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STEP ONE

PRELIMINARY CONSIDERATIONS: Check that the rear-panel Line Voltage Selector is properly set. Plug in the Processor Module(s), with Sampling Head if a Model 163. Turn on the instrument power and allow a fifteen minute warmup. Set all SCAN SELECT pushbuttons to the released position. Set the main-frame Time Constant to .1 mSEC (multiplier to CAL). Function switch should be set to 'A' or 'B'. Digital storage should be off (center knob of Function switch).

STEP TWO

TRIGGERING: Depress the EXT. Trigger Mode pushbutton. Then connect the externally derived trigger signal to the Trigger INPUT connector. Use the SLOPE pushbutton to determine on which slope of the applied signal triggering is to occur. Adjust the TRIGGER LEVEL control as required to establish proper triggering, as indicated by the TRIGGERED indicator lamp.

STEP THREE

APERTURE DELAY: Each trigger initiates an Aperture Delay Range interval as set by the APERTURE DELAY RANGE control. Signal to be processed must fall between trigger time and end of Aperture Delay Range interval. Set the APERTURE DELAY RANGE control as appropriate to achieve this timing requirement. Set % INITIAL A and B dials to 50% (five turns from fully counterclockwise position). These dials will be readjusted in later step.

M164

STEP FOUR

M164 INITIAL ADJUSTMENTS: Depress GND and EXP pushbuttons. Then select the desired Coupling mode (AC or DC, 1 MΩ or 50 Ω) and connect the input signal to the M164 INPUT connector. At main frame, set APERTURE DURATION (affects M164 only) according to resolution requirements (effective rise time equals selected Aperture Duration). Set M164 TIME CONSTANT to 1 μSEC. Set FUNCTION switch (main frame) to 'A' or 'B', whichever corresponds to position of Processor Module being adjusted. Next adjust the M164 ZERO control for '0' panel-meter indication. The response time will be determined by the main-frame Time Constant (100 μs) and by the Observed Time Constant [M164 Time Constant ÷ (Aperture Duration x Trigger Repetition Rate)]. When Zero adjustment is completed, release GND pushbutton and depress CAL pushbutton. Then set the associated adjustment for full-scale panel meter indication. Release the CAL pushbutton. (NOTE: If the selected input impedance is 1 MΩ, make a second zero adjustment, this one with the GND pushbutton released. The signal source should be connected but with the signal "off".) Increase the M164 Time Constant as required for the anticipated signal-to-noise improvement needed (SNIR = $\sqrt{2TC/AD}$, where TC is M164 Time Constant and AD is the Aperture Duration). If two M164 Processor Modules are to be used, change the Function switch setting so that it corresponds to the position of the second module, and repeat the procedure for the second module. NOTE: To match the aperture durations in the two modules, monitor the M164 GATE OUT connectors with an oscilloscope and match pulse widths by means of the associated TRIM adjustments. If two Processor Modules are to be used and the other is a M163, go through the M163 INITIAL ADJUSTMENTS before proceeding to step 5.

STEP FIVE

SINGLE POINT ANALYSIS: Position aperture using % INITIAL A and % INITIAL B dials, whichever corresponds to Processor Module position. If two modules are in use, adjust both dials as required to locate apertures at desired points. The dials are direct reading in % of selected Aperture Delay Range, and so directly indicate the delay between the trigger time and the aperture. NOTE: Proper operation cannot be assured with dialed delays of less than 3%. Once the meter indication stabilizes, the meter will indicate the average value of the signal over the aperture duration interval. The FUNCTION switch should be set to 'A' or 'B', whichever corresponds to the module position. If two Processor Modules are in use, the FUNCTION switch should probably be set to 'A-B' or to one of the OPTION positions. Do not select an option unless the unit in question is equipped with the option and the option function is understood. This includes DIGITAL STORAGE, which is selected with the inner knob. NOTE 1: Baseline Sampling and Digital Storage can not both be selected at the same time. NOTE 2: SCAN SELECT 'A' and 'B' pushbuttons must both be in released position for single-point analysis (these pushbuttons should still be in released position from step 1). It may prove convenient to depress the EXT. scan pushbutton. As long as no voltage is applied to the SCAN IN/OUT connector, the aperture position will be determined solely by the % INITIAL DELAY dials.

