tones. (There is a movable jumper inside the AA 501A Mod WQ to allow defeating the automatic test selection circuitry for special applications requiring IMD measurements in excess of 20%. Refer any jumper changes to qualified service personnel.)

The LO PASS filter may be selected in the IMD mode but will have little or no effect. The 400 Hz HI PASS and the WEIGHTING filters will cause erroneous readings because the IMD components of interest generated by the tests fall between 50 Hz and 1 kHz. These filters, when activated in the IMD mode, may attenuate some of the frequency components being measured and should be avoided.

Filters

The five buttons along the right edge of the instrument allow selection of four built-in frequency weighting filters plus an external filter, as desired. See Fig. 2.2.8 for response curves of the various filters. The 400 Hz, 30 kHz, and 80 kHz filters are both 3-pole (18 dB per octave rolloff) Butterworth alignment. The C MSG WTG filter weights the noise according to its perceived annoyance to a typical listener of standard telephone service. They are placed in the measuring circuitry immediately before the average or rms detectors. These filters are functional in all modes of operation. They also affect the signal at the FUNCTION OUTPUT connector.

To prevent inaccurate results, check the position of all filter push buttons before making measurements. Filtering takes place after all gain circuits. When operating in the manual distortion ranges with a filter selected, it is possible to overload part of the instrument, even though the display is not overranged. This may be checked by releasing the filter push buttons and checking the display for overrange or by pressing the AUTO RANGE push button.

The 400 Hz Hi PASS filter is used to reduce the effects of hum on the measurement. Although the differential input and common mode rejection of the AA 501A Mod WQ reduce the effects of ground loops, extremely bad measurement conditions may require use of this filter. The DUT may also generate an undesirable amount of hum, limiting the noise and distortion residuals obtainable. This filter may be used when measuring harmonic distortion of signals at about 400 Hz or greater, but should not be used when measuring levels at frequencies less than 1 kHz, nor when measuring intermodulation distortion.

The 30 kHz LO PASS filter provides bandwidth limiting for broadcast proof of performance testing. It is also useful for unweighted noise measurements on audio equipment, providing an equivalent noise bandwidth of 31.5 kHz. When the 30 kHz filter is used, the 80 kHz filter is disabled.

Use of the 80 kHz LO PASS filter reduces the effects of wideband noise and permits measurement of lower THD + N for input signals up to 20 kHz. For 20 kHz inputs, it allows measurement of harmonics up to the

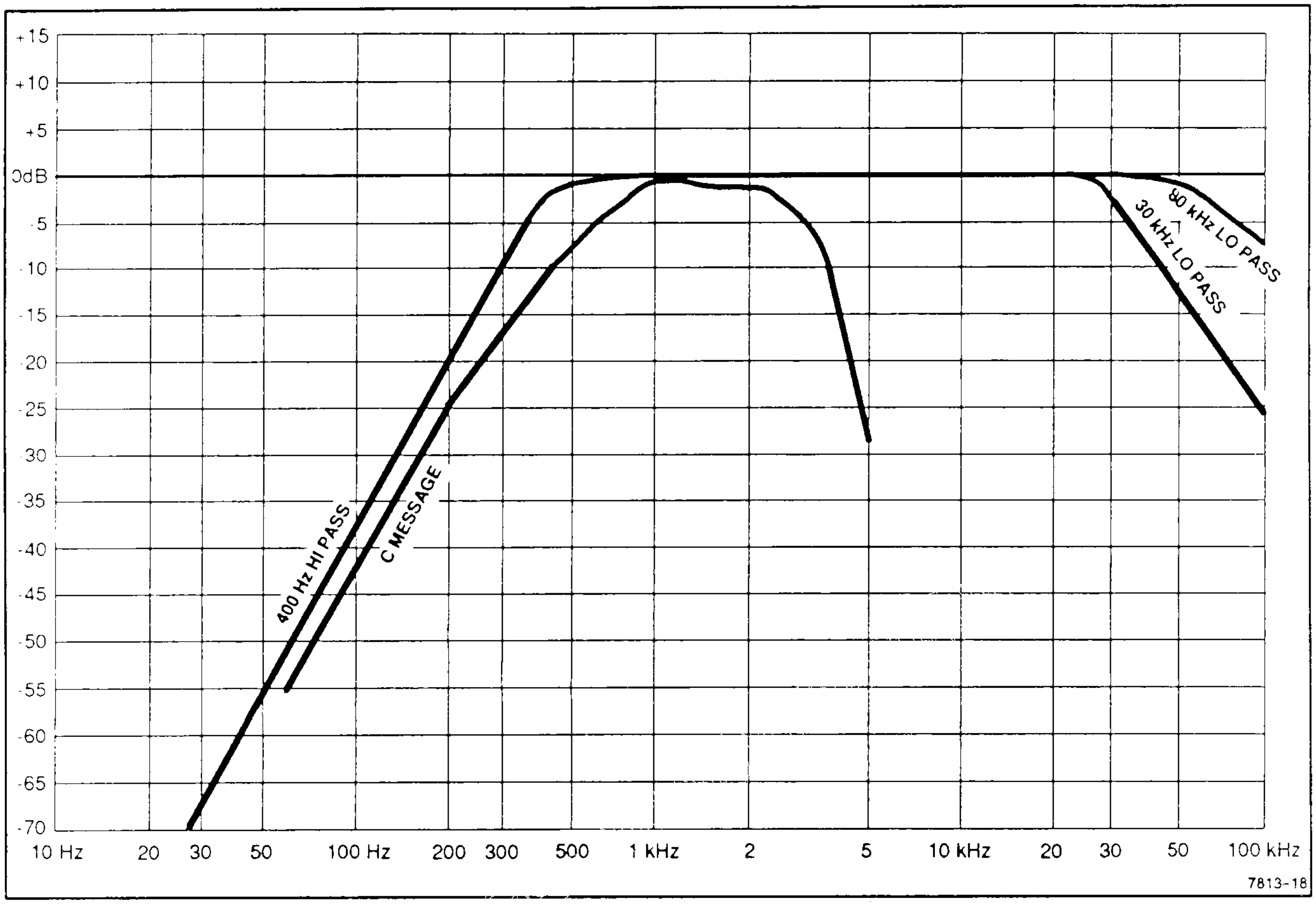

Fig. 2.2.8. Response curves for AA 501A Mod WQ filters.

fourth order. Do not use this filter if harmonic components above 80 kHz are of interest. When checking noise, the 80 kHz filter may be used to reduce the measurement bandwidth.

The C message weighting filter is used for measurement of noise in voice-frequency communications circuits. The filter is designed to weight noise frequencies in proportion to their perceived annoyance effect for telephone service.

Connections for an external filter are also provided. Press the EXTERNAL FILTER push button. Connect the external filter between the FUNCTION OUTPUT and the AUXILIARY INPUT. One application for the external filter is selective measurement of individual harmonics or components of an Input signal. This may be accomplished using a unity gain bandpass filter as an external filter and adjusting the frequency to the harmonic desired.

Displays

The AA 501A Mod WQ provides two display forms for manual measurements. The digital readout displays the selected function with units. Overrange Indication blanks all digits and displays a numeral 1 in the most significant digit slot.

For rapid nulling or peaking applications, the digital display is supplemented by an uncalibrated LED bar graph for an analog meter-like display. The bar graph responds logarithmically, with each segment representing approximately a 2.5 dB change in the selected function. Additionally, the intensity of the segments is modulated between steps permitting resolution of changes as small as 0.5 dB. The range of the bar graph is determined by the measurement range in use. When using this feature it may be desirable to select a manual range to prevent confusing displays caused by autoranging.

Monitoring

The interface capabilities of the AA 501A Mod WQ may aid considerably in the interpretation of measurements. Figure 2.2.9 shows an optional oscilloscope for visual monitoring. If connected as shown, channel 1 displays a sample of the input signal and channel 2 displays the distortion components when in the IM or THD + N function.

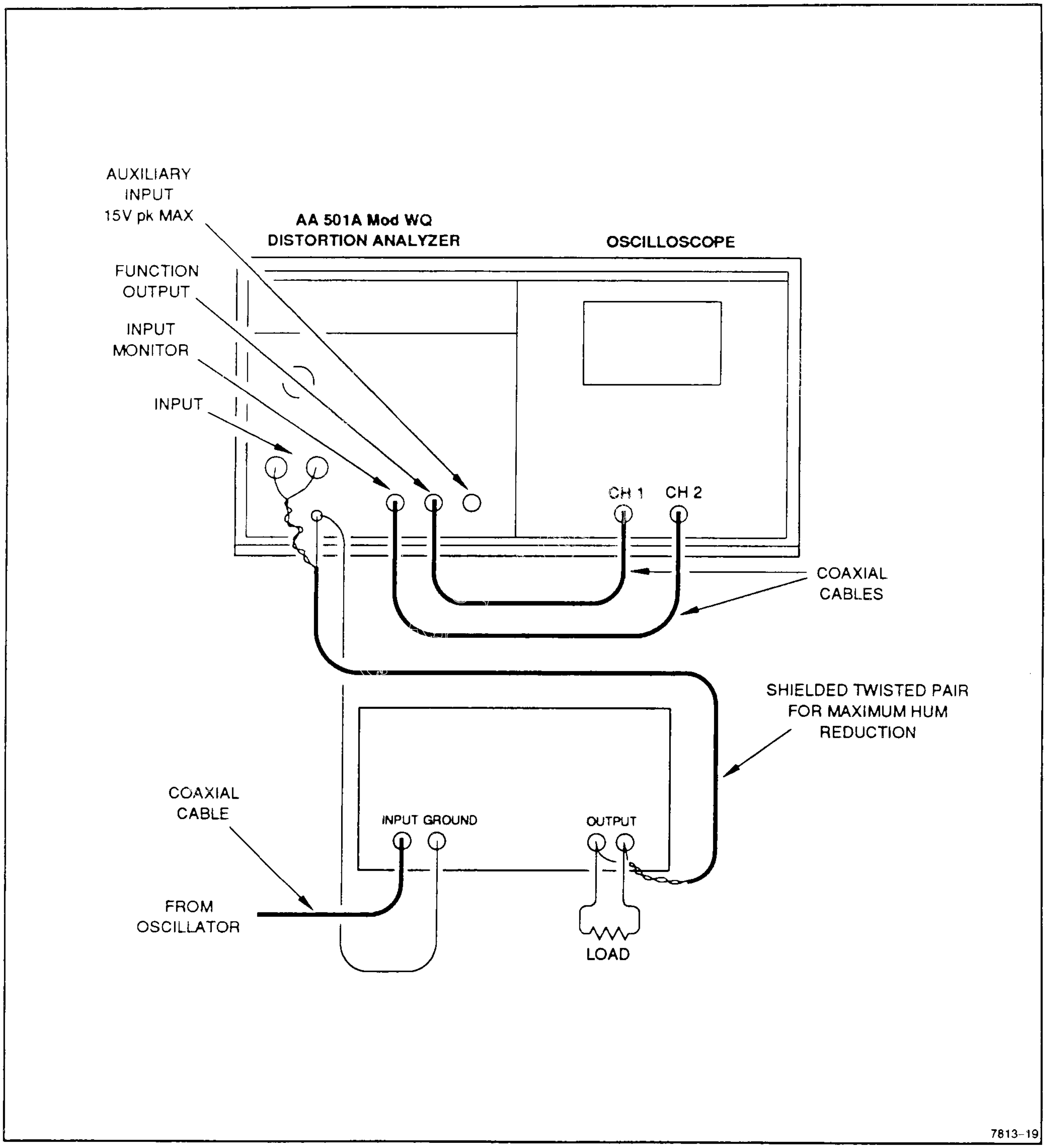

Fig. 2.2.9. Typical connections for distortion measurements with monitoring.

The INPUT MONITOR connector provides a fixed amplitude version (approximately equal to 1 V rms) of the input signal for input signals of 50 mV or greater. This allows display of the input signal on an oscilloscope, without constantly readjusting the oscilloscope sensitivity. At input levels below about 50 mV the INPUT MONITOR signal is approximately 26 dB (gain of approximately equal to 20) above the input signal level.

The FUNCTION OUTPUT is taken after the distortion measurement and high gain amplifier circuitry. It can be used for monitoring the signal read on the display. The signal at the FUNCTION OUTPUT connector is 2 V for a full scale reading on the display. In the level function this connector becomes an amplified version of the input signal. The gain from the input to this output is dependent on the LEVEL RANGE switch, and is given in Table 2-1. When the AA 501A Mod WQ is used as a constant gain differential amplifier, the INPUT RANGE switch must be set to a fixed range. In the distortion function this output can be displayed on an oscilloscope to view the distortion components. This output may also be used to drive a spectrum analyzer or selective voltmeter for examining the individual harmonics or modulation products. When an oscilloscope is used, the triggering signal is best taken from the sync output on the oscillator. If this is not possible (for example, in tape recorder or Telco link testing) it should be obtained from the INPUT MONITOR connector on the AA 501A Mod WQ.

One interesting use of the Function Output and Input Monitor signals is to investigate the nonlinearities of the transfer function of a DUT with the THD + N mode. For this measurement, the FUNCTION OUTPUT drives the vertical input of an oscilloscope while the INPUT MONITOR drives the horizontal. The resulting display is similar to Fig. 2.2.10, and represents the deviation from linearity of the transfer characteristic. In other words, it represents the transfer characteristic after the best fit straight line is removed. This can be particularly useful in diagnosing sources of nonlinearity such as clipping, crossover, etc. If the device under test has large amounts of phase shift at the test frequencies it may be necessary to introduce compensating phase shift into the horizontal channel. Since the FUNCTION OUTPUT is taken after the filters, they will affect the signal seen at this connector. The vertical scale is the deviation from the best fit line and is related to the distortion range and vertical sensitivity of the oscilloscope.

Table 2.2.1
Gains from INPUT terminals to FUNCTION OUTPUT connector for various settings of the INPUT LEVEL RANGE control

LEVEL RANGE Setting	Gain to FUNCTION OUTPUT
200 V	-40 dB
60 V	-30 dB
20 V	-20 dB
6 V	-10 dB
2 V	0 dB
600 mV	+ 10 dB
200 mV	+ 20 dB
20 mV	+ 40 dB
2 mV	+ 60 dB
200 µV	+ 80 dB

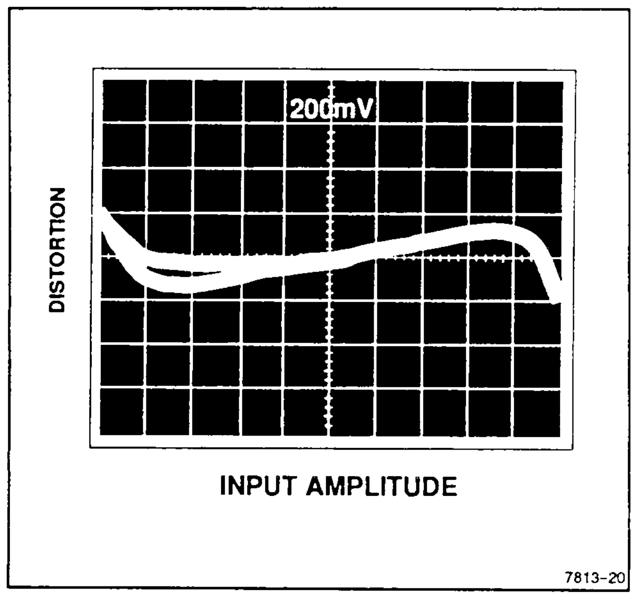

Fig. 2.2.10. Oscilloscope display of deviation from linearity.

Section 3
SG 505 Mod WQ
Test Signal Oscillator

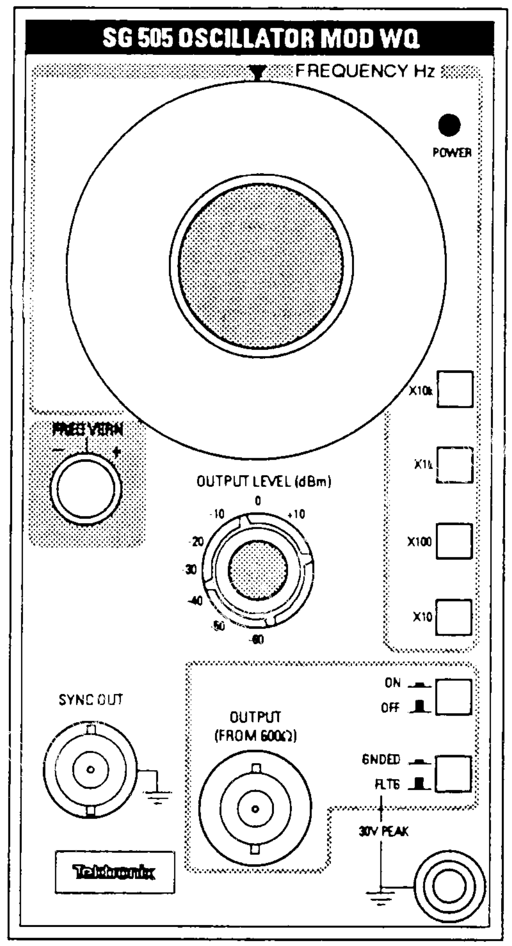

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Figure 3.1.1. The SG 505 Mod WQ Oscillator.

SPECIFICATION

Introduction

The SG 505 Mod WQ Oscillator generates an ultra low distortion sine wave over the frequency range from 10 Hz to 100 kHz This signal can be floated or referenced to chassis ground. The oscillator also provides a fixed amplitude ground referenced sine wave signal at the SYNC OUT connector that is identical in frequency to the signal from the OUTPUT connector. Versions of both output signals are available at the rear interface connector.

The SG 505 Mod WQ is designed to operate in the left-most compartment of the TM 504A Mod WQ Series Power Module.

Performance Conditions

The electrical characteristics are valid only if the SG 505 Mod WQ has been calibrated at an ambient temperature of +20°C to +30°C and is operating at an ambient temperature of 0°C to +50°C, unless otherwise noted. Items listed in the Performance Requirements column of the Electrical Characteristics are verified by completing the Performance Check in the Calibration section of this manual. Items listed in the Supplemental Information column are not verified in this manual. They are either explanatory notes or performance characteristics for which no limits are specified.

Table 3.1.1
Electrical Characteristics (Front Panel)

Characteristics	Performance Requirements	Supplemental Information
FREQUENCY		
Range	10 Hz to 100 kHz in four overlapping bands.	Typically 9 Hz to 110 kHz. Nominal range of each band is 0.90 to 11.0.
Vernier Range	≥ + 1% of frequency setting.	
Dial Accuracy	±3% of setting with vernier at center.	
Drift		Typically less than 0.01%/°C and 0.03%/hour.
OUTPUT LEVEL		
Calibrated Steps	+10 dBm to -60 dBm into 600 Ω in eight 10 dB steps, ±0.2 dB at 0 dBm and 1 kHz.	
Step Accuracy	±0.1 dB/10 dB step.	
Stability		Typically better than 0.01 dB/°C and 0.03 dB/hour.
Variable Range	≥ +2.2 dB to <-10 dB from calibrated position.	
Maximum Output	≥10 dBV (+12.2 dBm) or 3.16 V rms into 600 Ω.	≥6 V rms unloaded.
Setting Time		≤5 seconds to 0.2 dB of final value, 20 Hz-100 kHz, typically <3 seconds above 100 Hz. Worst case transient overshoot is ≤3 dB.

Table 3.1.1 (cont)

Characteristics	Performance Requirements	Supplemental Information
LEVEL FLATNESS (1 kHz reference)		
10 Hz-20 kHz	±0.1 dB.	
20 kHz-100 kHz	±0.2 dB (exclude -60 dB OUTPUT LEVEL attenuator range).	
DISTORTION ($R_L \geq 600\ \Omega$)		Refer to Buffered Main Output load impedance limitation under Electrical Characteristics (Rear Interface).
10 Hz-50 kHz	≤-80 dB THD.	
50 kHz-100 kHz	≤-60 dB THD.	
OUTPUT		
Impedance	600 Ω ±2%	Floating or grounded through approximately 30 Ω. Output impedance does not change with OUTPUT ON/OFF selection.
Dc Offset		≤1% of output ac rms voltage.
Maximum Floating Voltage		±30 V peak. (0.01 μF between output common and chassis ground in floating mode.)
Line Related Common Mode Output Voltage In Floating Mode		Typically ≤ 50 mV rms into an open circuit.
SYNC OUTPUT		Sine wave with same frequency as output.
Signal	200 mV rms ±20% sine wave to 20 kHz, at least 120 mV at 100 kHz.	THD is typically ≤ 3% and phase shift from OUTPUT is typically ≤ 5°, 20 Hz to 20 kHz.
Impedance		1 kΩ, ±10%, ground referenced and isolated from the main output.
ELECTRICAL CHARACTERISTICS (Rear Interface)		
Buffered Main Output		Pins 25A and 26A (common). Fixed output of ≈2 V rms from ≈300 ohms. Pin 26a is electrically connected to front panel OUTPUT common. To prevent possible instrument damage, do not float output in excess of ±30 V peak.
Sync Output		Pins 27B and 28B (ground). Approximately 200 mV rms sine wave identical to front panel SYNC output signal. Output impedance is approximately 50 Ω and always ground referenced.

Table 3.1.2
Miscellaneous

Characteristics	Performance Requirements	Supplemental Information
Power Consumption		6 VA or less.
Calibration Interval		1000 hours or 6 months.
Warm-up Time		20 Minutes.

Table 3.1.3
Environmental

Characteristics	Description	
Temperature		Meets MIL-T-28800B, Class 5.
Operating	0°C to +50°C.	
Non-Operating	-55°C to +75°C.	
Humidity	90-95% RH for 5 days cycled to 50°C.	Exceeds MIL-T-28800B, Class 5.
Altitude		Exceeds MIL-T-28800B, Class 5.
Operating	4.6 km (15,000 ft.)	
Non-operating	15 km (50,000 ft.)	
Vibration	0.38 mm (0.015") 10 Hz to 55 Hz, 75 minutes.	Meets or exceeds MIL-T-28800B, Class 5.
Shock	30 g's (1/2 sine), 11 ms, 18 shocks.	Meets or exceeds MIL-T-28800B, Class 5.
Bench Handling	45 degrees or 4" or equilibrium, whichever occurs first.	Meets MIL-T-28800B, Class 5.
E.M.C.	MIL-STD 461A/462.	Meets MIL-T-28800B, Class 5.
Electrical Discharge	20 kV maximum.	Charge applied to each protruding area of the product under test except for the output terminals.
Transportation		Qualified under National Safe Transit Association Preshipment Test Procedures 1A-B-1 and 1A-B-2.
Vibration	25 mm (1") at 270 rpm for 1 hour.	
Package Drop	10 drops from 91 cm (3 ft.)	

Table 3.1.4
Physical Characteristics

Characteristics	Description
Finish	Plastic-aluminum laminate front panel.
Net Weight	1.13 kg (2.49 lbs).
Overall Dimensions	67.06 mm (2.640") W x 308.36 mm (12.140") D x 126.24 mm (4.970") H.

OPERATING INSTRUCTIONS

CONTROLS AND CONNECTORS

FREQUENCY SELECTION

(1) **FREQUENCY Hz Dial**
Provides continuous frequency selection within each push button selected frequency range.

(2) **Multiplier Push Buttons**
Select any one of four frequency ranges.

(3) **FREQ VERNIER Dial**
Adjusts frequency ±1% from selected frequency.

OUTPUT LEVEL SELECTION

(4) **OUTPUT LEVEL (dBm) Dial**
Selects one of eight amplitude level steps, calibrated in dBm, into a 600 Ω load.

(5) **OUTPUT LEVEL (dBm) CAL Dial**
Provides continuous amplitude adjustment above and below the calibrated OUTPUT LEVEL (dBM) steps.

(6) **ON-OFF Push Button**
Connects or disconnects the signal to the OUTPUT connector.

(7) **GNDED-FLTG Push Button**
GNDED connects the OUTPUT connector outer conductor (shield) to chassis ground through a low impedance. FLTG connects the outer conductor to ground through a capacitor for floating operation.

CAUTION

If either SG 505 Mod WR or SG 505 Mod WQ GNDED/FLTG switch is set to GNDED, both instruments are then at ground reference.

OUTPUT CONNECTORS

(8) **OUTPUT Connector**
Provides a sine wave signal at a frequency selected by the FREQUENCY Hz dial and multiplier push button at an amplitude selected by the OUTPUT LEVEL.

(9) **SYNC OUT Connector**
Provides approximately 200 mV rms fixed amplitude and ground referenced sinusoidal signal at the same frequency as the OUTPUT signal.

(10) **Ground Binding Post**
Chassis ground.

(11) **Release Latch**
Pull to remove plug-in from the power module.

(12) **POWER Indicator**
Indicator lights when power is applied to instrument from power module.

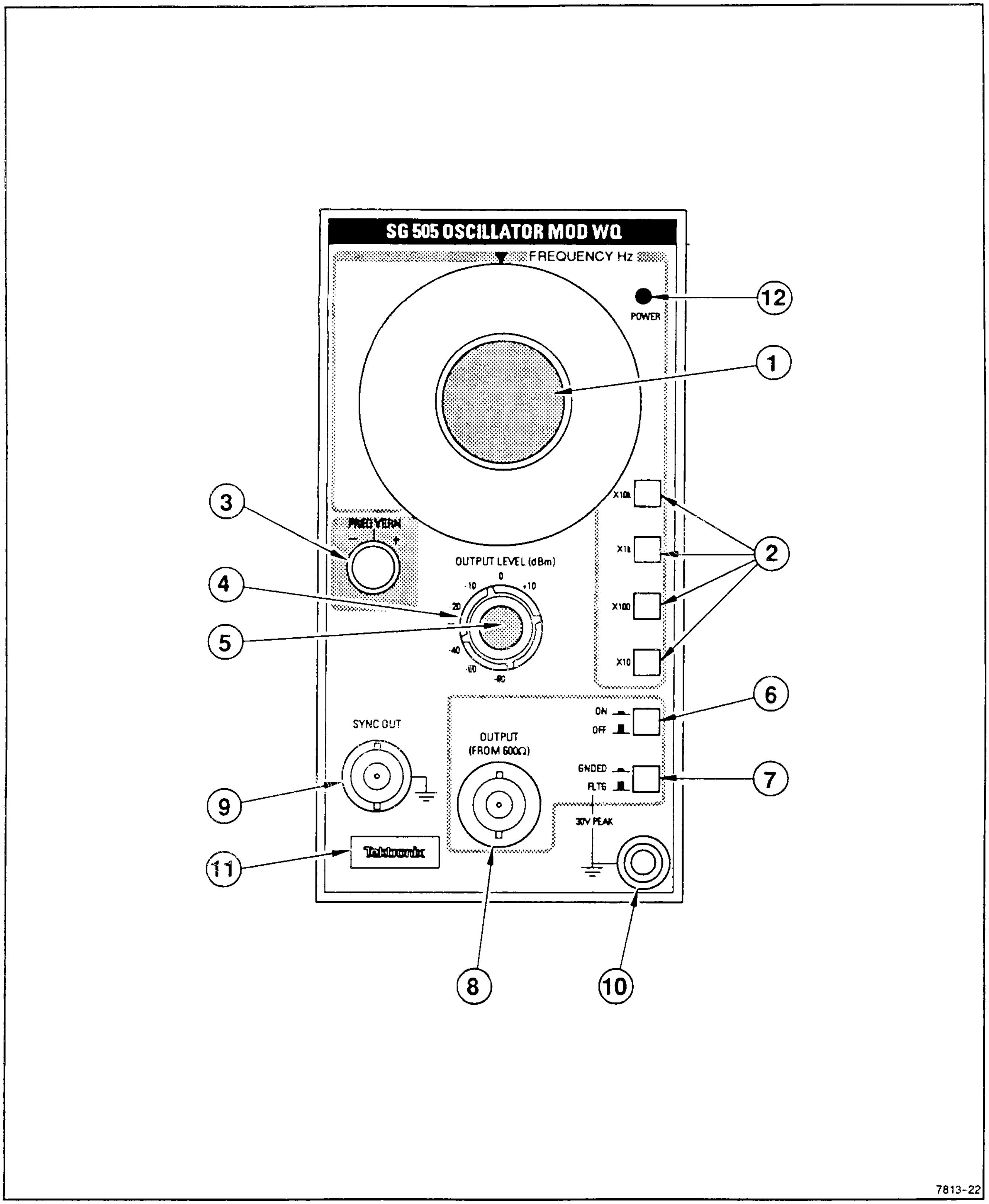


Fig. 3.2.1. Front panel controls and connectors.

OPERATORS FAMILIARIZATION

General Operating Information

With the SG 505 Mod WQ properly installed in the power module, allow twenty minutes warm-up time for operation to specified accuracy.

Output Connections

The output of the SG 505 Mod WQ at the OUTPUT connector is designed to operate as a 600 Ω voltage source working into a 600 Ω load. At higher frequencies, an unterminated or improperly terminated output may reduce amplitude accuracy. Loads less than 600 Ω may cause waveform distortion. To ensure waveform purity, observe the following precautions:

1. Use good quality coaxial cables and connectors.
2. Make all connections tight and as short as possible.

The signal at the SYNC OUT connector is designed for use as an external trigger for a counter, oscilloscope, or other device. This output is approximately 200 mV rms with a source impedance of 1 kΩ, and is always referenced to chassis ground (even when the main OUTPUT is floating).

CAUTION

To avoid damage to the SG 505 Mod WQ circuitry, do not apply a voltage exceeding 30 V peak with respect to chassis ground, to any front panel connector or to rear interface connector pins 14A-28A and 14B-28B.

Frequency Selection

The SG 505 Mod WQ produces a sine wave signal at any frequency from 10 Hz to 100 kHz. To set the frequency, set the FREQUENCY Hz dial to the desired frequency and press the appropriate multiplier push button. The FREQ VERNIER dial may be used to adjust the OUTPUT frequency 1 percent above and below the frequency selected by the FREQUENCY Hz dial and multiplier push button. With the FREQ VERNIER dial at the center position, the output frequency produced is the FREQUENCY Hz dial setting multiplied by the active multiplier value. Signals at the OUTPUT and SYNC OUT connectors are of the same frequency. The SYNC OUT signal can be used as an external signal for monitoring the OUTPUT, provided no more than approximately 200 mV is required from the SYNC OUT connector.

Output Level Selection

The OUTPUT LEVEL dial selects eight level steps from +10 dBm to -60 dBm. The CAL control, concentric within the OUTPUT LEVEL (dBm) dial, permits continuous adjustment above and below the calibrated output level steps. The signal at the OUTPUT connector may be ground referenced or floated up to ±30 V peak, using the FLTG-GNDED push button. The ON-OFF push button connects or disconnects the signal at the OUTPUT connector.

Rear Interface Signals

A fixed level buffered OUTPUT signal is available at rear interface connector pins 25A and 26A (common). When the rear interface OUTPUT signal is used, the rear interface load impedance (pins 25A and 26A) must be ≥ 1 kΩ, to prevent OUTPUT amplitude distortion. The ON-OFF and FLTG-GNDED push buttons affect the rear interface output signal as previously described for the front panel OUTPUT signal.

The signal at the front panel SYNC OUT connector is also available at the rear interface connector, pins 27B and 28B (ground). The output impedance at these rear interface pins is approximately 50 Ω and the signal is always referenced to ground.

Section 4
SG 505 Mod WR
Oscillator

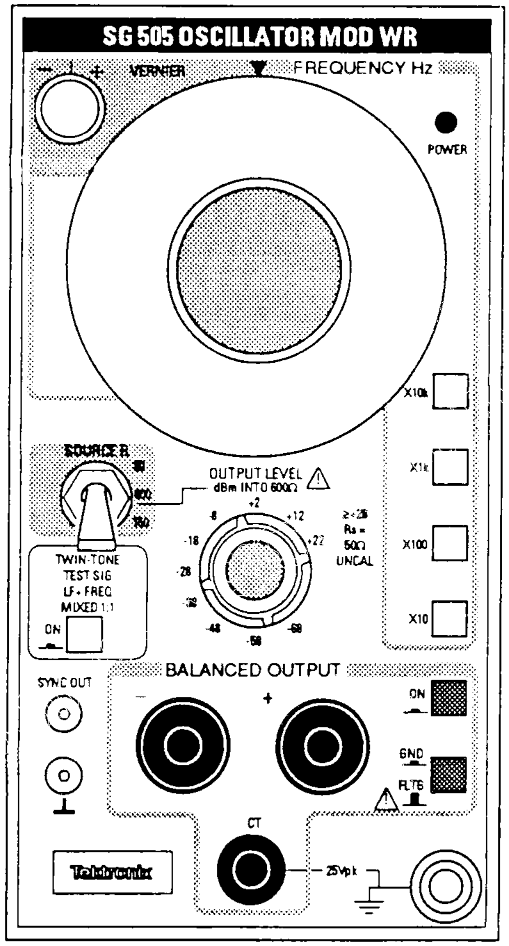


Figure 4.1.1. SG 505 Mod WR Oscillator.

SPECIFICATION

INTRODUCTION

The SG 505 Mod WR Oscillator generates an ultra low distortion sine wave over the frequency range from 10 Hz to 100 kHz. this signal can be floated or referenced to chassis ground. The oscillator also provides a fixed amplitude ground referenced sine wave signal at the SYNC OUT connector that is identical in frequency to the signal from the OUTPUT connector.

The SG 505 Mod WR is designed to be operated in the second-from-the-left compartment of the TM 504A Mod WQ Power Module.

PERFORMANCE CONDITIONS

The electrical characteristics are valid only if the SG 505 Mod WR has been calibrated at an ambient temperature of +20°C to +30°C and is operating at an ambient temperature of 0°C to +50°C, unless otherwise noted. Items listed in the Performance Requirements column of the Electrical Characteristics are verified by completing the Performance Check in the Calibration section of this manual. Items listed in the Supplemental Information column are not verified in this manual. They are either explanatory notes or performance characteristics for which no limits are specified.

Table 4.1.1
Electrical Characteristics

Characteristics	Performance Requirements	Supplemental Information
FRONT PANEL		
OUTPUT LEVEL		
Calibrated Output (f = 1 kHz)		Maximum output ≥21 V rms unloaded.
Rs = 600 Ω in CAL detent	+22 dBm (9.75 V rms) ±0.2 dB into 600 Ω.	Maximum output with variable out of CAL position increases to + 22.7 dBm.
Rs = 50 Ω just ccw of CAL detent		+28 dBm (19.46 V rms) ±0.3 dB into 600 Ω and at least +30 dBm (12.25 V rms) into 150 Ω.
Attenuator Step Accuracy (f-1 kHz)	±0.1 dB for any 10 or 20 dB step change.	Range is +22 dBm to -68 dBm.
Stability		Typically better than 0.01 dB/°C and 0.03 dB/hour.
Variable Range	At least 11 dB.	Nominal range is +0.7 dB to < -10dB.
Setting time		≤ 5 seconds to 0.2 dB of final value, 20 Hz – 100 kHz; typical < 3 seconds above 10 Hz. Worst case transient over-shoot is ≤ 3 dB.
LEVEL FLATNESS (1 kHz ref, R_L = 600 Ω)		
10 Hz – 20 kHz	±0.1 dB.	
20 kHz – 100 kHz	±0.2 dB.	Flatness is above 50 kHz unspecified on -58 dBm and -68 dBm ranges.

Table 4.1.1 (cont)

Characteristics	Performance Requirements	Supplemental Information
OUTPUT		
Impedance		Floating or grounded through approximately 30 Ω. Output impedance does not change with OUTPUT ON/OFF selection. Capacitance between output common and chassis ground in floating mode ≃ to 330 pF. .
	Balanced and selectable: 600 Ω ±2%, 150 Ω ±3%.	Impedance to CT is one-half the selected impedance.
Balance (if ≤ 20 kHz, Output GNDed)	≤ 0.5% mismatch of output open-circuit voltages referenced to CT.	
Typical Dc Offset		<0.5% of output ac rms voltage.
Maximum Floating Volt		±25 v peak, CT to GND.
DISTORTION (Maximum Specified Output, R_L ≥ 600 Ω)		
10 Hz—50 kHz	≤ -80 dB.	
50 kHz—100 kHz	≤ -60 dB.	
SYNC OUTPUT		
Signal	Sine wave 200 mV rms ±20% to 20 kHz; at least 120 mV rms at 100 kHz.	THD is typically≤ 3% and phase shift from OUTPUT is typically≤ 5°, 20 Hz to 20 kHz.
Impedance		Nominally 1 kΩ, ground referenced and isolated from main output.
TWIN-TONE TEST SIGNAL		
Signal	LF sine wave from SG 505 Mod WQ oscillator mixed with normal oscillator output in a 1 (±0.5 dB) to 1 amplitude ratio.	The test signal is generated by the SG 505 Mod WQ IMD test oscillator. SYNC OUT signal is low frequency component only.
REAR INTERFACE		
Buffered Main Output		Pins 25A and 26A. To prevent possible instrument damage, do not float output in excess of ±25 V peak. Output impedance is approximately 600 Ω. For specified distortion performance of the front panel main output, the rear interface load impedance must be ≥1 kΩ. This output is intended to provide an ac signal level reference for gain measurements. THD is typically≤ 0.035 for frequencies ≤20 kHz. Pins 25A and 26A are balanced and floating; 25A is inverted from + output, 26A inverted from - output. Signal is attenuated 20 dB and buffered from the actual output signal at the front panel connector.
Twin-Tone Input From SG 505 Mod WQ		Pins 25B and 26B are used to bring modulating tone in from SG 505 Mod WQ.

Table 4.1.2
Miscellaneous

Characteristics	Performance Requirements	Supplemental Information
Power Consumption		15 VA or less.
Internal Power Supplies		
+17 V		Nominally +17.0 V ±3%.
-17 V		Nominally -17.0 V ±5%.
Fuse Data		3 AG, 1 A, 250 V, fast blow.
Recommended Adjustment Interval		1000 hours or 6 months.
Warm-up Time		20 minutes (60 minutes after storage in high humidity environment).

Table 4.1.3
Environmental

Characteristics	Description	
TEMPERATURE		Meets MIL-T-28800C, Class 5.
Operating	0°C to +50°C.	
Non-Operating	-40°C to +75°C.	
HUMIDITY	95% RH, 0°C to 40°C. 45% RH, to 50°C.	Exceeds MIL-T-28800C, Class 5.
BENCH HANDLING	12 drops from 45°, 4" or equilibrium, whichever occurs first.	Meets MIL-T-28800C, Class 5.
PACKAGED PRODUCT VIBRATION AND SHOCK	Qualified under National Safe Transit Association Preshipment Test Procedures 1A-B-1 and 1A-B-2.	
ELECTROSTATIC IMMUNITY	20 kV maximum charge applied to instrument case.	
ELECTROMAGNETIC COMPATIBILITY	Within limits of F.C.C. Regulations, Part 15, Subpart J, Class A; VDE 0871; and MIL-461A tests RE01, RE02, CE01, CE03, RS01, RS03, CS01, CS02, and CS06.	

OPERATING INSTRUCTIONS

CONTROLS AND CONNECTORS

FREQUENCY SELECTION

(1) **FREQUENCY Hz**
Provides continuous frequency selection within each frequency range selected by multiplier push buttons.

(2) **Multiplier Push Buttons**
Select any one of four frequency ranges.

(3) **VERNIER**
Adjusts frequency up to ±1% from selected frequency.

OUTPUT LEVEL SELECTION

(4) **OUTPUT LEVEL dBm Into 600 Ω** ⚠
Selects one of ten amplitude level steps, calibrated in dBm into a 600 Ω load with SOURCE R set to 600 Ω.

(5) **OUTPUT LEVEL CAL**
Provides continuous amplitude adjustment from the calibrated OUTPUT LEVEL steps. Range is nominally +0.7 dB to <-10 dB relative to the clockwise CAL detent.

(6) **SOURCE R**
Selects 50, 150, or 600 Ω source impedance. Impedance to the CT terminal is one-half the selected source impedance.

(7) **TWIN-TONE TEST SIG**
Push button in provides a SG 505 Mod WQ IMD test oscillator sine wave mixed with any selected output frequency in a 1:1 amplitude ratio.

(8) **ON-OFF**
Connects or disconnects the signal to the BALANCED OUTPUT connectors (does not switch CT terminal). The selected source impedance is retained at the BALANCED OUTPUT connectors regardless of push button position.

(9) **GND-FLTG**
GND connects the CT (common) connector to chassis ground through a low impedance. FLTG disconnects the CT (common) from chassis ground for floating operation. Do not exceed ±25 V peak floating potential between the CT connector and chassis ground.

CAUTION

If either SG 505 Mod WR or SG 505 Mod WQ GNDED/FLTG switch is set to GNDED, both instruments are then at ground reference.

OUTPUT CONNECTORS

(10) **BALANCED OUTPUT**
The + BALANCED OUTPUT connector provides a sine wave signal with the frequency selected by the FREQUENCY Hz dial and multiplier push buttons and the amplitude selected by the OUTPUT LEVEL control. The - BALANCED OUTPUT signal is an inverted duplicate of the + BALANCED OUTPUT.

CT

The CT connector provides the reference point for the + and - BALANCED OUTPUTS. The CT connector can be floated above ground or ground-referenced with the GND-FLTG push button (see 9).

(11) **SYNC OUT**
Provides a fixed-amplitude and ground-referenced sine wave at the same frequency as the BALANCED OUTPUT signal. This signal is in phase with the + BALANCED OUTPUT.

(12) **Ground Binding Post**
Chassis ground.

(13) **Release Latch**
Pull to remove plug-in from the power module.

(14) **POWER Indicator**
Indicator lights when power is applied to instrument from power module.

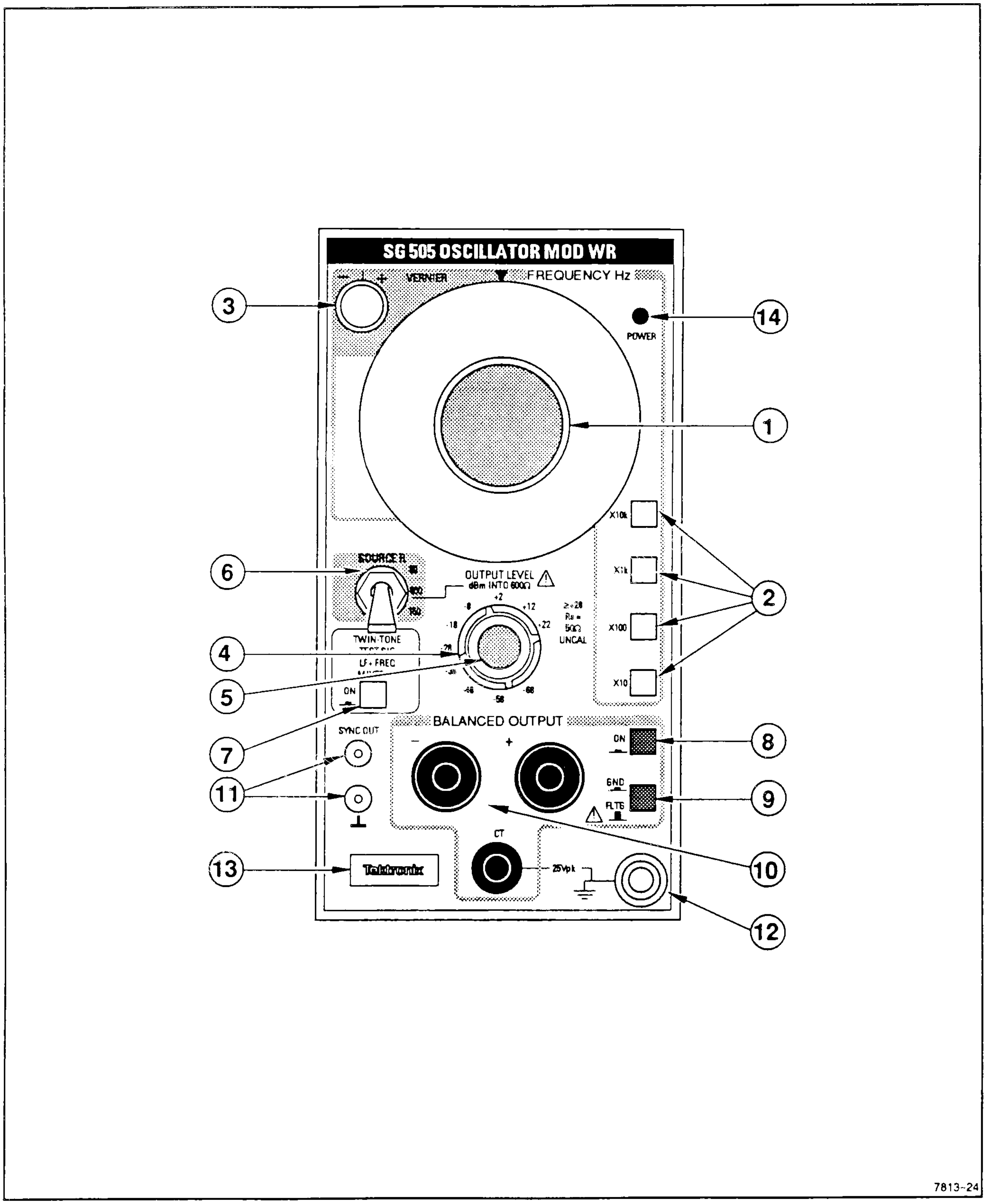


Fig. 4.2.1. SG 505 Mod WR front panel controls and connectors.

OPERATORS FAMILIARIZATION

General Operating Information

With the SG 505 Mod WR properly installed in the power module, allow twenty minutes warm-up time for operation to specified accuracy (60 minutes after storage in or exposure to a high humidity environment).

Frequency Selection

The SG 505 Mod WR produces a sine wave signal at any frequency from 10 Hz to 100 kHz. To set the frequency, press the appropriate multiplier push button and set the FREQUENCY Hz dial to the desired base frequency. The VERNIER control adjusts the frequency 1 percent above and below the frequency selected by the FREQUENCY Hz dial and multiplier push button. With the VERNIER control at the center position, the output frequency produced is the FREQUENCY Hz dial setting multiplied by the active multiplier value. Signals at the BALANCED OUTPUT and SYNC OUT connectors are of the same frequency. The SYNC OUT signal can be used as an external signal for monitoring the frequency of the BALANCED OUTPUT, provided no more than approximately 200 mV rms is required.

Output Level Selection ⚠

The OUTPUT LEVEL selects ten level steps from +22 dBm to −68 dBm into a 600 Ω load with SOURCE R set to 600 Ω. If SOURCE R is set to 50 Ω, the level will increase by about 5.3 dB into 600 Ω. If SOURCE R is set to 150 Ω, the output level into a 150 Ω load is exactly 6 dB higher than the levels marked on the panel. The OUTPUT LEVEL CAL control permits continuous adjustment from the calibrated output level steps over the range of approximately +0.7 dB to <−10 dB from CAL. The signal at the BALANCED OUTPUT connectors may be ground referenced or floated up to 25 V peak, using the GND-FLTG push button. The ON-OFF push button connects or disconnects the signal at the BALANCED OUTPUT connectors.

Twin-Tone Test Signal

With the TWIN-TONE TEST SIG push button in, a SG 505 Mod WQ IMD test oscillator sine wave is mixed with any selected frequency at the OUTPUT connectors in a 1:1 amplitude ratio for intermodulation distortion tests. The composite peak-to peak amplitude is the sum of the two unmodulated output signals.

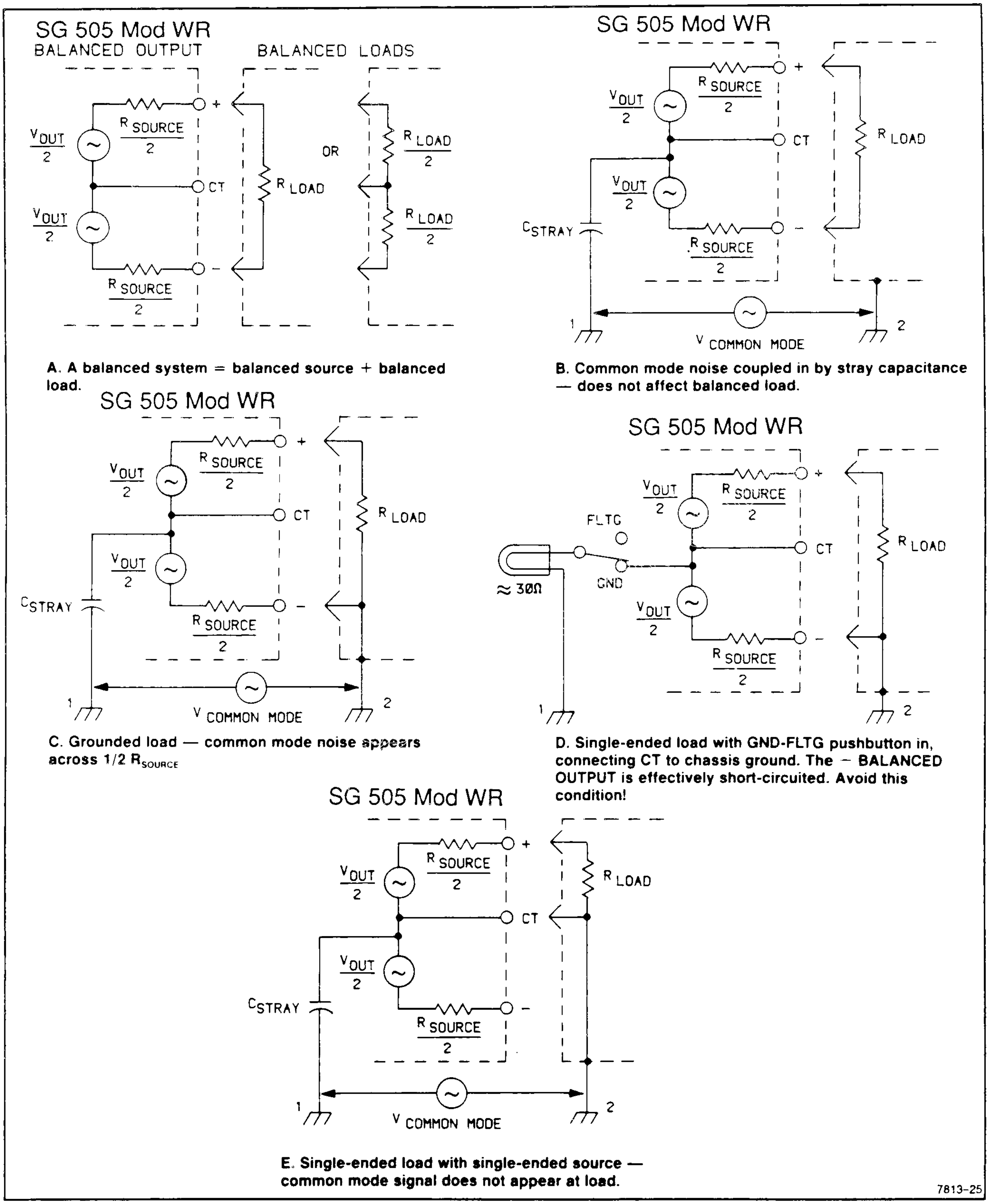
Output Connections

CAUTION

To avoid damage to the SG 505 Mod WR circuitry, do not apply a voltage exceeding ±25 V peak, with respect to chassis ground, to any front panel connector or to rear interface connector pins 14A–28A and 14B–28B.

The SG 505 Mod WR is designed primarily as a balanced source of low distortion sine waves. Thus, it is intended to be used in systems where the load is also balanced or differential. The balanced configuration is preferable in high quality audio applications because of its inherently superior rejection of common mode signals, such as induced hum or RF voltage. See Fig 4.2.2A and 4.2.2B. The SG 505 Mod WR can also be used to drive unbalanced or single-ended loads if the output is taken using either the + or − BALANCED OUTPUT connector as the high side and the CT connector as the low. In this mode, the output voltage and the source resistance are both half the calibrated or selected value. See Fig. 4.2.2E. Driving unbalanced loads from the full balanced output is not recommended because of possible degradation due to common mode signals such as power line hum or noise spikes coupling across one-half of the output resistance. See Fig. 4.2.2C. Even when the SG 505 Mod WR is floating unavoidable stray capacitances within the instrument and those associated with external cabling can cause small amounts of these common mode signals to couple to the load. The coupling magnitude is independent of the oscillator's output attenuation and will become progressively worse as output amplitude is reduced. Thus, the common mode noise may dominate any distortion products in the system, especially at lower output levels. The stray capacitance can also adversely affect high frequency flatness. If the SG 505 Mod WR GND-FLTG push button selects GND in this configuration, then half the output voltage is short-circuited. See Fig 4.2.2D. To minimize the contribution of these common mode signals, it is recommended that the SG 505 Mod WR not be operated in the high power compartment of any TM 500 or TM 5000 series power module. These compartments provide higher power series-pass transistors with substantially higher stray capacitance to chassis, which couples larger amounts of common mode signals into the SG 505 Mod WR.

The GND-FLTG push button either connects the CT connector (common) to chassis ground through approximately 30 Ω or disconnects the CT from chassis ground.



A. A balanced system = balanced source + balanced load.

B. Common mode noise coupled in by stray capacitance — does not affect balanced load.

C. Grounded load — common mode noise appears across 1/2 R_{SOURCE}

D. Single-ended load with GND-FLTG pushbutton in, connecting CT to chassis ground. The – BALANCED OUTPUT is effectively short-circuited. Avoid this condition!

E. Single-ended load with single-ended source — common mode signal does not appear at load.

Fig. 4.2.2. Connection configurations.

Normally the SG 505 Mod WR is floated to break up any ground loops between it and the load. Standard practice is to ground all sources (microphones, etc.) at the unit under test (console, etc.). See Fig. 4.2.3.

Under some conditions, it may be desirable to ground the SG 505 Mod WR CT connector. This may be true in a high RF environment to prevent the CT from floating on RF induced in the output cables. If it is of sufficient amplitude, such RF may otherwise degrade the linearity of the SG 505 Mod WR output stages. The best procedure under high RF environment is to use high-quality shielded cable. Connect the shield to the SG 505 Mod WR CT terminal and a high quality 0.01 to 0.1 μF capacitor connected between the CT terminal and the chassis ground post. The RF is effectively coupled to ground, while at low frequencies the SG 505 Mod WR still floats to break up ground loops. See Fig. 4.2.4. As an alternative, the GND FLTC push button can be pushed to GND with the cable's shield connected to the ground post. Double-shielded cable will improve rejection of RF interference. See Fig. 4.2.5. Under worst-case conditions, use three-conductor twisted, shielded cable (double-shielded is preferred) with the shield connected to the chassis ground post and the three conductors connected to the + and - BALANCED OUTPUT and CT connectors.

Ground the CT wire to the ground of the unit under test (console) and float the SG 505 Mod WR. The popular XLR connector allows this type of connections. See Fig. 4.2.6.

The sine wave at the SYNC OUT connector is in phase with the + BALANCED OUTPUT and is designed for use as an external trigger for a counter, oscilloscope, or other device. This output has a source impedance of 1 kΩ, and is always referenced to chassis ground (even when the BALANCED OUTPUT is floating).

Rear Interface Signals

The front panel BALANCED OUTPUT signal (buffered and attenuated 20 dB) is available at rear interface connector pins 25A and 26A. The signal at these pins is balanced and floating; 25A is inverted from the front panel + BALANCED OUTPUT, and 26A is inverted from the - BALANCED OUTPUT. When the rear interface Buffered Main Output signal is used, the rear interface load impedance (pins 25A and 26A) must be >1 kΩ to prevent OUTPUT amplitude distortion. The ON-OFF and GND-FLTG push buttons affect the rear interface output signal as previously described for the front panel BALANCED OUTPUT signal.

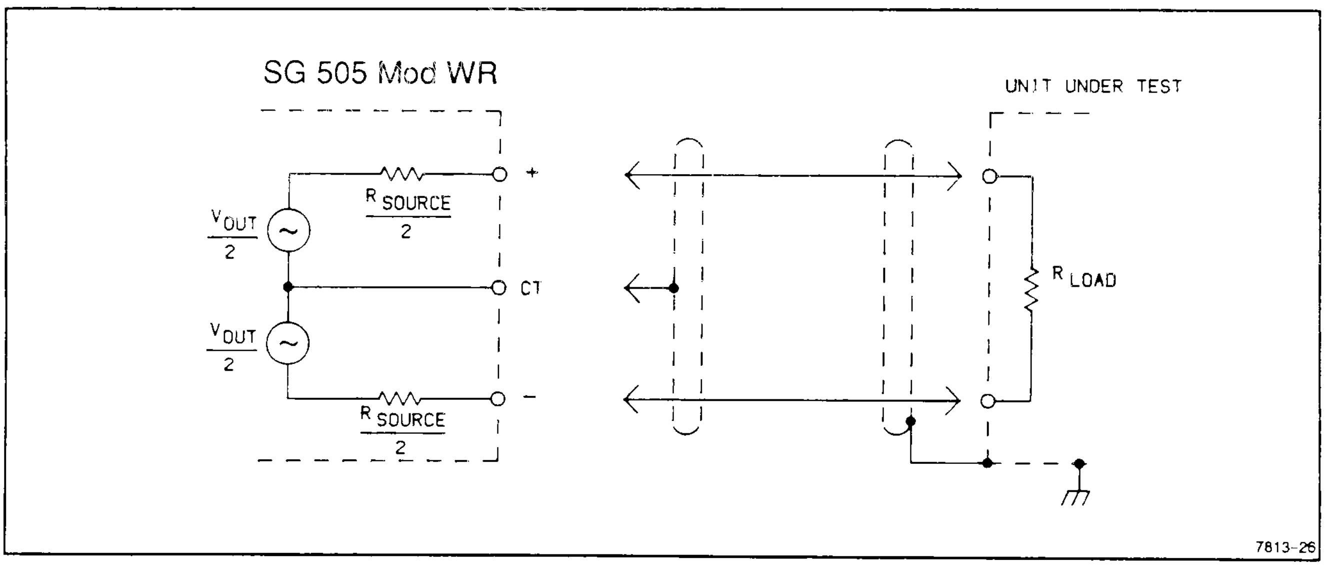


Fig. 4.2.3. Floating oscillator grounded to unit under test to break up ground loops.

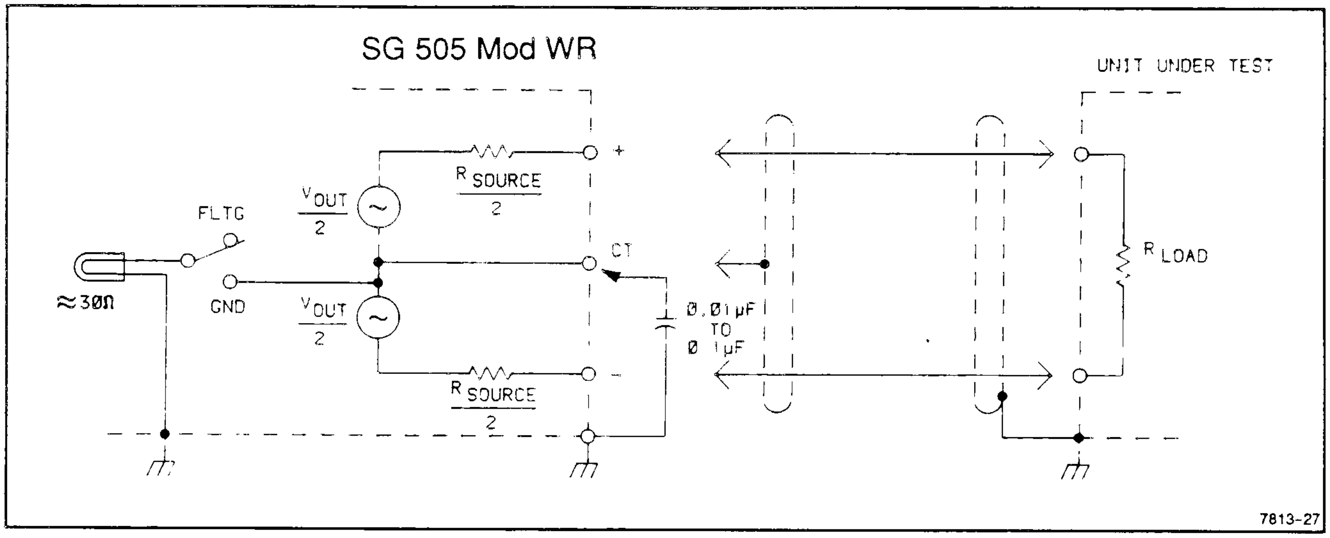


Fig. 4.2.4. Added capacitor between CT and chassis ground improves RFI rejection.

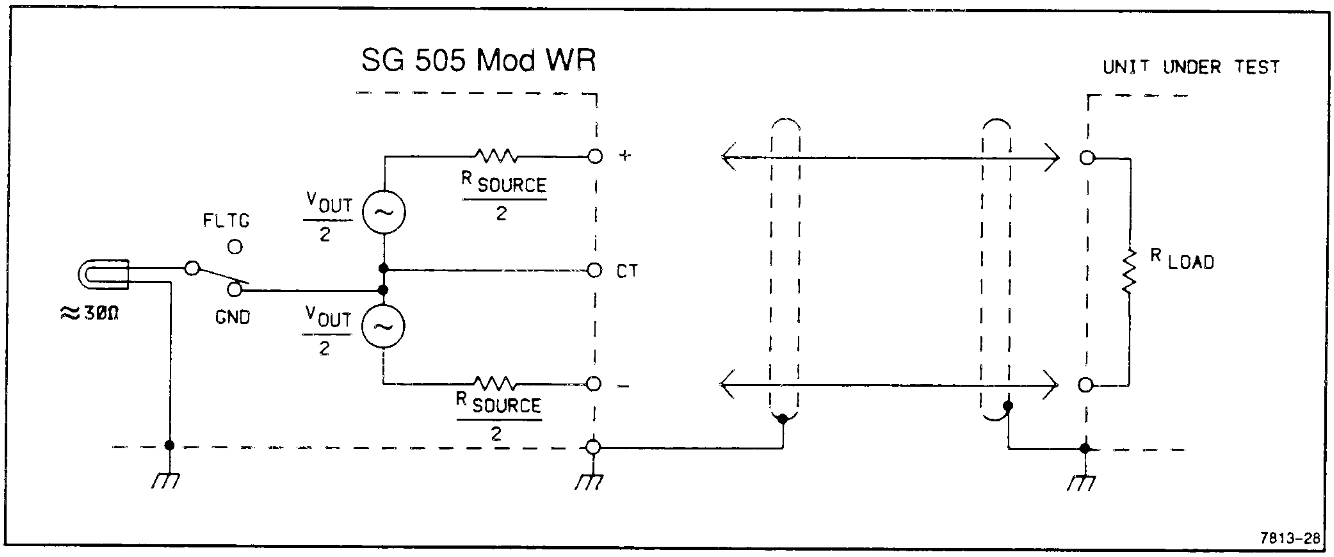


Fig. 4.2.5. SG 505 Mod WR CT terminal grounded and cable shield connected to ground post. Reduces RF interference but may cause low frequency ground loop.

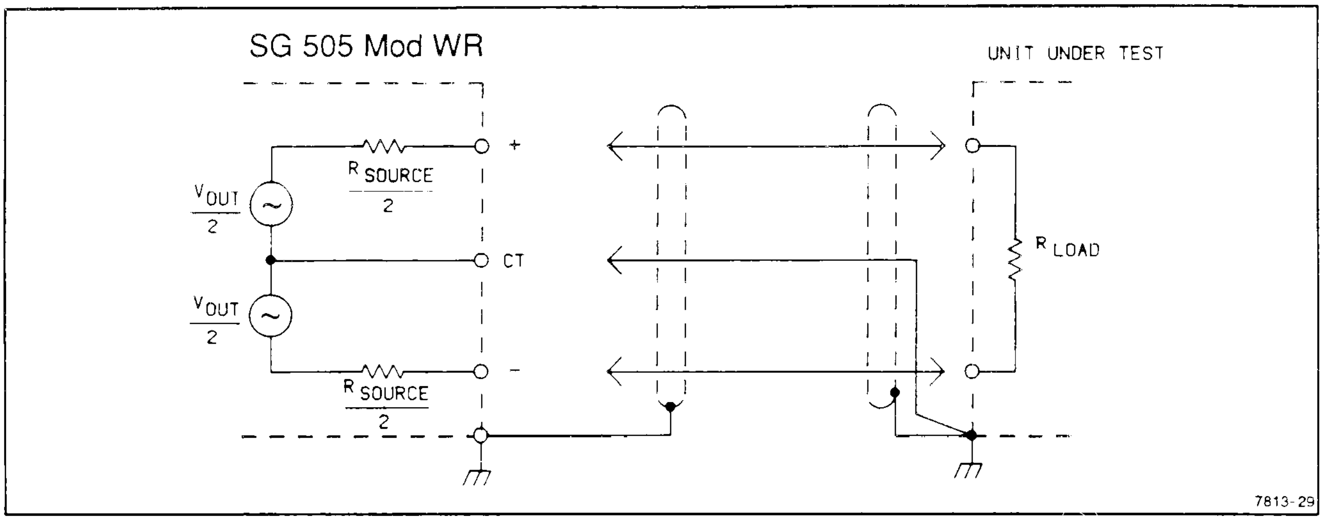


Fig. 4.2.6. Three conductor shielded cable allows CT to be remotely grounded while cable shield is grounded at both ends.

Section 5
TM 504A Mod WQ
Power Module

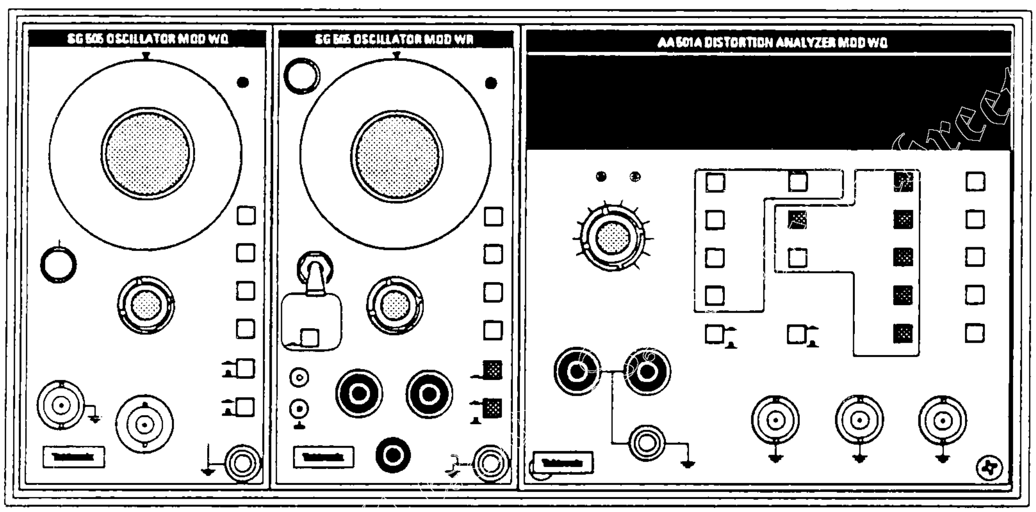


Figure 5.1.1. TM 504A Mod WQ Power Module with Plug-Ins.

SPECIFICATION

INTRODUCTION

Description

The TM 504A Mod WQ is a four-wide power module compatible with all TM 500 plug-ins. It provides unregulated dc and ac supplies and non-dedicated power transistors for plug-in usage. Rear interface connections allow interconnection of signals between plug-ins.

Performance Conditions

The values listed below are valid only when the instrument is operated at an ambient temperature between 0°C and 50°C.

Table 5.1.1
Electrical Characteristics

Characteristics	Performance Requirements	Supplemental Information
SUPPLIES		
+33.5 Vdc		
Tolerance[a]		+23.7 V to +40.0 V.
PARD (Periodic and Random Deviation)		≤2.5 V pp.
Maximum load		350 mA.
Maximum load di/dt		10 mA/μs.
-33.5 Vdc		
Tolerance[a]		-23.7 V to -40.0 V.
PARD		≤2.5 V pp.
Maximum load		350 mA.
Maximum load di/dt		10 mA/μs.
+11.5 Vdc[b]		
Tolerance[a]		+7.6 V to +16.0 V.
PARD		≤2.5 V pp.
Maximum load		
Standard compartment		1.3 A.
High-power compartment		4.0 A.
Maximum load di/dt		20 mA/μs.
25 Vac (2 each)		
Range		25.0 V rms +10%, -15% floating.
Maximum load		
Standard compartment		25 VA.
High-power compartment		60 VA.
Maximum floating voltage		350 V peak.

Table 5.1.1 (cont)

Characteristics	Performance Requirements	Supplemental Information
SUPPLIES (cont)		
17.5 Vac[b]		
Range		With a grounded center tap 20.5 V rms +10%, -20%.
Maximum load		
Standard compartment		30 VA.
High-power compartment		95 VA.
Maximum plug-in power drawn from mainframe[c]		
Standard compartment		35 Wdc or 75 VAac.
High-power compartment		45 Wdc or 125 VAac.
Combined power drawn sharing limitation[c]		
Standard compartment		VAac + 2.1 (Wdc) <75 VAac.
High-power compartment		VAac + 2.1 (Wdc) <150 VAac.
Fuse data		
+33.5 Vdc		2.5 A, 3 AG, fast blow.
-33.5 Vdc		2.5 A, 3 AG, fast blow.
+11.5 Vdc		7.5 A, 3 AG, fast blow.
-11.5 Vdc, high power		5 A, 3 AG, slow blow.
SERIES PASS TRANSISTORS		
Type		One each NPN or PNP per compartment.
Maximum dissipation		
Standard compartment		7.5 W each, 15 W total.
High-power compartment		30 W each, 50 W total.
SOURCE POWER REQUIREMENTS		
Voltage ranges		Selectable 100 V, 110 V, 120 V, 200 V, 220 V, and 240 V nominal line ±10%.
Line frequency		48 Hz to 440 Hz.
Max power consumption		Approximately 320 W.
Fuse data		
100 V, 110 V, 120 V ranges		4 A, 3 AG, slow blow.
220 V, 220 V, 240 V ranges		2 A, 3 AG slow blow.

Table 5.1.1 (cont)

Characteristics	Performance Requirements	Supplemental Information
MISCELLANEOUS		
Maximum recommended plug-in power dissipation		
One-wide		10 to 15 W.
Two-wide		25 to 35 W.

[a] Worst case; low line-full load and high line-no load values including PARD:
[b] Floating in high-power compartment, 350 V peak.
[c] At nominal line voltage.

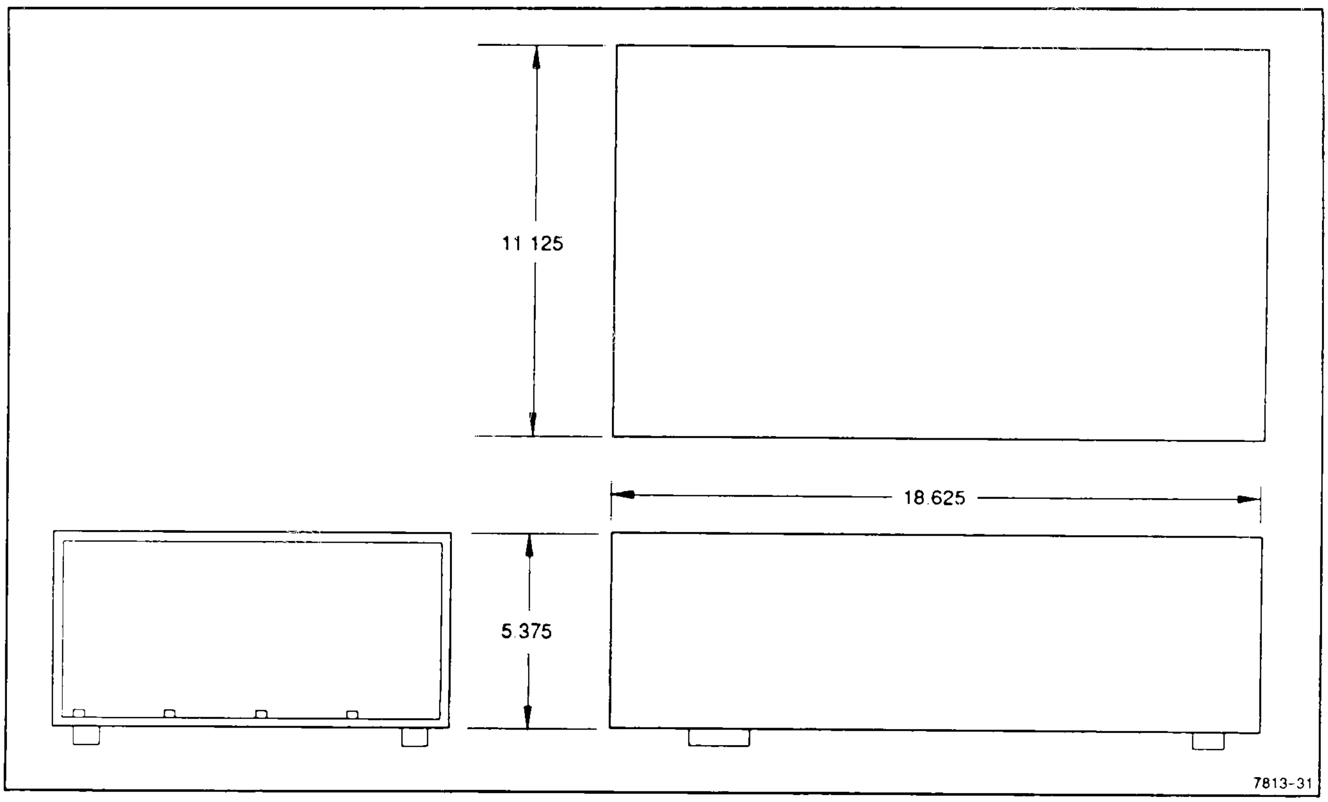


Fig 5.1.2. TM 504A Mod WQ Outline Drawing.

Table 5.1.2
Physical Characteristics

Characteristics	Supplemental Information
ENVIRONMENTAL	
Overall	Meets or exceeds MIL-T-28800B, Class 5 requirements.
Temperature	
Operating	0°C to +50°C.
Non-operating	-55°C to +75°C.
Humidity	90-95% RH for 5 days cycled to +50°C.
Altitude	
Operating	4.6 km (15,000 ft).
Non-operating	15 km (50,000 ft).
Vibration	0.38 mm (0.015"), 5 Hz to 55 Hz, 75 minutes.
Shock	20 g's (1/2 sine), 11 ms, 18 shocks.
Bench handling	45°, 4", or equilibrium, whichever occurs first.
Transportation	Qualified under National Safe Transit Association Preshipment Test Procedures 1A-B-1 and 1A-B-2.
MECHANICAL	
Net Weight	
TM 504A	18.5 lbs (8.4 kg).
Overall dimensions	
TM 504A	5.4 in (13.7 cm) H, 11.1 in (28.2 cm) W, 18.6 in (47.2 cm) L.

OPERATING INSTRUCTIONS

GENERAL

Installation

For full installation instructions refer to the procedure at the end of this section.

Power Source

The TM 504A Mod WQ is designed to operate from a power source with its neutral at or near earth (ground) potential with a separate safety-earth conductor. It is not intended for operation from two phases of multi-phase system.

Power Usage

With four plug-ins installed, the TM 504A Mod WQ may require up to 220 watts at the upper limits of high line voltage ranges. Actual power consumption depends on the particular plug-in configuration and operating modes selected.

High Power Compartment. Some TM 500 series plug-in modules require high power to operate at their maximum capabilities. To meet this requirement the TM 504A Mod WQ has a high power compartment. When viewed from the front this compartment is on the extreme right side of the unit.

Loading Considerations. The power capability of the TM 504A Mod WQ can best be used by carefully planning the plug-in configuration, the external loads, and the resulting power distributions. Optimum conditions may be obtained by:

1. Having equal loads in all compartments.
2. Dissipating as much power as possible in the external loads.
3. Operating the system in an ambient temperature near 25°C.

Each plug-in is provided access to a pair of heat-sinked, series-pass transistors, one NPN and the other PNP. These transistors enable the plug-in to operate in power ranges not possible if the power were to be dissipated in the plug-ins themselves.

Line Voltage Selection/Fuse Replacement

The line voltage selector, fuse, and power switch are all part of the line cord plug assembly, located on the rear of the power module. Verify that the voltage shown in the selector window is correct for the line voltage available.

If the displayed voltage selection is incorrect (the voltage is indicated by the red-marked window) or the fuses need replacement, perform the following procedure. Refer to Fig. 5.2.1.

Fuse Replacement

1. Make certain that the power module power switch (located below the plug-in housing on the front) is turned off and the line cord is not plugged into the line voltage connector.
2. To check or replace the main power fuses, press downward on the tab located on the Line Voltage Selector just above the power cord receptacle. The door will open, and the fuses can be inspected or replaced.
3. Close the door to reconnect the fuse.

Line Voltage Selection

1. Assure that the power module power switch is turned off and the line cord is not plugged into the line voltage connector.
2. See Figure 5.2.1. Press downward on the tab located on the Line Voltage Selector just above the power cord receptacle. this opens the selector door.
3. Using a small screwdriver, gently pry, first on one edge, then the other, to remove the line selector cards. This etched circuit card is approximately 3/4" square and 1/8" thick.
4. Note that on each edge of the selector card there is a red mark, but that the mark is in a different position on the edge.

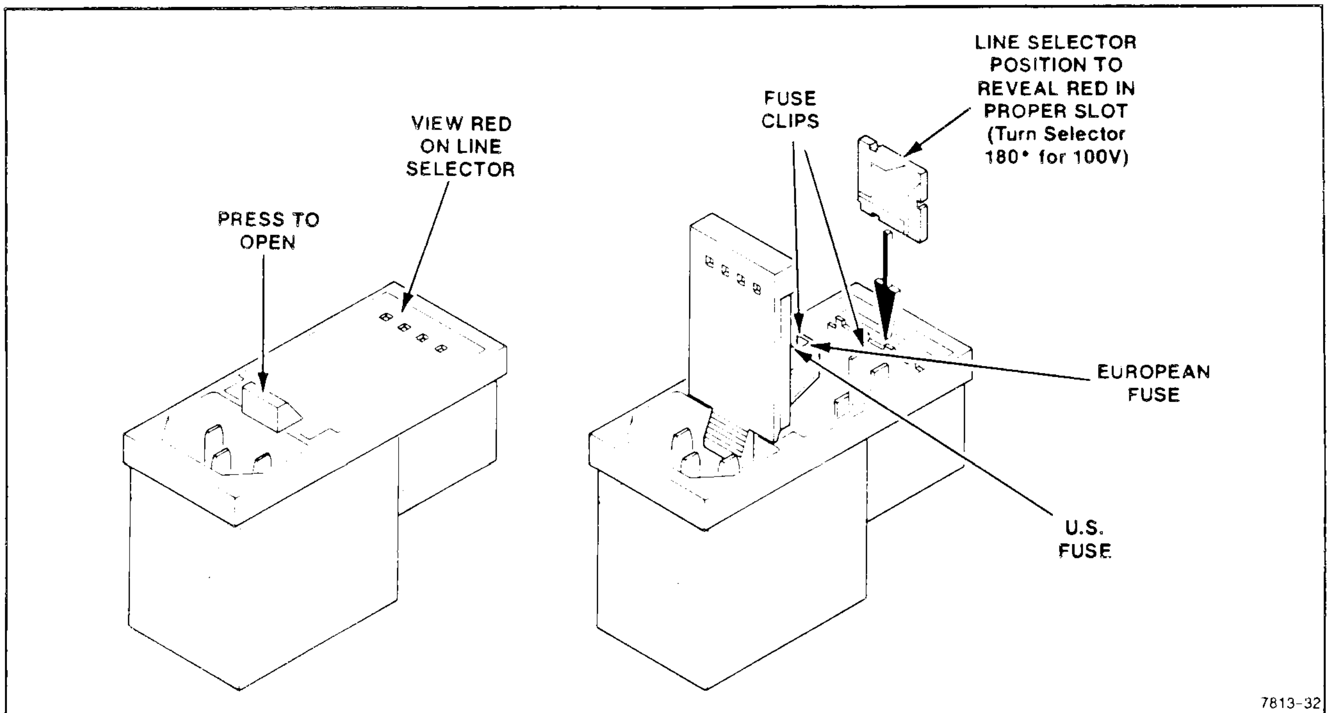


Fig. 5.2.1. Line voltage selection/fuse replacement.

5. Orient the selector card for the desired voltage range, and press the card into its receptacle.

6. Ensure that the installed fuse matches the range selected.

7. Close the selector door. The proper range should show through the correct window.

8. Reconnect the power cord. The TM 504A Mod WQ is ready for use.

Operating Temperatures

The TM 504A Mod WQ can be operated in an ambient air temperature of 0°C to 50°C. Thermal cutout devices protect the system by disconnecting the power to the TM 504A Mod WQ Power Module when internal temperatures rise above a safe operating level. These devices automatically return power to the unit when the internal temperatures return to a safe level.

Since the TM 504A Mod WQ can be stored in temperatures between -40°C and +75°C, allow the instrument's chassis to return to within the operating limits before applying power.

Power Modules

It is not necessary that all the plug-in compartments be utilized in order to operate the Power Module. The only modules needed are those necessary to complete the task.

CAUTION

Turn the Power Module off before inserting the plug-in; otherwise damage may occur to the plug-in circuitry.

Module Installation

1. Check the location of the white plastic barrier keys on the TM 504A Mod WQ interconnecting jack to ensure that their locations match the slots in the edge of the plug-in module's circuit board.

2. Align the plug-in module chassis with the upper and lower guides of the selected compartment. Push the module in and press firmly to seat the circuit board in the interconnecting jack. (Remove the plug-in module by pulling on the white release latch in the lower left corner of each module.)

3. Install the plug-in module retaining bar.

Plug-In Module Retainer Bar Installation

The plug-in module retaining bar is used to ensure that the installed plug-in modules cannot come out of the power module while it is being moved or transported. Note that plug-in modules cannot be removed or inserted with the retainer bar installed.

To install the plug-in module retaining bar, stand the power module on its rear-end. Remove the round-head Phillips screws (holding the top cabinet cover) located on each side of the TM 504A Mod WQ just behind the front casting. Align the holes on each side of the retainer bar with the chassis holes, with the plug-in module retaining bar extending forward and into the module opening, over the bottom edge of the plug-in module. Reinstall the screws.

Turn-On Procedure

After completing the installation procedure, found at the end of this section, and installing the plug-ins, turn on the POWER switch on the TM 504A Mod WQ.

BUILDING A SYSTEM

Family Compatibility

Mechanically, the plug-in modules are very similar to other Tektronix product families. However, they are not electrically compatible. Therefore, the TM 504A Mod WQ interface has barriers on the mating connectors between pins 6 and 7 to ensure that incompatible modules cannot be inserted. See Fig. 5.2.2. A compatible module will have a matching slot between pins 6 and 7 of its main circuit board edge connector. This slot and barrier combination is the primary keying assignment.

INSTALLATION AND PRE TURN ON PROCEDURE

Check the rear panel markings. If the factory settings are compatible with the available line voltage and frequency, remove the plug-in retaining bar from the TM 504A Mod WQ and insert the desired plug-ins. Use the bail to raise the front of the instrument. If a line voltage change is needed, refer a qualified service person to the procedure in the Maintenance section of this manual.

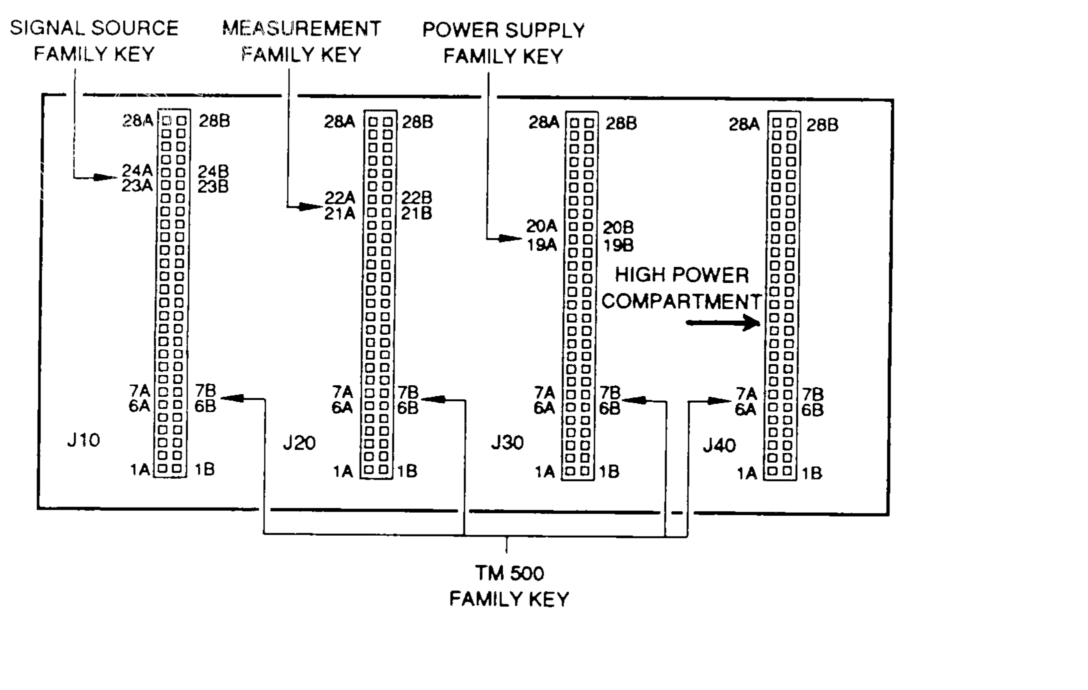


Fig 5.2.2. Keying assignments for family functions. One of many possible sequence combinations.

Section 6
Applications

APPLICATIONS

INTRODUCTION

The AA 501A Mod WQ Distortion Analyzer is fast and easy to operate, yet its features and flexibility make it ideal for very sophisticated, demanding applications. This application note explains how to use the AA 501A Mod WQ and SG 505 Audio Oscillator, plus a number of other Tektronix instruments, to make the more common audio-frequency measurements in a variety of applications.

The AA 501A Mod WQ Distortion Analyzer has a number of features to aid level measurements in all three level modes (VOLTS, dBm, and dB RATIO). It covers a dynamic range of 156 dB, from a maximum of 199.9 V (+48.2 dBm) to a guaranteed noise floor of 3 µV (-108.2 dBm) with the 400-Hz and 80-kHz filters selected. Typical noise levels are 1.7 µV with the AVG detector and 2.4 µV using the RMS detector. Defeating the 80-kHz filters opens the full 300-kHz bandwidth and typically doubles the noise.

The AA 501A Mod WQ has a high impedance, fully differential (bridging, fully balanced) input. Impedance from either side to ground is 100 kΩ. Maximum safe input is 300 V peak or 200 V rms. The common-mode rejection ratio (CMRR) is at least 50 dB at 50 and 60 Hz, typically holding to at least 40 dB at 300 kHz. By rejecting common-mode noise picked up on input cabling, this CMRR permits effective use of the instrument's low input noise and wide dynamic range in typical applications. The maximum common-mode voltage at which the CMRR specifications hold varies as Table 6.1.1 shows.

With no filters selected, the bandwidth of the AA 501A Mod WQ in LEVEL functions typically extends to 330 kHz at -3 dB, and 20 Hz to 20 kHz within 0.1 dB. The 400-Hz highpass, 30-kHz lowpass, and 80-kHz lowpass are three-pole Butterworth filters with their -3dB points at the frequency stated and an ultimate rejection slope of 18 dB per octave (60 dB per decade). The 400-Hz filter thus typically provides 50 dB or more of rejection of 50- or 60-Hz noise generated in the device under test. The fourth filter in the AA 501A Mod WQ is the 'C' MSG filter, meeting the requirements of IEEE 743-1984. The 'C' MSG weighting filter is one of a number of filters that approximate the response sensitivity of the human ear at different frequencies. Signal-to-noise measurements made through the 'C' MSG filter will correlate better with human subjective perceptions than flat-response (unweighted) measurements.

To provide maximum accuracy and correlation to measurements made with older instruments or methods, the AA 501A Mod WQ contains both true-rms and average-responding, rms-calibrated detectors. When a relatively pure sinewave signal is being measured, each detector will give the same result. If significant distortion, noise, or multiple signals are present, only the true-rms detector will give an accurate measurement. However, most audio voltmeters and distortion analyzers have average-responding, rms-calibrated detectors. When you need measurements that will correlate with those made using older instruments, the AVG detector should be used. For a fuller discussion of true rms versus average measurements, refer to Tektronix Note AX-4285, "True Rms Ac Measurements".

Table 6.1.1
Variation of Common Mode Voltage with Input Level

INPUT LEVEL VOLTAGE RANGE	MAXIMUM COMMON MODE VOLTAGE
200	100
60	30
20	10
6	3
2 (and below)	1

When connecting the device or unit under test to the AA 501A Mod WQ, be sure to use shielded cable. Connect balanced-output devices with a shielded, balanced cable (two conductors under shield). The two high conductors connect to the two input connectors of the AA 501A Mod WQ. The shield may be either grounded or floating at either AA 501A Mod WQ input or device output, depending on which yields lower noise. Devices with single-ended outputs are connected by a shielded cable, with the shield going to one of the AA 501A Mod WQ balanced inputs and the high conductor to the other.

Basic Level Measurements

Level, or amplitude, is the fundamental and most common audio measurement. Frequency response, power, gain, loss, signal-to-noise ratio, crosstalk, and separation are examples of level measurements.

Voltage

The VOLTS mode, in LEVEL function, is used to make level or amplitude measurements when the desired units are voltage or power. Select the AUTO RANGING position of the INPUT control and the desired detector and filter (if any). Then connect to the signal and read the result from the digital display. LED indicators to the right of the digits show whether volts, millivolts, or microvolts are being displayed. You can normally use AUTO RANGING for all measurements, but if you need to set the input range manually, rotate the input control until neither the DECREASE RANGE nor INCREASE RANGE indicator is lit.

dBm

Another common expression of level in many professional audio applications is dBm, decibels referred to a power level of one milliwatt in 600 Ω. The dBm mode of the AA 501A Mod WQ is provided for such measurements. Note, however, that the AA 501A Mod WQ input is high-impedance (bridging), not 600-Ω-terminated. Thus, dBm readings will be correct only when the AA 501A Mod WQ is connected across a 600-Ω system or when the user provides a 600-Ω termination when making measurements outside a terminated system. The AA 501A Mod WQ in dBm mode is not a power meter but a dB-reading high-impedance voltmeter whose 0-dB reference s 0.775 V.

dB Ratio

The LEVEL mode likely to be most useful is the dB RATIO mode. This should be used for all relative audio measurements (frequency response, signal-to-noise, gain, etc.) and for dB measurements with any reference other than one miillwatt in 600 Ω.

In dB RATIO mode, the user may establish any present value of signal amplitude as a new 0-dB reference at any time. Simply pressing the "PUSH TO SET 0 dB REFERENCE" button causes the display to go to 0.0 dB, an internal register to store the signal amplitude, and all future readings then to be made in dB above or below that reference until either the button is pressed again or power is removed from the AA 501A Mod WQ. Changing to another mode or function will not change a previously-stored reference.

Harmonic Distortion (THD + N)

Harmonic distortion measurements are made using the input and voltmeter sections of the instrument previously described, plus automatic set-level and automatic notch-filter circuitry. Harmonic distortion is created by nonlinearities in a device under test that cause it to generate harmonics (integer multiples) of an applied input signal. Fig. 6.1.1 shows in frequency-domain representation how a nonlinear device will add harmonic distortion to a pure sine-wave input signal. The AA 501A Mod WQ and other distortion analyzers eliminate the fundamental component with an extremely sharp rejection filter and then measure the residual components with a voltmeter. Fig. 6.1.1 also shows the block diagram of the analyzer. Since the voltmeter is a wide-band device and only the fundamental frequency has been notched out, any broad-band noise or discrete interference such as ac power-supply ripple from the device under test will also be measured. Thus, the THD + N (Total Harmonic Distortion plus Noise) terminology selected by the Institute of High Fidelity (IHF) in 1978, is used to distinguish distortion analyzer measurements from those made by a series of individual harmonic-amplitude measurements with a selective voltmeter, followed by a root-sum-square calculation. Older distortion analyzers do not carry the TDH + N terminology but they operate in the same way. Making harmonic-distortion measurements with the AA 501A Mod WQ Distortion Analyzer is simplicity itself. Select input AUTORANGE THD + N function, distortion AUTO, connect the signal, and read the digital display. The AA 501A Mod WQ will automatically establish a 100-percent set-level reference on any input-signal amplitude between 60 mV and 200 V (70 dB dynamic range), automatically null out any fundamental frequency between 10 Hz and 100 kHz (four-decade frequency range), automatically autorange its digital voltmeter to 100%, 20%, 2%, or 0.2% full-scale for best resolution, and digitally display the result. Typical settling times are 5 seconds or less for a complete measurement with the maximum 7 seconds required at low fundamental frequencies and at extremely low distortion levels. You can alternately display distortion in dB below fundamental, instead of percentage, by selecting the dB button below the 0.2% button.

This full automation does not require any "cooperative" signal source, unlike semi-automatic analyzers that incorporate the oscillator into the same unit and use the oscillator to pretune the analyzer. Thus, the AA 501A Mod WQ provides fully automatic hands-off measurements regardless of whether the test signal comes from a local SG 505 Audio Oscillator, the user's previous or experimental oscillator, a network or satellite feed, or a previously recorded test tape or disc.

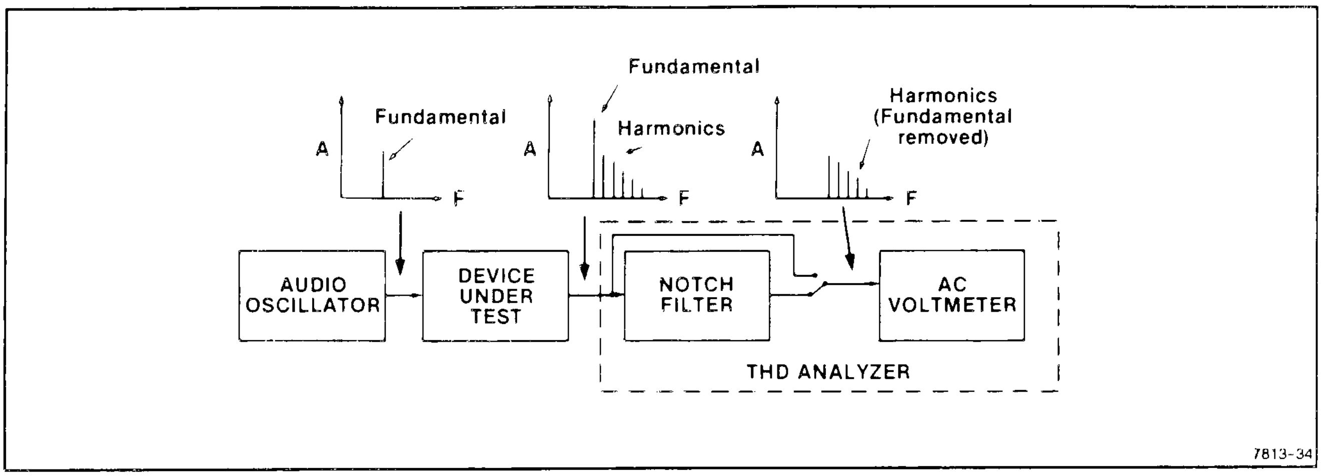


Fig. 6.1.1. Harmonic distortion added by device under test is measured with THD analyzer.

For real accuracy in THD + N measurements the true-rms detector should always be used since the signal after the notch filter typically consists of several harmonics plus broad-band noise. The average-responding, rms-calibrated detector typically shows readings 1 to 2 dB lower; its use is required when it is necessary to correlate measurements to specifications based on the use of earlier instruments with average-responding detectors.

You can improve accuracy at low device-distortion levels by properly selecting filters since the broadband noise component often then becomes the limiting item. The 80-kHz low-pass filter is typically used when the fundamental frequency is 20 kHz or below, since it will still pass second, third, and fourth harmonics while significantly reducing the effect of wide-band noise. Similarly, you can safely select the 30-kHz filter when the fundamental frequency is below approximately 7 kHz. The 400-Hz high-pass filter will help reject the distortion-masking effect of power-line-related hum due to inadequate shielding or power-supply filtering in the device under test, but it should not be used with fundamental frequencies below about 500 Hz.

While the AA 501A Mod WQ will automatically make THD + N measurements on any signal amplitude above 60 mV, the results may be limited (depending on device-distortion levels) by internal noise in the AA 501A Mod WQ unless the signal amplitude is at least 250 mV (see Fig. 6.1.2). Above 250 mV, with fundamental frequencies between 20 Hz and 20 kHz, and with the 80-kHz filter selected, typical residual distortion and noise levels of a complete SG 505-AA 501A system are 0.0012% to 0.0016% with AVG detector, and 0.0015% to 0.0022% with true-rms detector (see Fig. 6.1.3). Selecting the 30-kHz filter further reduces noise, in many cases producing AVG-detector typical residual levels below 0.001 %.

Intermodulation Distortion

Another way to measure the effects of device nonlinearity is to use intermodulation distortion (IMD) testing. In such testing, two or more discrete test tones are applied simultaneously to the device input and the products resulting from the mixing action of nonlinearities are measured. Several popular techniques exist. The F7523A1 Mod WQ test system automatically provides this capability through the Twin-Tone function.

SMPTE and DIN

The Society of Motion Picture and Television Engineers (SMPTE) and the Deutsches Institut fur Normalizung (DIN) have promulgated two similar intermodulation distortion standards. Both (see Fig. 6.1.4) use a two-tone test signal comprised of a low-frequency tone four times the amplitude of a high-frequency tone. In the SMPTE standard, the tones are 60 Hz and 7 kHz. The DIN standard permits a number of harmonically related pair choices, 250 Hz and 8 kHz being the most common. Device nonlinearities will produce low-frequency modulation sidebands around the high-frequency signal, as shown in the figure. Fig. 6.1.4 also shows the simplified block diagram of the AA 501A Mod WQ when measuring SMPTE, DIN, or Twin-Tone IMD. A high-pass filter eliminates the low-frequency tone, an am demodulator recovers the side-bands, and a calibrated voltmeter measures their amplitude.

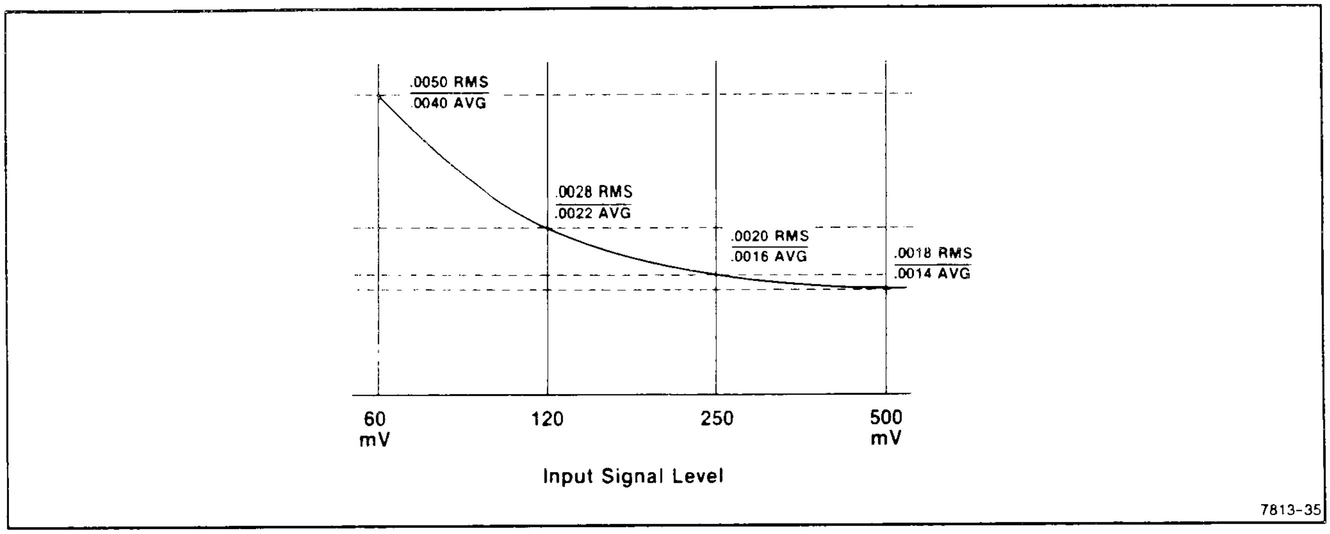


Fig. 6.1.2. Typical noise limitation to THD + N reading (with 80-kHz filter selected).

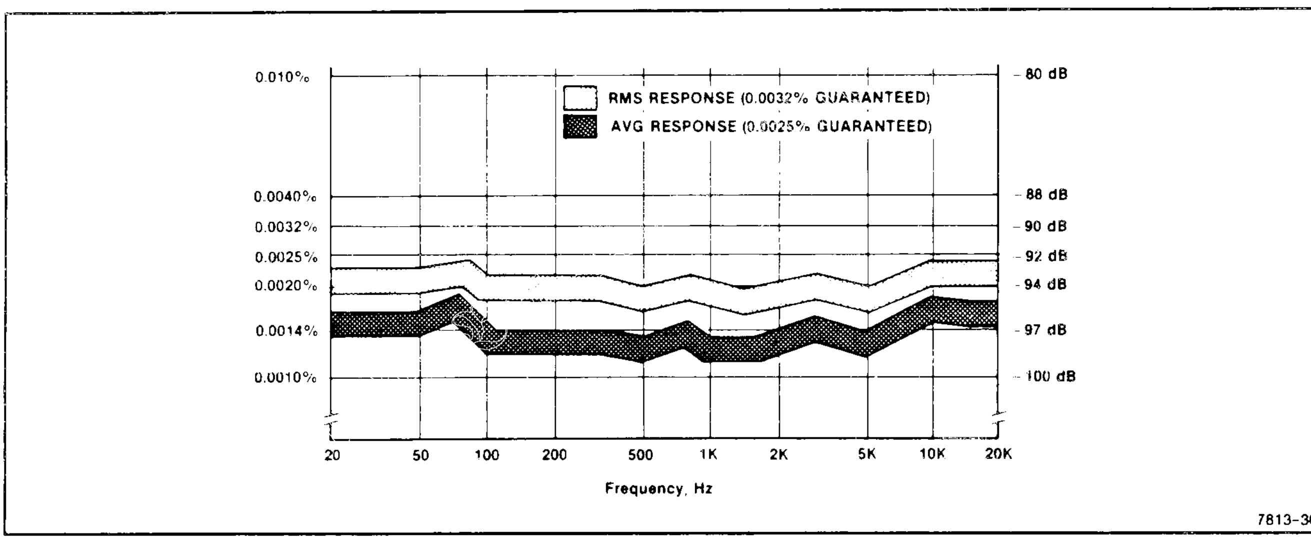


Fig. 6.1.3. Typical Residual THD + Noise AA 501A/SG 505 System (V input> =250 mV with 80-kHz-Noise-Limiting Filter).

To perform SMPTE and DIN tests using the F7523A1 Mod WQ, it is necessary to manually set the test tones and mix them externally. The SG 505 Mod WQ should always be used to set the lower frequency tone. For example, to generate a SMPTE test using 60 Hz and 7 kHz tones, the following procedure may be used:

Adjust the frequency dial on the SG 505 Mod WR to 7, and press the X1K range push button. Connect the output of the SG 505 Mod WR oscillator to the input of the AA 501 A Mod WQ, and press the LEVEL push button on the AA 501A Mod WQ. Adjust the SG 505 Mod WR OUTPUT LEVEL controls for a convenient level, such as 1.00 Volt. Disconnect the SG 505 Mod WR from the AA 501 A Mod WQ.

Next, adjust the frequency dial on the SG 505 Mod WQ to 6, and press the X10 range push button. Connect the output of the SG 505 Mod WQ oscillator to the input of the AA 501A Mod WQ, and verify the LEVEL push button on the AA 501A Mod WQ is still depressed. Adjust the SG 505 Mod WQ OUTPUT LEVEL controls to exactly four times the level measured from the SG 505 Mod WR, in this example, 4.00 Volts. Disconnect the SG 505 Mod WQ from the AA 501A Mod WQ.

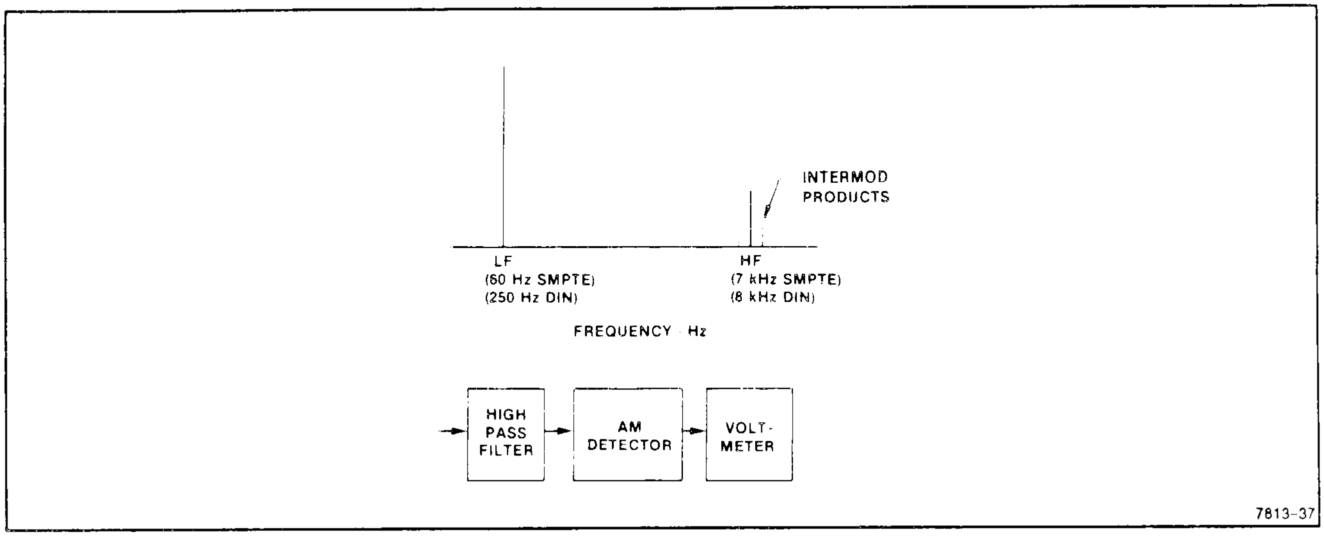


Fig. 6.1.4. SMPTE or DIN Intermod test.

Connect a "T" connector to the input of the device under test. Connect the output of the SG 505 Mod WR to one branch of the "T" connector, and the output of the SG 505 Mod WQ to the other branch. Connect the output of the DUT to the input of the AA 501A Mod WQ and turn on both SG 505 oscillators. You are now ready to make SMPTE IMD distortion tests.

While mixing tones in this manner, be sure both SG 505 test signal generator outputs are in the same mode; that is, both FLTG/GND switches must be in the same position. Mismatched push button positions will not damage the test equipment, but may result in unexpected or erroneous test results. Also, the SG 505 Mod WR must be set to the 600 Ω position to ensure proper amplitude mixing of the tones.

Twin-Tone

To perform Twin-Tone Intermodulation testing, both the SG 505 Mod WR and SG 505 Mod WQ must be used, but manual level setting and external mixing is not necessary. Push the TWIN-TONE TEST SIG push button in on the SG 505 Mod WR to automatically activate this function. In this mode, the SG 505 Mod WR provides the high frequency tone, and the SG 505 Mod WQ provides the low frequency tone. The frequencies of the tones are set by the operator using the respective SG 505 front panel controls. The tones are automatically mixed as equal peak-to-peak voltage amplitudes (1:1 ratio), and are available at the SG 505 Mod WR output.

When in the Twin-tone Test mode, be sure both SG 505 test signal generator outputs are in the same mode; that is, both FLTG/GND switches must be in the same position. Mismatched push button positions will not damage the test equipment, but may result in unexpected or erroneous test results.

Operation of the AA 501A Mod WQ in Twin-Tone IMD testing is as simple as THD testing; select AUTO input, IMD mode, and AUTO display, then read the result. The 400-Hz filter should not be used; the 80-kHz or 30-kHz filters will have little effect, since the voltmeter's measurement bandwidth is already narrow due to low-pass filtering after the am demodulator. Dynamic range for auto-set level is the same 60-mV to 200-V range as in THD + N mode.

CCIF Difference Tone (IHF-IM)

The Twin-Tone Test can be used for the CCIF test, shown schematically in Fig. 6.1.5. Two equal-amplitude closely spaced signals are fed to the device under test. If asymmetric nonlinearities exist, a second-order difference product will be produced at the low-frequency signal equal to their spacing. To make this measurement requires a low-pass filter followed by a voltmeter, as provided by the AA 501A Mod WQ. The AA 501A Mod WQ will automatically measure the amplitude of the difference tone.

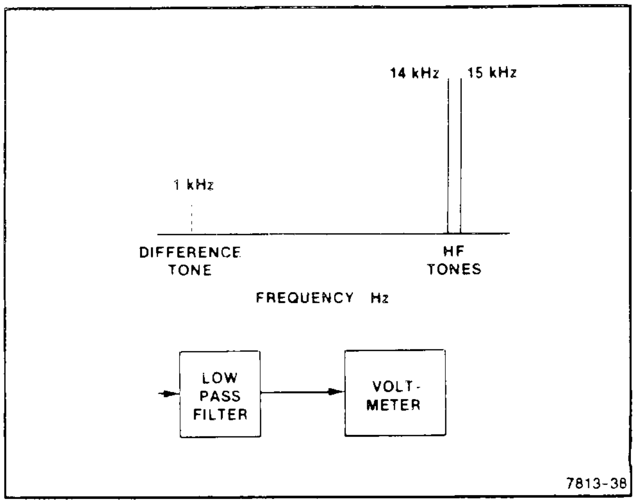


Fig. 6.1.5. CCIF intermod test.

Switching between the two IMD block diagrams – SMPTE or DIN on the one hand and CCIF on the other – is done automatically within the AA 501A Mod WQ. The instrument compares the amplitudes of the low-frequency (below 1 kHz) and high-frequency (above 1 kHz) energy in the input signal to decide which type of test is being made. If the low-frequency amplitude is at least equal to the high-frequency amplitude, the instrument assumes a SMPTE or DIN test and operates relays to set up the block diagram of Fig. 6.1.4. If the low-frequency energy is at least 14 dB below high-frequency energy, the AA 501A Mod WQ assumes the CCIF standard (with no more than 20% IMD) and operates relays to set up the Fig. 6.1.5 diagram. If this automatic sensing and changeover are undesirable for any reason, a three-position internal jumper can be moved to either the SMPTE/DIN position or CCIF position instead of the AUTO position.

Make Common Audio Measurements Easier

While the preceding text covers all the standard, built-in modes and features of the AA 501A Mod WQ, the following discussion provides additional insight into how to perform many commonly made audio measurements in the fastest and easiest manner.

Power

Audio power measurements are performed by measuring the voltage across a known load resistor and calculating power from $P = V^2/R$.

Fig. 6.1.6 provides quick voltage-power conversions for the three common loudspeaker impedances of 4, 8, and 16 Ω. When the signal is a clean sinewave, either AVG or RMS detectors may be used. Filters are not normally used during power measurements. Often, you may want to measure power exactly at the clipping point of an amplifier; the oscilloscope monitoring section of this note describes an extremely sensitive method to determine clipping threshold.

Decibels

One standard reference for decibel measurement is built into the AA 501A Mod WQ. Selecting dBm provides dB scaling and a reference (0 dB) value of 0.775 V, which is 1 mW in 600 Ω. As noted previously, the AA 501A Mod WQ always has a high-impedance (bridging) input and the user must assure that a 600-Ω termination is externally provided for dBm calibration to be correct.

For those who prefer decibels referred to one volt (dBV), the dBm button can be converted to dBV by connecting a jumper between pins 8 and 9 on J1600 on the logic board.

To measure dBV or dB to any other reference value without modifying the instrument, you may use the dB RATIO mode. First, determine the voltage corresponding to the desired reference; table 2 shows a number of common references. Connect the SG 505 Mod WR or any variable-amplitude audio oscillator to the AA 501A Mod WQ input; select LEVEL and VOLTS mode and adjust the oscillator amplitude for the desired reference voltage. Then select dB RATIO mode and press the PUSH TO SET 0 dB REFERENCE button. The dB RATIO mode will now be calibrated to read dB with respect to the new reference until either the power is removed from the AA 501A Mod WQ or the PUSH TO SET ... button is pressed again.

Gain and Loss

Two different philosophies exist for measuring gain: voltage gain and transducer gain.

Voltage gain is the ratio of signal voltage at the output to the signal voltage at the input of a device. To measure voltage gain, connect the output of the SG 505 Mod WR to the input of the AA 501A Mod WQ. Select the LEVEL mode on the AA 501A Mod WQ and adjust the SG 505 Mod WR to the recommended level compatible with the input of the DUT. Next, select the dB mode on the AA 501A Mod WQ, and push the PUSH TO SET 0 dB push button. Now connect the output of the DUT to the input of the AA 501A Mod WQ. The AA 501A Mod WQ will now directly display the DUT voltage gain or loss in dB.

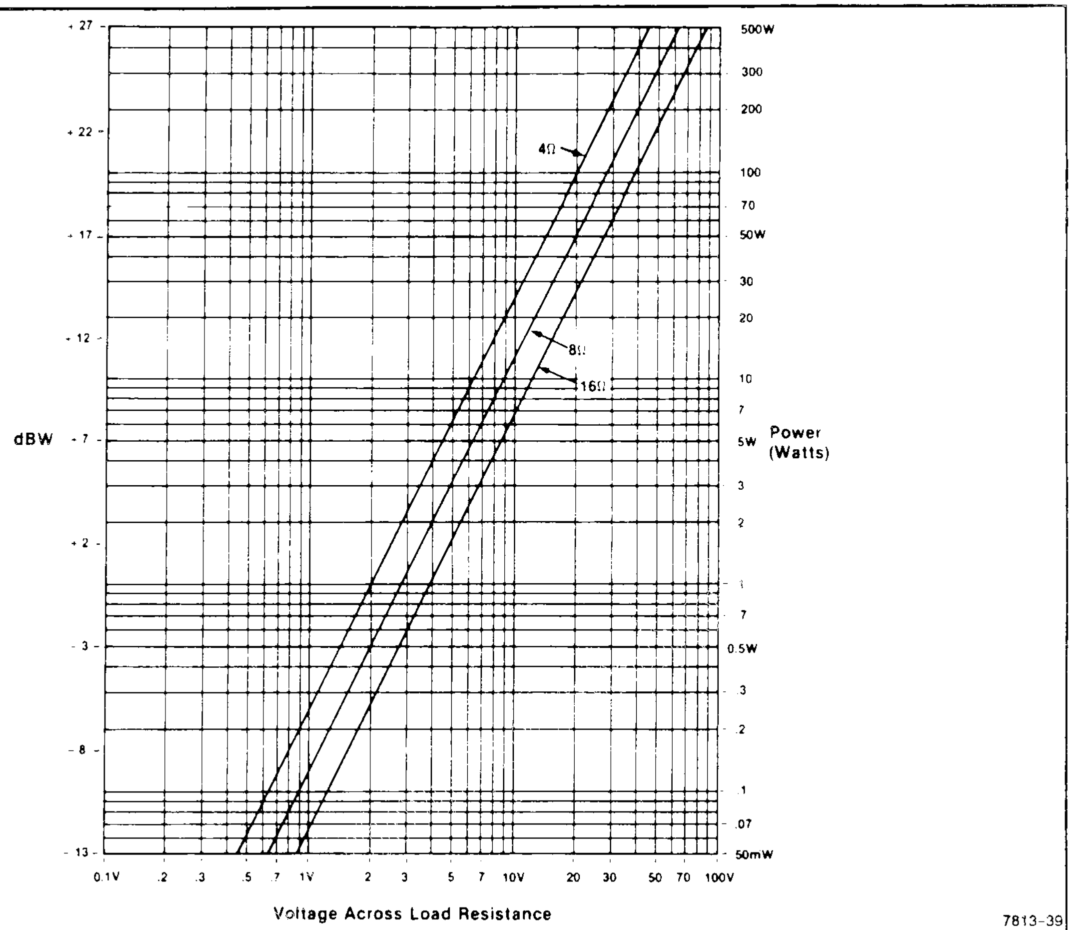


Fig. 6.1.6. Voltage across load versus power (watts or dBW).

Table 6.1.2
0 dB Reference Voltages

Reference Level	Voltage of 0 dB Reference
1 volt (dBV)	1.000 V
1 mW in 600 Ω	0.775 V
6 mW in 600 Ω	1.897 V
1 mW in 150 Ω	0.387 V
6 mW in 150 Ω	0.949 V
1 mW in 50 Ω	0.224 V
6 mW in 50 Ω	0.548 V

Transducer gain is the ratio of power delivered to a specific load impedance, to power available from a source of specific impedance. As in a voltage gain measurement, adjust the SG 505 Mod WR oscillator for the frequency and device output amplitude desired. Disconnect the oscillator output from the device input; terminate the oscillator with a precise 600-Ω load, and connect it to the AA 501A Mod WQ input. Select dB RATIO and press the PUSH TO SET ... button. Remove the termination and reconnect the oscillator to the device input. Connect the device output (terminated in 600 Ω) to the AA 501A Mod WQ input. The AA 501A now displays transducer gain. The oscillator frequency can be changed to any other frequency and transducer gain measured directly, since the SG 505 Mod WR flatness is within 0.1 dB.

Note that the transducer gain technique and voltage gain technique will give identical measurements if the device input is truly a 600-Ω resistance.

Frequency Response

No filters should be selected during a frequency-response measurement of an external device. To measure frequency response on a transducer response basis, set the SG 505 Mod WR to 1 kHz or other appropriate midband reference frequency. Connect the SG 505 Mod WR output to the device input and the device output to the AA 501A Mod WQ. In one of the two absolute LEVEL modes, VOLTS or dBM, adjust the SG 505 Mod WR amplitude and/or device gain controls to obtain the output level from the device at which response is to be measured. Select dB RATIO mode and press the PUSH TO SET 0 dB REFERENCE button. The SG 505 Mod WR can now be changed to any desired frequency and frequency response can be read directly from the AA 501A Mod WQ. The 'Spectrum Analyzer Driven From AA 501A Mod WQ INPUT MONITOR Connector' section, described later in this application, explains the technique for a swept, stored frequency response measurement.

The AA 501A Mod WQ and SG 505 Mod WR flatness (as a system) is typically 0.1 dB from 20 Hz to 20 kHz.

For frequency response measurements on the voltage basis (zero source impedance) the SG 505 Mod WR amplitude must be readjusted when necessary to provide a constant input voltage across the device terminals.

Both the voltage technique and the transducer technique of measuring frequency response will produce exactly the same relative response if the device input is purely resistive, or if any shunt reactive component remains approximately two or more orders of magnitude above the oscillator output impedance across the frequency range.

Signal-To-Noise Ratio (S/N)

Signal-to-noise measurements are extremely simple using the dB RATIO mode and autoranging feature of the AA 501A Mod WQ with the SG 505 Mod WR output OFF-ON switch. Adjust the SG 505 frequency and amplitude to provide the device output desired as the S/N reference. Select dB RATIO mode; press the PUSH TO SET ... button, and then press the SG 505 Mod WR OFF button. This disconnects the oscillator and back-terminates the SG 505 Mod WR output connector with a 600-Ω resistor. The AA 501A Mod WQ will directly display the device S/N ratio. If an 'C' MSG or low-pass-filtered measurement is preferred select the appropriate filter and read the display. Any other desired psophometric filter could be provided via the external-filter capability. For more information, see the section on user-supplied external filters.

If absolute noise measurements are required instead of S/N ratio, use the VOLTS or dBm modes and the SG 505 Mod WR OFF button. It is sometimes necessary to express noise in terms of equivalent device-input noise rather than output noise. This is done by making an absolute-output-noise measurement, a voltage gain measurement, and dividing the output-noise voltage by the device-voltage gain.

Harmonic Distortion Versus Frequency

When characterizing a device or system, it is common to measure distortion at a number of spot frequencies across the band, all at a constant output voltage or power level from the unit under test. Use the following procedure to make such measurements. Set the SG 505 Mod WR frequency to a midband reference such as 1 kHz. Then adjust its amplitude to provide the desired device reference output across a specified load, using the AA 501A Mod WQ in LEVEL and as appropriate, in either VOLTS or dBm mode. Select dB RATIO and press the PUSH TO SET ... button. Select THD + N and read the distortion. Now, select each new frequency desired for a distortion measurement. At each frequency, select dB RATIO mode and, if necessary, adjust the SG 505 Mod WR output amplitude for a 0.0 dB reading (no adjustment will be necessary if the device has a flat frequency response). Then, select THD + N and read distortion.

Some power amplifiers and am transmitters will not withstand continuous sine-wave power output at or near their maximum ratings. In such a case, either the SG 505 Mod WR output OFF-ON switch or step attenuator may be used to eliminate or reduce signal levels and permit cooling of the device between short tests, yet allow a quick return to the desired test level for a quick THD + N test.

Continuously swept distortion tests are not practical with the AA 501A Mod WQ, since it tunes in frequency bands and requires several seconds to settle after each automatic band switching.

Distortion Versus Power or Voltage

Another common way to characterize a device is by a series of distortion measurements at a single frequency (usually midband), but across the entire dynamic range of the device. This technique is particularly important when you are looking for amplifier-crossover distortion or other problems occurring at low levels rather than at a device's maximum output.

At the selected frequency, drive the device to maximum rated out-put across the specified load, measuring with the AA 501A Mod WQ in LEVEL and in either VOLTS or dBm mode. Select dB RATIO, press the PUSH TO SET ... button, select THD + N, and measure the distortion. Select dB RATIO again and reduce the SG 505 Mod WR output until the next lower level at which distortion is to be measured is indicated in dB. For example, if readings are to be made at maximum power and then at 2:1 power reductions below that, readings will be taken at -3.0 dB, -6.0 dB, -9.0 dB, etc. As each new level is established, select THD + N and read the distortion. Since distortion typically increases rapidly near maximum power, it may be desired to make several 1 dB reductions first and then go to larger steps. If only a few quick measurements across a wide dynamic range are needed, the step attenuator of the SG 505 Mod WR permits 10 dB changes without use of the variable control. The lower limit of dynamic range is set by the AA 501A Mod WQ 60-mV minimum requirement for set level corresponding to power levels of 0.9 mW, 0.45 mW, and 0.225 mW respectively across 4-, 8-, and 16-Ω loads.

Distortion and Response Versus Frequency At Constant Modulation Percentage

In the broadcasting industry, regular proof-of-performance tests are required to assure that adequate audio quality is being delivered to listeners. Each station normally has an accurate modulation monitor that not only measures percent modulation, but delivers a low-distortion (and de-emphasized, in the case of frequency-modulation broadcasting) output for connection to a Distortion Analyzer such as the AA 501A Mod WQ.

Two slightly different procedures are used, depending on whether the studio and modulation monitor are at the same location (within convenient audio-cable run distances) or at separate sites. Where studio and modulation monitor are at the same site, the connection shown in Fig. 6.1.7 is used. Defeat or bypass any non-linear audio processing equipment in the chain. Connect the SG 505 Mod WR output to the principal microphone input jack, and connect the modulation monitor output to the AA 501A Mod WQ input (see Fig. 6.1.7). After adjusting microphone gain controls and SG 505 output amplitude for approximately 25% modulation with the AA 501A Mod WQ in THD + N mode, determine whether the GND or FLOATING connection of the SG 505 Mod WR results in the lowest distortion and noise product. Use whichever is lowest.

At midband (usually 1 kHz), adjust the SG 505 Mod WR amplitude until the modulation monitor indicates exactly 100%. Select LEVEL and dB RATIO; press the PUSH TO SET ... button, select THD + N and record the distortion value. Record a 0.0 dB value for relative frequency response. At the same frequency, reduce the oscillator amplitude to obtain the next lower required modulation percentage (usually 85%) on the monitor. Select LEVEL and record the dB reading; select THD + N and record the distortion reading. A complete run normally consists of oscillator level and THD + N readings at four modulation percentages (usually 100%, 85%, 50%, and 25%) and at a number of frequencies across the audio band.

Distortion graphs may be plotted directly from the data. Frequency response graphs require all algebraic signs to be interchanged on the level readings (plus/minus, minus/plus), since a fall-off in station frequency response requires an increase in oscillator level to obtain a constant modulation percentage.

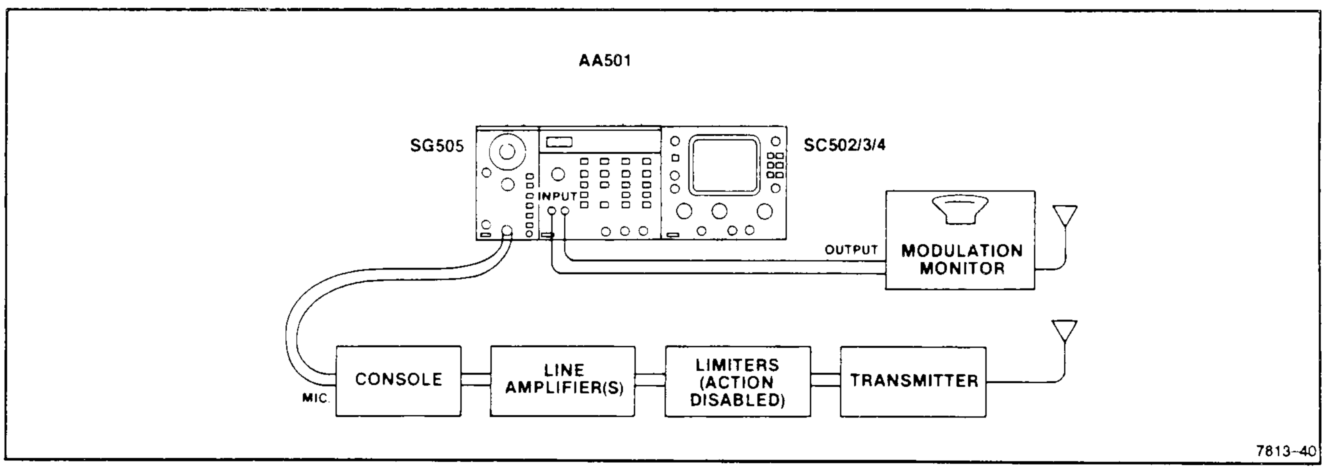


Fig. 6.1.7. Interconnection diagram for distortion and response vs frequency measurements.

A separated studio and transmitter set-up requires two test-equipment packages: an oscillator, a level meter, and (possibly) a frequency counter at the studio, and the AA 501A Mod WQ Analyzer at the transmitter site. Fig. 6.1.8 shows two variations on the "send" package at the studio. One uses a DM 502A auto-ranging, dB-reading multimeter as a digital-readout level meter continuously bridged across the SG 505 Mod WR output. The other uses a second AA 501A Mod WQ in LEVEL and dB RATIO modes as the level indicator. A frequency counter fed from the SG 505 Mod WR SYNC OUT is convenient in either case if a relatively unskilled helper is assisting with the proof-of-performance at the studio end.

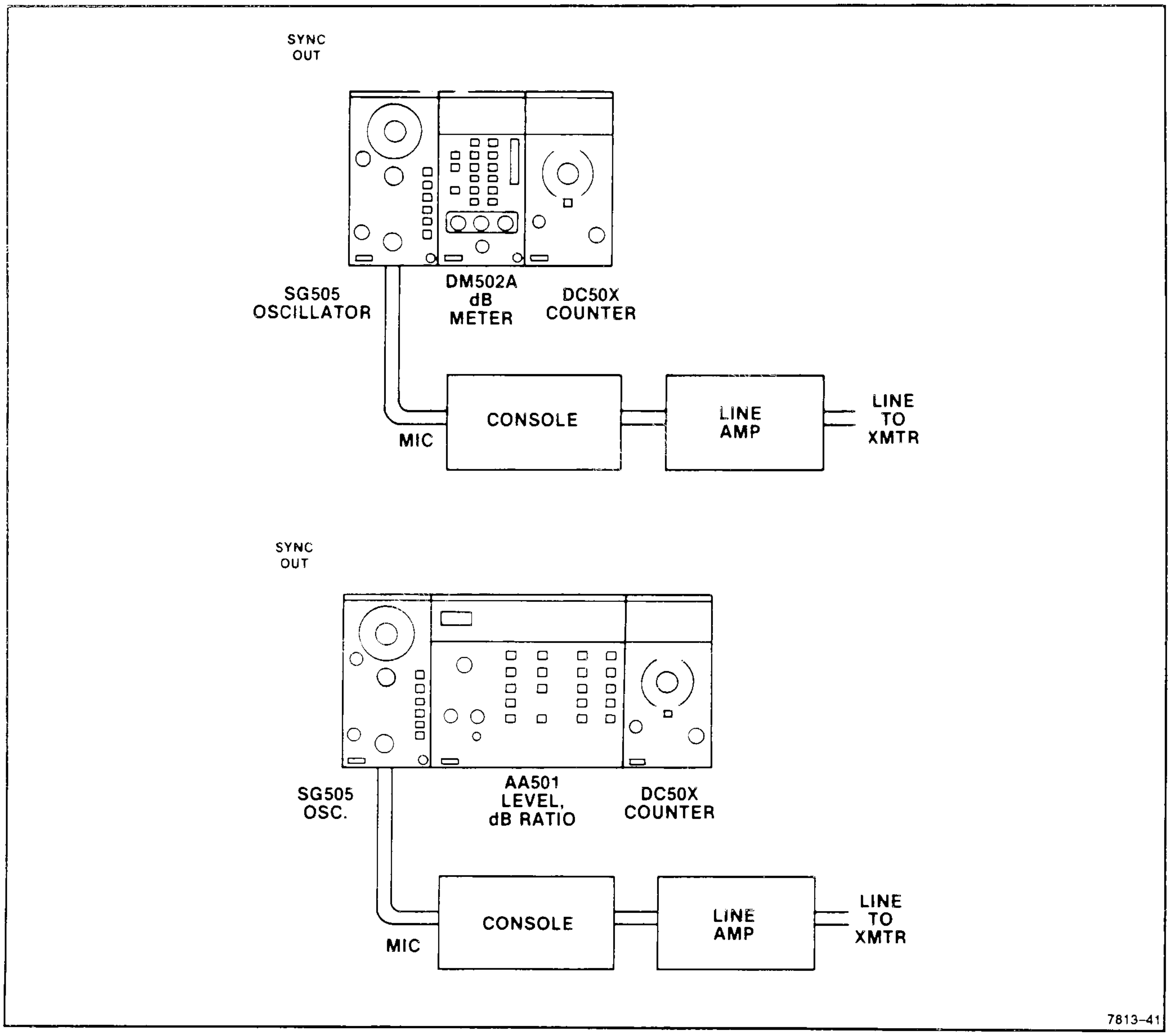


Fig. 6.1.8. Two variations of the "send" package.

In either case, the engineer at the transmitter controls the test. He or she need never touch the AA 501A Mod WQ (which has been connected as before to the modulation-monitor output); the AA 501A Mod WQ remains in THD + N mode at all times. The transmitter engineer requests each test frequency from the studio operator. If this operator is only semi-skilled, the frequency counter's digital display is a powerful advantage and virtually eliminates frequency-setting errors. Over the intercommunication facility, the transmitter engineer requests upward or downward oscillator-level adjustments until the desired modulation percentage is achieved. The transmitter engineer then records the THD + N reading and asks the studio operator to provide the digital display of amplitude, in dB. If the DM 502A is being used, this will be an absolute reading in dBm or dBV. If a second AA 501A Mod WQ is available for studio use, it can be used in LEVEL and dB RATIO mode and normalized at midband via the PUSH TO SET button. This normalization is particularly convenient in fm proofs, where transmitter pre-emphasis causes the required oscillator level to vary over a wide dynamic range. The mid-band normalized dB readings can be immediately compared to the permissible limits without arithmetic computations.

The procedures described in the preceding paragraphs use the voltage method of determining frequency response. The voltage method and transducer method normally produce identical results when measuring broadcast system frequency response, since broadcast console microphone inputs typically approximate a pure resistance within the audio band. If, however, you wish to measure response on a transducer basis, a calibrated constant-impedance step attenuator (gain set) must be inserted at the oscillator output. The oscillator amplitude will then be left fixed, and the attenuator (gain set) controls manipulated to obtain the desired modulation percentage. Operationally, the voltage method is more convenient when semi-skilled helpers are involved. They can read amplitude directly with 0.1 dB resolution from either the DM 502A or AA 501A Mod WQ with much less chance of error than when using a complex step attenuator.

Several Tektronix TM 500 frequency counters are suitable for this application. The DC 504 is the lowest-priced, and its 5-digit display is adequate for the application; 1-Hz resolution (1 second gate time) should be selected. The DC 508/A offers more digits and an audio-frequency resolution multiplier providing 1-Hz resolution in a 0.01-second gate time. While considerably more expensive. The DC 508A also makes rf measurements through VHF and UHF frequencies. The DC 509 should also be considered for its ability to make high-resolution measurements even at low frequencies due to its dual-register architecture.

Determining Amplitude for a Specific Distortion Percentage

Certain applications, particularly those involving measurements of magnetic-tape recorders, require determining a reference amplitude level. This level is defined as the amplitude that produces X% distortion. The auto-set-level capability of the AA 501A Mod WQ adds particular speed to this measurement.

Select THD + N mode and adjust the signal amplitude until you observe the desired distortion percentage, frequently 3% in tape systems. Since a digital display is not optimum for analog adjustments, you may wish to calibrate the 10-segment LED indicator if you frequently make these measurements. To do this calibrating, carefully adjust the level until the desired distortion percentage is obtained. Lock out the percent-distortion autoranging feature by selecting the lowest range button that does not produce an over-range indication. Note how many segments of the LED "bar-graph" are lighted, and the degree of variable intensity of the uppermost lighted one. Now you can quickly adjust levels to approximate this "bar-graph" display in future tests, observing the digital display for fine tuning.

SINAD

As specified in EIA Standard RS 204A, July 1972, the SINAD test is a standard specification for sensitivity of two-way mobile fm receivers. SINAD stands for the following ratio:

$$\frac{\text{Signal + Noise + Distortion}}{\text{Noise + Distortion}}$$

The test is performed with a frequency-modulated calibrated rf-signal generator and a distortion analyzer as shown in Fig. 6.1.9. The rf generator is modulated at two-thirds the rated peak deviation for the receiver being tested. The automatic-nulling and auto-set-level features of the AA 501A Mod WQ Distortion Analyzer greatly speed SINAD testing compared to what can be done with earlier analyzers. The AA 501A Mod WQ is placed in THD + N mode, and dB readout of distortion is selected. The AA 501A Mod WQ input is driven from the speaker-output terminals (across a resistive load) of the receiver. Start from a moderately higher rf-signal level that produces at least a -20 dB SINAD reading. Then reduce the generator rf output until the AA 501A Mod WQ indicates -12dB. At this point, the generator output is equal to the 12-dB SINAD sensitivity of the receiver. Note that the audio signal being measured by the AA 501A Mod WQ at this point is definite nonsinusoidal, consisting of large amounts of noise. Thus, theoretically, the true-RMS detector in the AA 501A Mod WQ should be used for accuracy. However, when the SINAD technique was developed and rated sensitivities for fm-mobile receivers were established, all distortion analyzers had only average-responding, rms-calibrated detectors. Therefore, to obtain correlation with existing sensitivity specifications, you must use the AA 501A Mod WQ AVG detector for SINAD tests.

Observation of the analog bargraph indicator may be useful to get close to the 12dB SINAD value, with the digital display then observed for the final adjustments.

Intermodulation Distortion at Nonstandard Frequencies

Users may wish to use a high-frequency tone lower than the 7 kHz of SMPTE or 8 kHz of DIN when measuring low-bandwidth equipment. For example, a voice-grade communications link or recorder with cutoff above 3 or 3.5 kHz could not be tested for IMD with the 7-kHz tone, but could be by bringing the upper tone within its passband.

Higher-than-standard upper-frequency tones are used principally in determining the transient-intermodulation susceptibility or slew-rate problems of a wide-band, high-quality audio amplifier. The advantages of a SMPTE-like IMD test with upper-frequency tones between 15 kHz and 100 kHz are discussed in depth in a technical paper, "A Comparison of Nonlinear-Distortion Measurement Methods".[1]

These tests are far simpler to perform than other suggested dynamic-intermodulation (DIM) or transient-intermodulation (TIM) tests and can be done fully automatically by the F7523A1 Mod WQ test system.

Filters-Internal and External

The ac voltmeter section of the AA 501A Mod WQ Analyzer, that ultimately performs all the analyzer's measurements, is a wideband unit typically down 3 dB at 330 kHz. In many measurement applications this full bandwidth is unnecessary or even undesirable. Furthermore, some particular applications call for very specific control of bandwidth, perhaps passing or rejecting only narrow frequency bands. Consequently, the AA 501A Mod WQ was designed with four commonly used filters as standard, and with convenient external connections for any other desired filters.

Built-In Filters

Figures 6.1.10 through 6.1.13 show the typical frequency responses of the four built-in filters of the AA 501A Mod WQ. The 400-Hz high-pass filter (Fig. 6.1.10) is used to reduce the effect on distortion or noise measurements due to power-supply hum in the unit under test. It should not be used for distortion measurements at fundamental frequencies below approximately 500 Hz.

1 Richard C. Cabot, Audio Engineering Society paper No. 1638, May 1980.

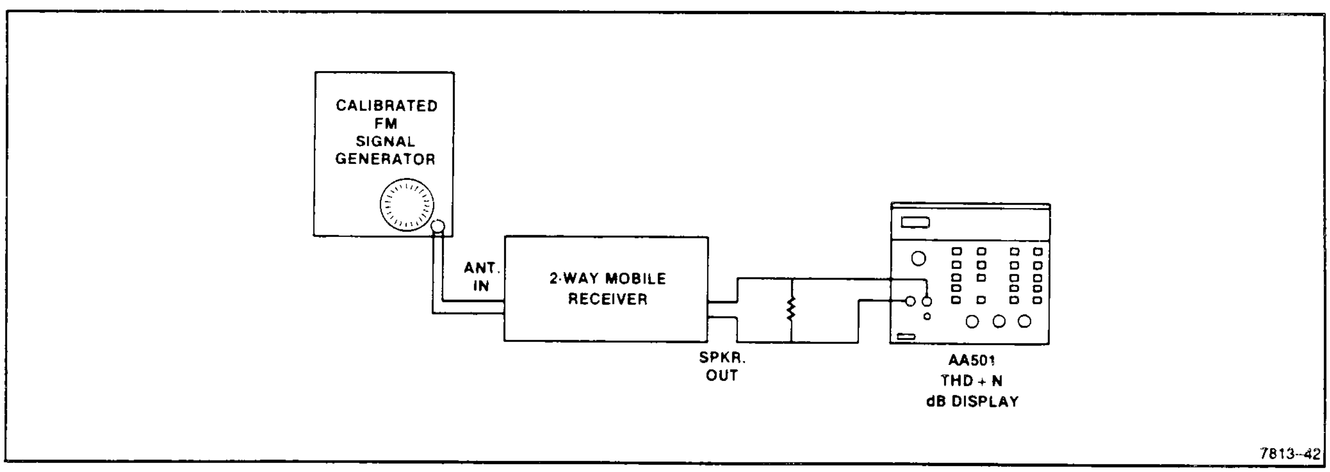


Fig. 6.1.9. SINAD measurement setup.

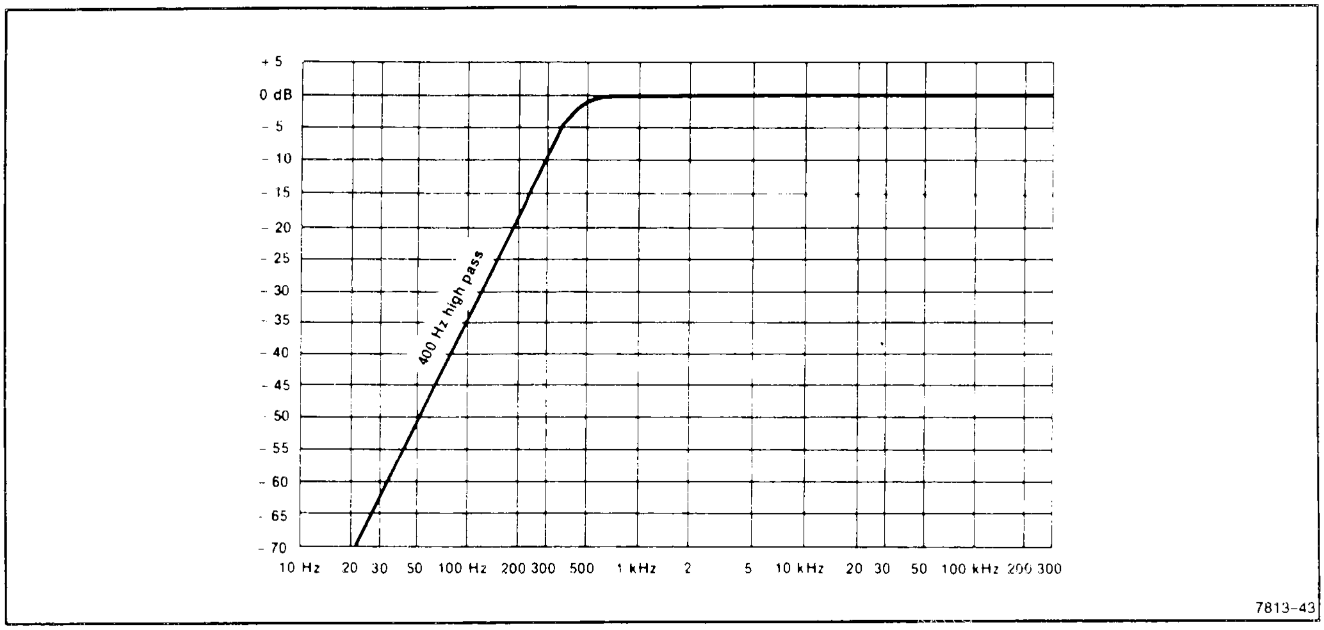


Fig. 6.1.10. Frequency response curve for 400 Hz high-pass filter.

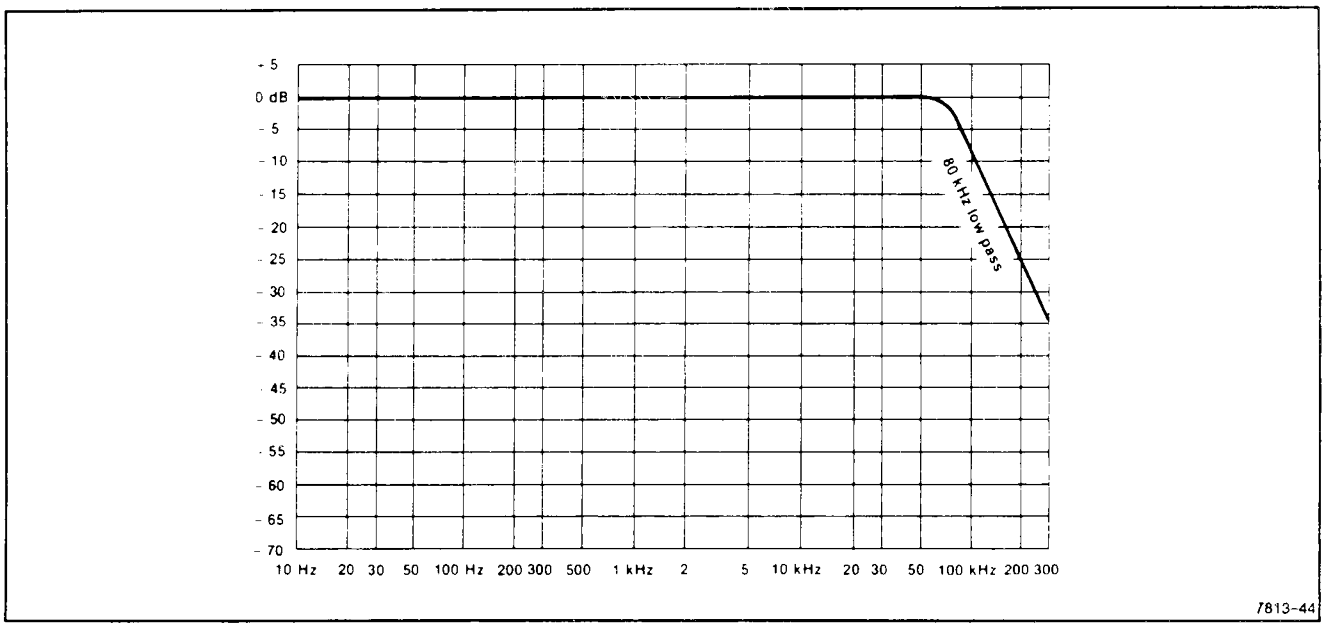


Fig. 6.1.11. Frequency response curve for 80 kHz low-pass filter

The 80 kHz and 30 kHz filters (Figures 6.1.11 and 6.1.12) reduce the noise contributions to permit measurement of lower distortion levels. Of course, they also reduce harmonic-distortion products and are not normally used when measuring distortion at fundamental frequencies above one-fourth to one-third their cutoff frequencies. The US Federal Communications Commission permits use of the 30 kHz filter during broadcast-station proof-of-performance tests.

'C' MSG (Fig. 6.1.13), normally used only during noise measurements, provides better correlation to human perceptions of noise levels because its low- and high-frequency roll-off approximates the frequency response of the human ear.

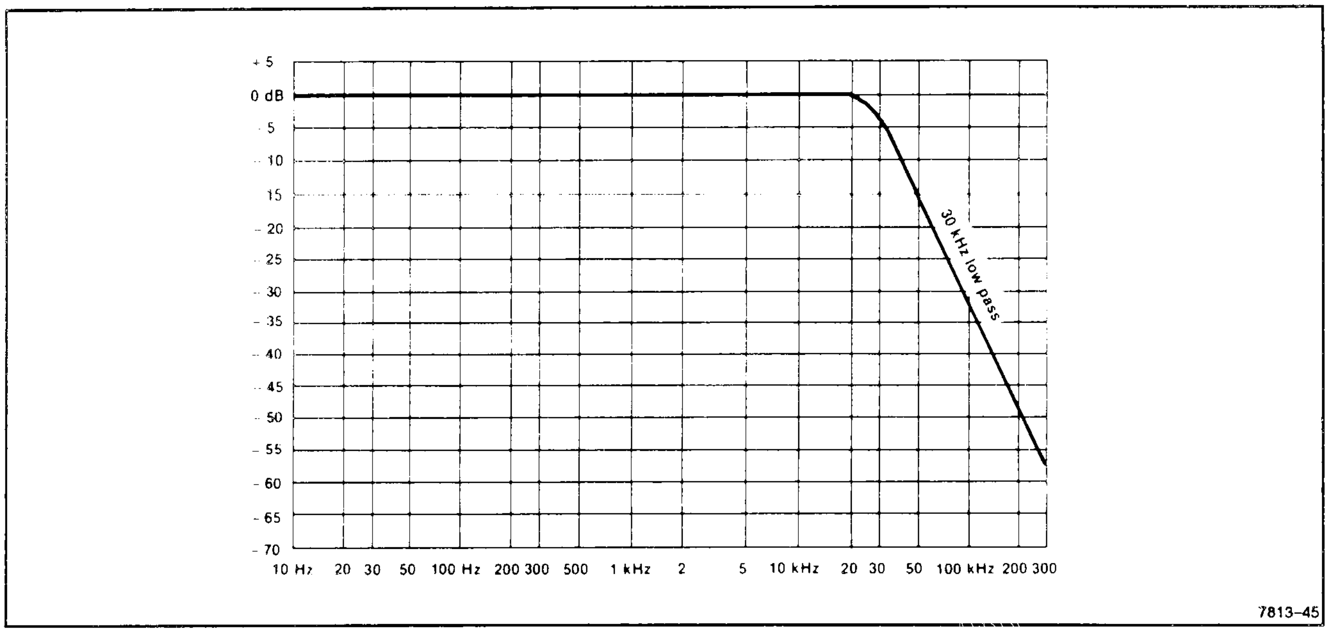


Fig. 6.1.12. Frequency response curve for 30 kHz low-pass filter.

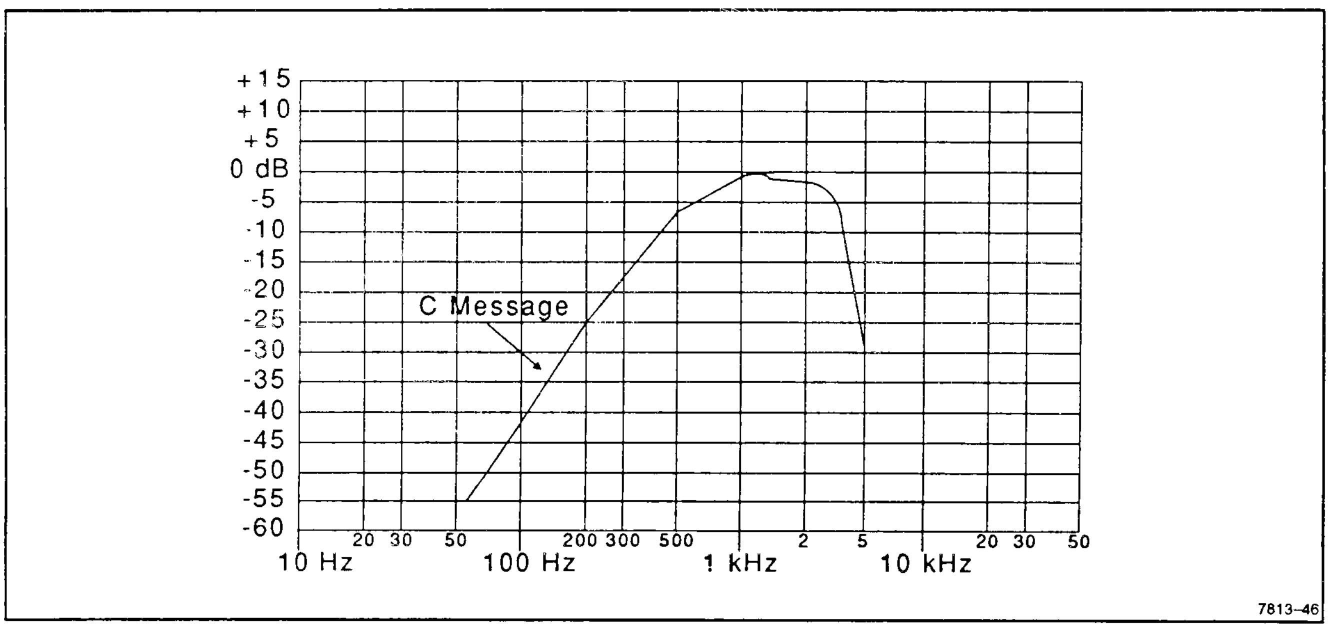


Fig. 6.1.13. Frequency response curve for the 'C' MSG weighted filter.

The 'C' MSG, 400-Hz, and 80-or 30-kHz filters are independent, additive, and may be used in any combination. H :wever, the 80-and 30-kHz filters share components; if both are selected, only the 30-kHz response is in effect.

Modifying a 30-kHz filter to the 22.4-kHz IEC Standard

You can convert the 30-kHz filter to a 22.4-kHz cutoff as specified in IEC standard 268 and CCIR recommendation 468-2 by replacing three resistors. Change R1110, R1112, and R1210 to 21.0 kΩ. Parts-location information is provided in the F7523A1 Mod WQ Service Manual.

User-Supplied External Filters

There are many specific applications where it is desirable to employ one or more specific filters such as:

- a 19-kHz reject (notch) filter to prevent the stereo-pilot carrier from masking distortion or noise measurements of fm tuners and receivers.
- multiple-pole 300-Hz high-pass to reject continuous tone squelch-signaling (CTSS) tones when making measurements in two-way mobile radio systems.
- narrow band-pass filters to permit measurement of second harmonic only or third harmonic only, rather than total harmonic distortion. Such measurements are common in magnetic-tape system measurements.
- psophometric filters other than 'C' MSG.
- Dolby CCIR.
- low-pass or notch filters, as appropriate, to reject remote-control signaling tones used in some broadcasting networks with unattended remote transmitters.
- a notch filter to reject a tone used to hold companders in an audio transmission line at some reference gain level while making absolute noise measurements.

External filters can be conveniently connected either via AA 501A Mod WQ front-panel jacks or rear-interface connections. FUNCTION OUTPUT (front panel, or pins 23B high and 24B ground at the rear) drives the filter input. The filter output connects to AUXILIARY INPUT (front, or pin 25B high and pin 26B ground at rear). Both are single-ended, ground-reference signals. Source impedance at FUNCTION OUTPUT is 1 kΩ; input impedance at AUXILIARY INPUT is 100 kΩ and ac coupled. The filter must be unity (X1) gain in its pass-band, and capable of passing 2-volt rms signals without clipping or compression.

User-Built Filters

Commercial, lab-grade filters with the appropriate characteristics may be used with the AA 501A Mod WQ, but most users will find it more convenient and less expensive to build their own in TM 500 custom plug-in kits, using modern active-filter technology. These kits are available in three versions. The single-width kit without power-supply components is Tektronix P/N 040-0652-05; a single-width kit including parts to build regulated plus-and-minus supplies on the rear part of the board is Tektronix P/N 040-0803-02; and a double-width kit without power-supply components is Tektronix P/N 040-0754-07. Each consists of the mechanical structure (in knocked-down form) of a TM 500 plug-in. The circuit board (or two boards in the 040-0754-07) is perforated on 0.100-inch centers for convenient construction of custom circuits with integrated circuits and/or discrete components.

Custom kits include information on interfacing with the TM 500 mainframe's unregulated power supplies. More detailed information is available in Tektronix Application Note number AX-3303-2, Suggested Power-Supply Circuits for the TM 500 Blank Plug-in Kit. Switches and connectors can be easily mounted on the kit's front panel section. The completed filter project plugs into any TM 500 mainframe.

Using the INPUT MONITOR and FUNCTION OUT Connections

INPUT MONITOR provides a buffered, constant-amplitude version of the AA 501A Mod WQ input signal. Output impedance is 1 kΩ, ground referenced; rear-interface pins are 24A high and 23A ground. Amplitude will be a constant one-volt rms with input signals between 60 mV and 200 V. Below the agc and auto-set-level threshold at approximately 60 mV, the INPUT MONITOR output signal will decrease with a constant gain of approximately 26 dB (X20) above the INPUT connector.

FUNCTION OUT provides the ac signal following all processing and filtering, just prior to feeding the 1.999-volt full-scale ac voltmeter that comprises the final section of the AA 501A Mod WQ. This signal thus comes after the notch filter in THD + N mode, after the filters and demodulator in IMD mode, and after the four built-in filters in all modes. Source impedance is 1 kΩ, single-ended; rear-interface terminals are 23B high and 24B ground. Since this signal is effectively at the input to a 1.999-volt full-scale voltmeter, the calibration is always one millivolt rms output per count in the digital display (except in dB-display modes). For example, at a displayed voltage of 1.456 mV, the output will be 1.456 V; a displayed THD + N reading of 0.0083% will provide 83 mV at this jack. Decibel conversion in the AA 501A Mod WQ follows the detector and thus does not affect the FUNCTION OUTPUT signal.

Oscilloscope Monitoring

Useful information on the content of the signal being measured by the AA 501A Mod WQ Analyzer can be obtained by observing the FUNCTION OUTPUT signal on an oscilloscope. Interpretation and stable oscilloscope triggering are aided by also observing the INPUT MONITOR signal on a dual-trace oscilloscope and triggering from the channel displaying INPUT MONITOR. The FUNCTION OUTPUT trace can then show whether the predominant signals are broadband noise, individual harmonics or a combination of harmonics, or power-line-related hum. Power-line-related hum is most easily detected by placing the oscilloscope time base on 2 ms per division and selecting LINE triggering; 50- or 60-Hz line-related noise will then be stable while actual distortion products will run through the display.

The dual-trace scope, triggered from the INPUT MONITOR channel and with the time base adjusted to display one to two cycles on the INPUT MONITOR trace, also becomes an extremely sensitive indicator of the clipping threshold of the device under test.

Such a setup makes it easy to detect clipping even when the products are below 0.01% (-80 dB), long before any flattening can be visually observed on the device's output waveform.

Some users prefer to use a monitoring oscilloscope as an X-Y monitor rather than in conventional time-domain fashion. With the INPUT MONITOR and FUNCTION OUTPUTS as the two signals, Lissajous patterns result, from which a trained observer can determine harmonic-order content.

Spectrum Analyzers and the AA 501A Mod WQ

Spectrum analyzers and total-harmonic-distortion analyzers are often considered as alternative, even competing, approaches to obtaining quantitative information about the distortion produced by a device.

The total-harmonic-distortion analyzer produces a single reading that lumps together the effects of all harmonics, wide-band noise, and any interfering signals such as power-supply hum. A THD analyzer is simpler to operate and interpret (particularly a totally automatic digital-read-out instrument like the AA 501A Mod WQ) than a spectrum analyzer. Although ultimately limited by noise since they are wide-band instruments, state-of-the-art analyzers like the AA 501A Mod WQ are capable of readings approaching 100 dB below fundamental (average-responding detector).

The spectrum analyzer, however, provides more information than a THD analyzer. It shows the amplitude of each individual spectral line – fundamental and harmonic. It can also show interfering signals like power-supply hum as discrete spectral lines. However, it requires higher skill to use and interpret than a THD analyzer. Furthermore, if a single % THD number is required, a user with only a spectrum analyzer must perform a root-sum-square computation upon the amplitudes of the individual harmonics. The scanning spectrum analyzer can be a very narrow-band device, depending on choice of resolution bandwidth, and so is theoretically less noise-limited than the wide-band THD analyzer. However, current state-of-the-art spectrum analyzers are limited to approximately 80- to 90-dB dynamic range and thus cannot match the -90- to -100-dB residual floor of the AA 501A Mod WQ.

An audio spectrum analyzer such as the Tektronix 7L5 or 5L4N can be connected with the AA 501A Mod WQ Distortion Analyzer to synergistically obtain greater measurement power than either instrument provides alone. Two connections are possible; each has different applications and different benefits.

Spectrum Analyzer Driven From AA 501A Mod WQ FUNCTION OUTPUT Connector

The primary advantage of this setup (see Fig. 6.1.14) is that it extends dynamic range, permitting measurements significantly below what either AA 501A Mod WQ or spectrum analyzer could do alone. Such measurements are possible because the AA 501A Mod WQ eliminates the fundamental signal as a limiting item on spectrum-analyzer dynamic range, and the narrow resolution bandwidths possible in the spectrum analyzer reduce the basic-noise-floor limitation of the wide-band AA 501A Mod WQ. This dual analyzer configuration also converts a single-ended spectrum analyzer to a high-CMRR differential input as far as the signal is concerned. Furthermore, the autoranging circuitry of the AA 501A Mod WQ prior to FUNCTION OUTPUT makes it unnecessary ever to reset the spectrum analyzer's amplitude controls after an initial setup. The spectrum analyzer can do its usual job of individual distortion-product analysis, but now at levels it could not touch if fed directly from the signal.

Amplitude setup and scaling to the signal are simple. The spectrum analyzer will normally be set for a one-volt (0 dBV) reference level; one exception will be noted below. As noted earlier, the scaling of the FUNCTION OUTPUT jack is one millivolt per count in the display. If, for example, the THD is exactly 0.1% (-60dB), the AA 501A will have autoranged to the 0.2% scale; a reading of 0.1 000% and a FUNCTION OUTPUT of 1000 mV (1 V) rms will result.

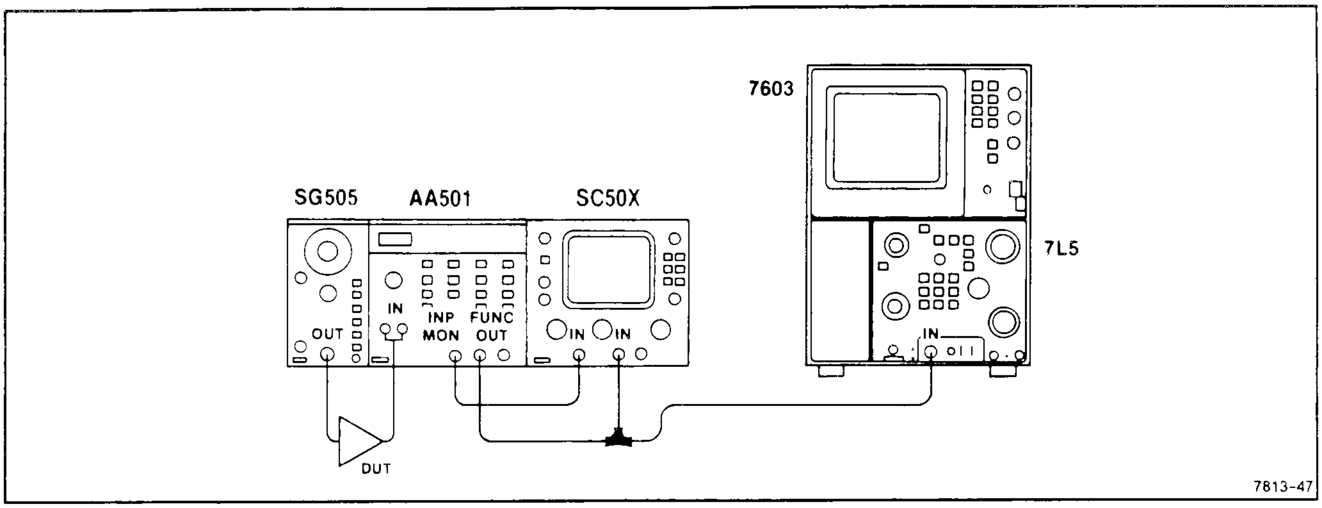


Fig. 6.1.14. Spectrum analyzer driven from AA 501A Mod WQ FUNCTION OUT connector.

The 0-dBV reference line on the spectrum analyzer will thus be 60 dB below the signal fundamental and a 10 dB per division vertical calibration will provide convenient readings down to the 100 to -120 dB levels, where other limitations set in (to be discussed below). When the AA 501A Mod WQ autoranges or is manually ranged to a higher scale, the same one-millivolt-per-count relationship holds at FUNCTION OUTPUT. The 0-dBV reference line on the spectrum analyzer that is -60dB (referred to the AA 501A Mod WQ input signal) on the 0.2% range becomes -40 dB on the 2%, -20 dB on the 20% range, and 0 dB on the 100% range of the AA 501A Mod WQ. It is easy to determine which range the AA 501A Mod WQ has autoranged to by finding which button does not change the decimal point's position in the display.

The one exception to a 0-dBV reference setting on the spectrum analyzer occurs if any spectral-line peaks are above the top (reference) graticule line of the spectrum analyzer's CRT. This condition would occur only on percent THD readings between 0.1% and 0.2%, between 1% and 2%, and between 10% and 20%. In these cases the FUNCTION OUTPUT voltage will be between one and two volts rms. Even then, depending on the individual harmonic amplitudes, displayed spectral lines may not go above the reference line. If they do, go to a +6-dBV (two-volt) reference and remember that the reference-line-to-signal relationships are now -54dB, -34 dB, or -14 dB respectively.

The ultimate limitations of the dual analyzer configuration cannot be rigidly specified, varying somewhat from AA 501A Mod WQ unit to unit, with temperature, and with frequency. However, residual harmonic distortion at the FUNCTION OUTPUT jack with fundamental frequencies between 20 Hz and 20 kHz is typically -100 to -115 dB at second and third harmonic and even less than -115 dB at higher harmonics. Noise floors are a function of spectrum-analyzer bandwidth, sweep rate, and averaging; -120 dB is easily obtainable. Fig. 6.1.15 is an example of a 7L5 spectrum-analyzer display when the AA 501A Mod WQ and 7L5 are measuring a low-distortion device. The 7L5 shows the suppressed fundamental at 1.6 divisions (16 kHz), second harmonic at -98 dB, third at -104 dB, and a noise floor of approximately -128 dB.

In harmonic-distortion analysis with the AA 501A Mod WQ and spectrum analyzer, it is normally convenient to select a center frequency that places the suppressed fundamental near the left of the screen and a span that positions the first five to ten harmonics across the screen. It is worth noting that the suppression of the fundamental depends upon the amount of harmonic energy present in the signal. The fundamental will always be suppressed at least 10 dB below the strongest harmonics and thus has a negligible effect on the AA 501A Mod WQ THD measurement. Likewise, it will not limit the dynamic range of the spectrum analyzer. The full fundamental rejection of 100 dB or more will occur only when the signal harmonics are also 90 dB or more below the fundamental.

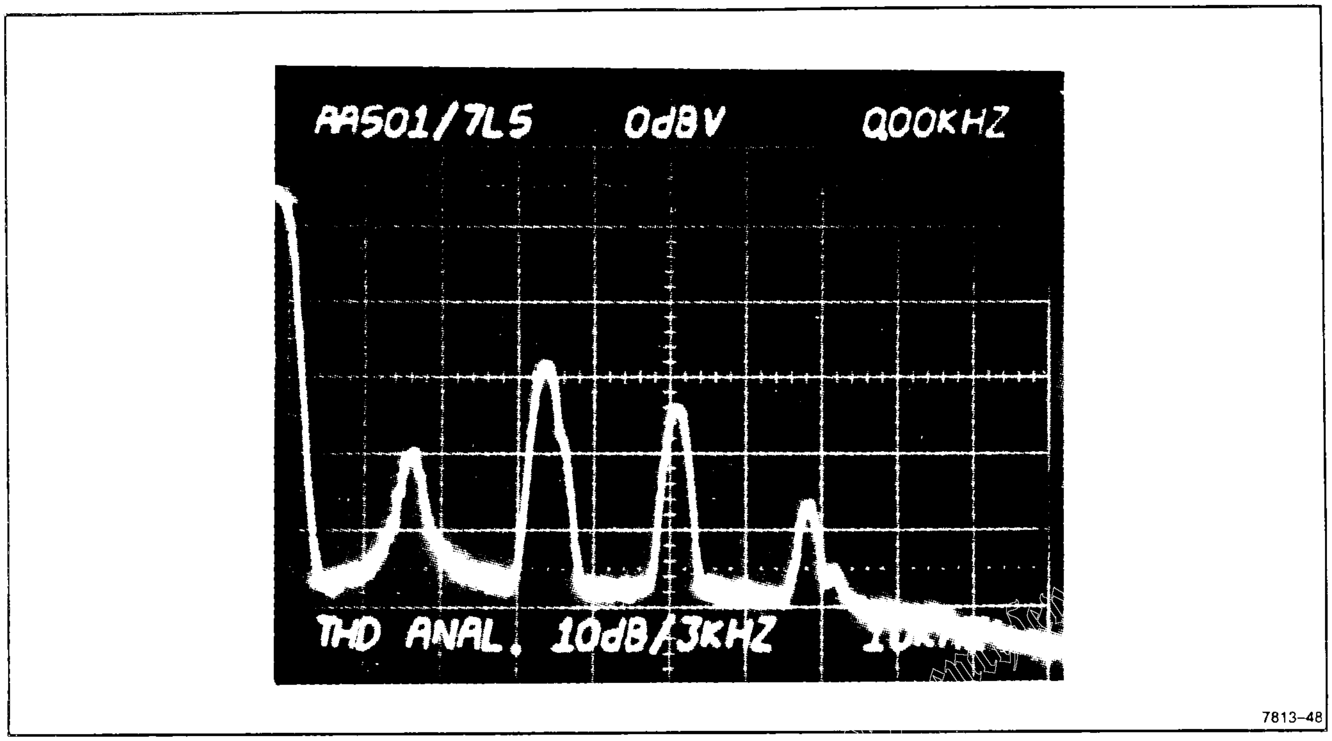


Fig. 6.1.15. Spectrum analyzer display with AA 501A Mod WQ and 7L5 distortion device.

Spectrum Analyzer Driven From AA 501A INPUT MONITOR Connector

This configuration (Fig. 6.1.16) does not increase the effective dynamic range of the spectrum analyzer, since no filtering precedes the INPUT MONITOR connector. It does convert single-ended spectrum analyzers to differential input for good noise rejection. The constant one-volt-rms signal level with any AA 501A Mod WQ input above 60 mV means the spectrum analyzer can be set once for a 0-dBV (1 volt) reference and never changed.

This configuration is generally used in intermodulation testing when information on higher order products is desired. For example, assume a Twin-Tone test is being performed with frequencies 14 kHz and 15 kHz. The AA 501A Mod WQ in IMD mode will provide an automatic digital readout of the amplitude of the second order difference product at 1 kHz. If information is needed on the second order sum at 29 kHz, third-order products at 13, 16, 43, and 44 kHz, or still higher-order products, a spectrum analyzer must be used (see Fig. 6.1.17). The constant output from the AA 501A Mod WQ is particularly convenient when IMD-versus-power-level tests are being performed, since no adjustments of the spectrum analyzer will be required after the initial 0-dBV setup.

Other intermodulation-testing techniques have been proposed, though none is an accepted standard at this writing. These techniques include three-tone tests, combined sine-square tests, and phase-modulated sawtooth tests. The AA 501A Mod WQ INPUT MONITOR – spectrum analyzer connection expedites and simplifies any of these tests. However, as discussed in the Cabot paper previously mentioned ("A Comparison of Nonlinear-Distortion Measurement Methods") SMPTE-like tests over an extended frequency range will quantify the same device short-comings and are performed easily with the SG 505 Mod WQ and AA 501A Mod WQ without the complexity of a spectrum analyzer.

Decibel-Converter Output

This signal provides a replica of the dc voltage after the ac detector and dB converter that drives the digital display in all decibel-readout modes; the signal is present even when a decibel display mode is not selected. Source impedance is 1 kΩ, and the scale factor is one millivolt dc per count displayed. Since display resolution is 0.1 dB, this voltage equates to 10 mV dc per dB. Polarity of this output voltage is exactly as in the display. For example, a display of 40.3 dB would produce an output of 403 mV, and -63.7 dB yields -637 mV.

The decibel-converter output can be used to drive a storage oscilloscope in X-Y mode or a paper chart recorder during swept-frequency-response testing. A complete audio-response sweeper package can be quickly assembled from three standard TM 500 instruments as shown in Fig. 6.1.18.

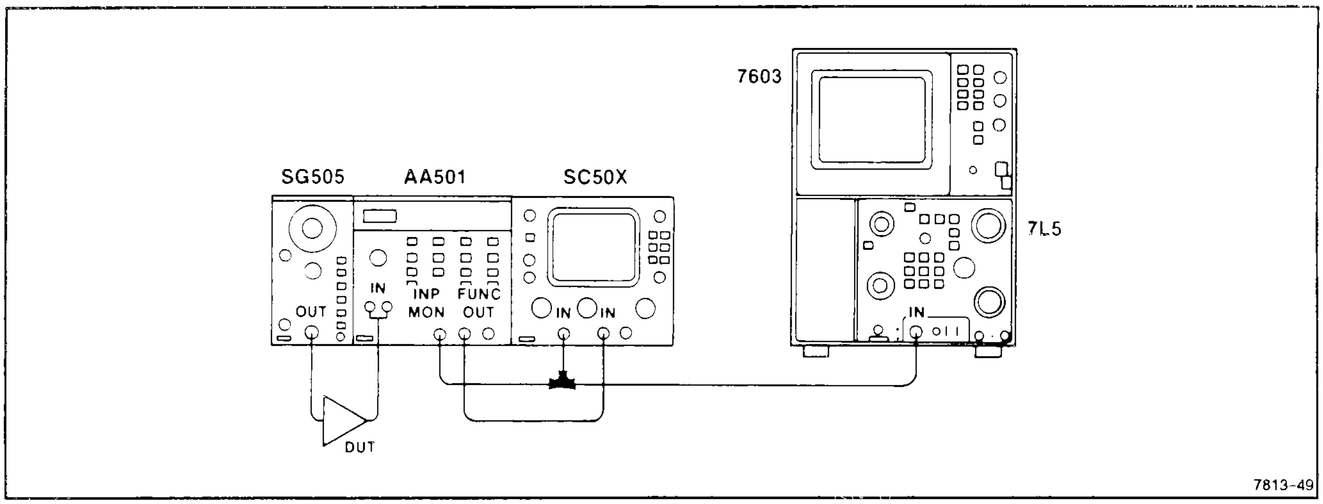


Fig. 6.1.16. Spectrum analyzer driven from INPUT MONITOR connector.

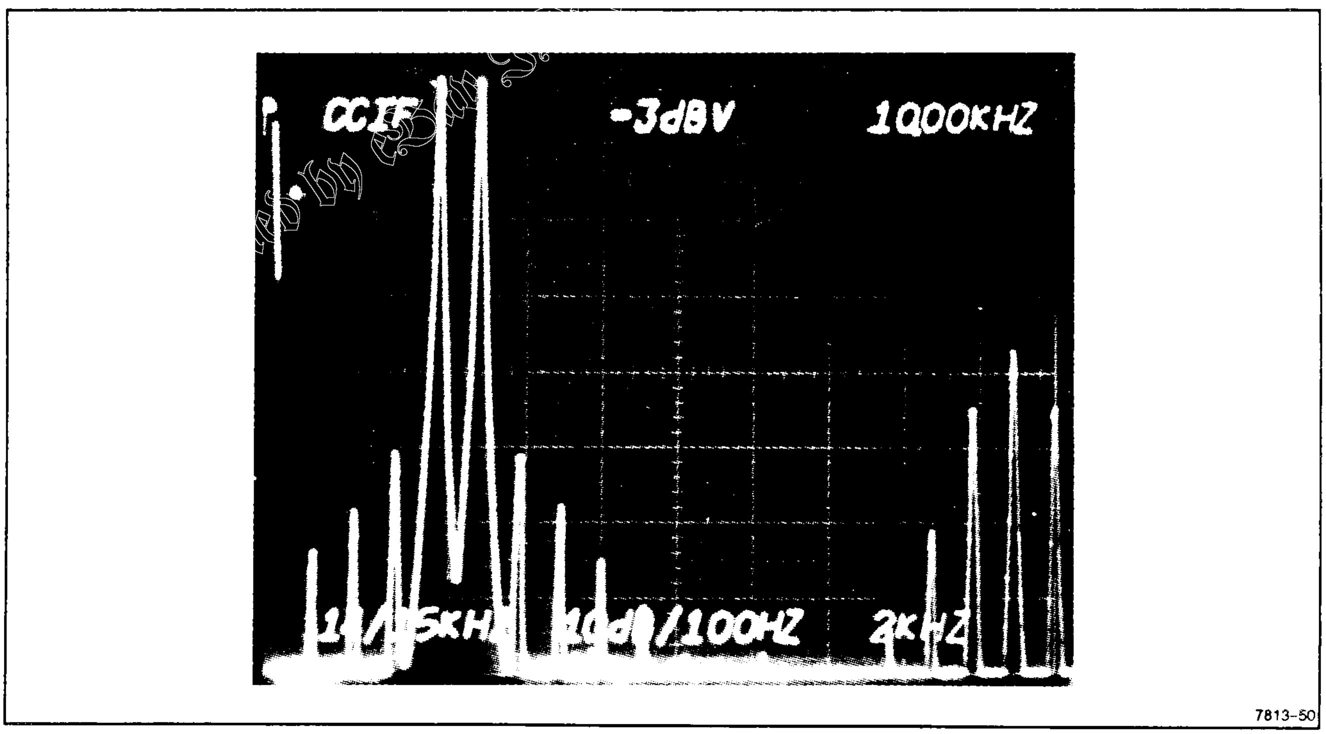


Fig. 6.1.17. Spectrum analyzer display showing second and third order products.

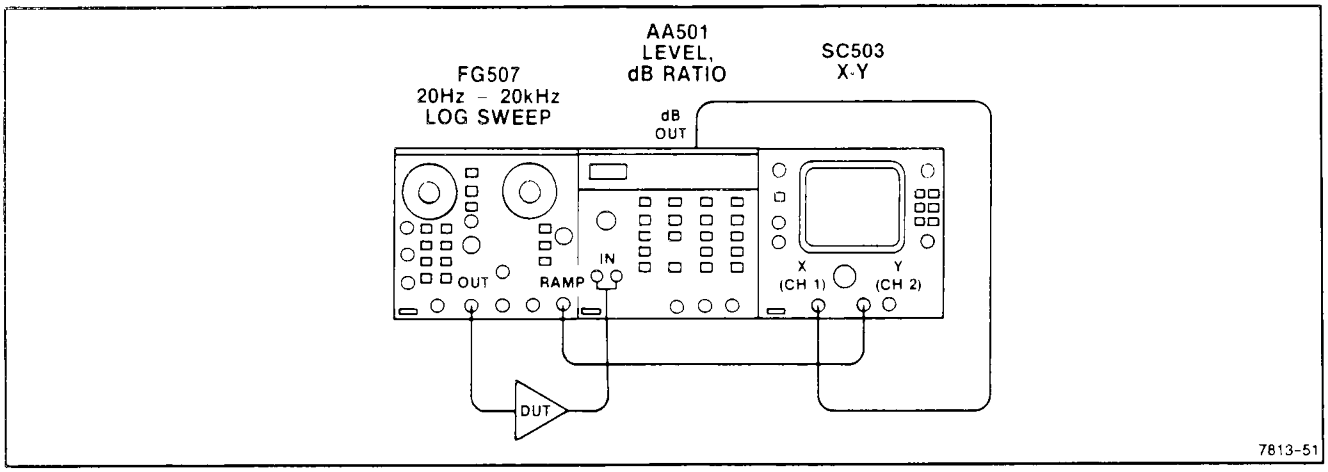


Fig. 6.1.18. Audio-response sweeper package using AA 501A Mod WQ with FG 507 and SC 503.

The Sweeping Function Generator (FG 507 or FG 504) provides a three-decade log sweep from 20 Hz to 20 kHz, and its linear-ramp output provides X-axis deflection for the storage oscilloscope (or X-Y recorder, if desired). The output of the device under test drives the AA501A Mod WQ input. The AA 501A Mod WQ, in Level and dB RATIO modes, serves as detector and dB converter. Its dB converter output drives the Y axis of the storage scope.

Slow sweep speeds, on the order of 10 seconds or longer, must be selected when sweeping from a 20-Hz starting frequency if significant fm distortion is to be avoided. The AA 501A Mod WQ detector and dB converter also have finite response times. If the device being tested has steep amplitude variations with frequency, sweep times up to one minute may be necessary to provide accurate response measurements.

For continuous sweep recordings, AUTORANGE should not be used on the INPUT LEVEL RANGE switch, since a glitch on the display will result each time the AA 501A Mod WQ autoranges. Instead, the generator should be manually swept to the frequency that produces maximum device-under-test output. This is extremely easy with the MANUAL SWEEP mode of the FG 507, which does not disturb sweep end points. The AA 501A Mod WQ INPUT LEVEL RANGE switch should then be turned to the position at which neither the DECREASE RANGE nor INCREASE RANGE LEDs are lighted. This will optimally position the 40-to-50-dB dynamic range of the dB converter with respect to maximum signal. You can now return the generator to triggered sweep and make a response sweep.

Another possible application for the AA 501A Mod WQ dB converter output would be in connecting the instrument to a computer for data logging or manipulation. In either THD + N, IMD, or LEVEL-dBm modes, this output could be computer-interfaced via an appropriate analog-to-digital converter. A convenient method would be to use an inexpensive (perhaps talk-only) GPIB dc voltmeter with millivolt resolution on a one-or-two-volt dc full scale. The fixed decimal location of the AA 501A Mod WQ in all dB modes simplifies system interfacing.

Decibel Conversion Limitations – Apparent and Real

Decibel displays in distortion, dBm, and dB RATIO modes are provided by a log converter following the ac detector. This converter has an effective dynamic range of 40 to 50 dB. In certain applications, this dynamic range sets performance limitations. In other cases, it may appear to limit performance but actually does not. This section explains the functioning of the AA 501A Mod WQ in these respects.

Autoranging of the AA 501A Mod WQ involves manipulation of the decimal point's location and annunciator in the digital display, adding precise dc offsets at the output of the dB converter, and gain/attenuator switching in the instrument's front end. The AUTORANGING function (or manual setting of the INPUT RANGE switch so that both INCREASE/DECREASE RANGE indicators are off) assures that the input to the detector is always between 2 V and 0.2 V rms except at AA 501A Mod WQ inputs below 20 μV in LEVEL modes or distortion values below 0.01% in THD and IMD modes. Thus, the dB converter is normally working in the top 20 dB of its dynamic range. As the input signal's amplitude is decreased, the

AA 501A Mod WQ front end switches to keep detector and dB-converter signal levels in their optimum range. The switching also adds precise dc-offset voltages at the dB-converter output so that the display shows the absolute value of the signal.

Input-level sensing, which controls the autoranging, occurs prior to all filtering. Selecting filters will thus not change the attenuator range, but can change drastically the signal level to the detector and dB converter. As an example, assume an input-signal frequency of 50 Hz at an amplitude of 0.775 V (0 dBm). Selecting the 'C' MSG filter will attenuate the 50-Hz signal by typically 60 dB. Selecting the 400-Hz high-pass filter will attenuate the signal by typically 54 dB. When both are selected simultaneously, they are truly additive and the combined attenuation will typically be 114 dB. However, the AA 501A Mod WQ display will typically indicate only about -50 to -60 dB due to the limited dynamic range and low-level output noise of the dB converter. The desired goal of attenuating 50-Hz components by 114 dB is occurring; their effect on a 1 kHz THD reading or a noise reading is truly reduced by that amount. But, due to the limited range of the dB converter, it cannot be demonstrated by single frequency tests using the AA 501A Mod WQ display. Thus, the limitation is only apparent, not actual.

In applications where a fixed input range is selected, however, the dB converter's dynamic-range limitation becomes real. In the swept-frequency-response application described above, for example, autoranging must be defeated to avoid glitches on the display each time the AA 501A Mod WQ autoranges. On whichever manual range is selected, the converter floor some 40 to 50 dB below normal levels will mask measurements at still lower levels, and the response time becomes progressively slower as the signal level approaches this floor.

Detector Output

The detector output provides a replica of the dc voltage at the output of whichever detector, true RMS or AVG, has been selected at the front panel. As with most other inputs and outputs, the scale factor is one millivolt per displayed count. Thus, for example, displays of 1.296 V, 129.6 µV, or 12.96% distortion would each produce 1296 mV (1.296 V) as the detector output. Source impedance is 500 Ω.

Principal applications would be in swept frequency response testing, as described above, if linear rather than dB vertical display were desired. This output could also be used via an A-to-D converter or GPIB voltmeter to interface to a computer if linear data were needed. However, instrument autoranging will cause the decimal point to move in distortion measurements and both decimal point and annunciators (VOLTS, mV, µV) to change in LEVEL measurements. The dB converter output would be simpler to interface since no decimal point or annunciator data would be needed by the computer, even over the full dynamic range of the AA 501A Mod WQ.

As noted earlier, the AA 501A Mod WQ will not successfully track a continuously changing signal in THD+N mode. If the detector output were to be used with a chart recorder for plots of THD versus frequency, the pen would have to be lifted before each frequency change and lowered after the AA 501A Mod WQ had settled at each new spot frequency.

Twin-Tone High-Frequency-Tone Output

This rear-interface output provides the high frequency tone plus sidebands due to intermodulation by the low frequency tone in Twin-Tone IMD testing. The signal thus follows the high-pass filter, which excludes the low tones, but precedes the demodulator, which recovers the sideband energy. Source impedance is 2 kΩ; amplitude typically varies between 0.5 V and 3 V, depending on input signal level and low-to-high amplitude ratio.

This output could be connected with a frequency counter to measure only the high frequency tone, valuable in extended IMD testing with higher frequencies than the standard 7 kHz. This output, rather than the complex signal itself, can also be used to feed a spectrum analyzer, adding 12 dB of dynamic range to the spectrum analyzer for analysis of individual distortion products since the low frequency tone.

Operator Traps

The AA 501A Mod WQ Distortion Analyzer and SG 505 Audio Oscillator were designed with human-engineering considerations playing an important part. These instruments also provide excellent flexibility for sophisticated measurements. Use within Tektronix has shown that certain operator traps sometimes lead to a nonfunctioning or apparently improperly functioning instrument. Following is a list of several of these traps.

- Leaving the SG 505 Mod WR output switch in OFF position following signal-to-noise measurements
- Selecting EXT Filter on the AA 501A Mod WQ, but not connecting a filter
- Selecting any filter when inappropriate, especially during frequency-response tests

- Selecting the Twin-Tone signal on the SG 505 Mod WR when only a single sine-wave signal is desired
- Leaving the AA 501A Mod WQ in IMD mode when THD testing was intended
- Sending a signal to the AA 501A Mod WQ below 60 mV when THD testing is to be performed
- Measuring low levels of external signals while either SG 505 in the same mainframe is ON and set to high amplitudes and/or high frequencies. Capacitive coupling across the AA 501A Mod WQ REAR INTFC/INPUT switch will cause the SG 505 signal to set a threshold preventing low-level measurements. The cure is turning both SG 505 outputs OFF.
- Leaving either SG 505 GND/FLTG push button in the GND position may increase distortion readings due to noise pickup.

Use of a dual-trace oscilloscope monitoring INPUT MONITOR and FUNCTION OUTPUT, as described earlier, has the additional benefit of quickly bringing to the operator's attention any of these traps except the selection of EXT FILTER with no filter connected.