M163

STEP FOUR

M163 INITIAL ADJUSTMENTS: Set the INPUT RANGE switch to 1 V and the SAMPLES AVERAGED switch to '1'. The outer knob of the BASELINE SAMPLING control should be fully counterclockwise and the inner 'pushbutton' should be 'in'. The main-frame FUNCTION switch should be set to 'A' or 'B', whichever corresponds to the position of the Processor Module being adjusted. Connect input signal source but with the signal "off". Adjust the M163 ZERO control for '0' panel meter indication (response time will be slow if trigger rate is low). Then set the INPUT RANGE switch to 100 mV and adjust the Sampling Head DC BALANCE adjustment for panel-meter '0'. NOTE: A Sampling Head Extender (supplied with M163) is required to make DC BAL adjustment for any Sampling Head except the S-5, for which the DC BALANCE adjustment is located on the front panel. On all other Sampling Heads, the DC BALANCE adjustment is located on the left side, facing the instrument from the front. The main-frame power should be off anytime the Sampling Head is being plugged in or removed. Alternate between 1 V and 100 mV positions of INPUT RANGE switch, alternately adjusting the M163 ZERO and Sampling Head DC BALANCE adjustments until no further improvement in the meter '0' indication can be obtained. Remove the Sampling Head Extender and return the head to its proper position in the Model 163. (Power should be off for this step.) Leave the INPUT RANGE switch set according to the anticipated signal amplitude. Set SAMPLES AVERAGED switch according to desired signal-to-noise improvement (varies as the square root of samples averaged). If Baseline Sampling is desired (with baseline sampling, module output is difference between level at signal sampling aperture position and level at baseline sampling aperture position; without baseline sampling, module output is difference between level at signal sampling aperture position and ground), monitor M163 GATE OUT connector with scope and adjust outer knob of BASELINE SAMPLING control to position baseline sampling aperture as desired (signal sampling aperture-position gate will also be observed; both gates will be 0.5 μs wide.)

If two Processor Modules are to be used, change the FUNCTION switch setting so that it corresponds to the position of the second module. If second module is M163, repeat this procedure with second module. If second module is M164, go through M164 INITIAL ADJUSTMENTS before proceeding to step 5.

SCANNED ANALYSIS

SNGL. POINT ANALYSIS

STEP FIVE

SCANNED ANALYSIS: If entire aperture delay range interval is to be scanned, set % INITIAL A dial, B dial, or both, as appropriate, to 5%. NOTE: Dials could be set fully counterclockwise. However, proper operation cannot be assured for the real time interval corresponding to the scanning of the first few percent of the Aperture Delay Range. If only a portion of interval is of interest, dials can be used to exclude part of range. Scan will begin at delay corresponding to dial setting and terminate at delay corresponding to end of selected Aperture Delay Range. If both channels are to be scanned, understand that scan will terminate when either aperture reaches 100% of the Aperture Delay Range. If only one scan is desired, SINGLE pushbutton should be depressed. Repetitive scans will take place if SINGLE pushbutton is in released position. Select the SCAN TIME as appropriate to the resolution and readout device requirements. The Scan Time is the time required to move the aperture position over the entire Aperture Delay Range interval. Minimum Scan Time commensurate with good resolution is computed differently for the two Processor Module types. For both, MST = 5 x Effective Time Constant x the ratio of the Delay Range to a Resolution Element. Effective Time Constant and Resolution Element are computed differently for the two module types. For the M163, a Resolution Element is simply the Sampling Head Rise Time (100 ps if Sampling Head Rise Time is less than 100 ps). Effective Time Constant = square root of sum of the squares of main-frame Time Constant and Observed Time Constant, where Observed Time Constant = selected SAMPLES AVERAGED (M163) divided by two times the trigger repetition rate. For the M164, a Resolution Element is the Aperture Duration itself. Effective Time Constant equals square root of sum of the squares of main-frame Time Constant and Observed Time Constant, where Observed Time Constant equals M164 Time Constant ÷ (Aperture Duration x Trigger Repetition Rate). If module is M163 and baseline sampling is being used, scan must be a factor of two slower than value computed. If two Processor Modules are to be scanned, scan times must be no faster than the slower of the two computation results. After setting SCAN TIME controls, depress SCAN SELECT 'A', 'B', or both pushbuttons as appropriate. Connect recording device and adjust its controls (X axis drive for X-Y plotter can be taken from rear-panel SCAN IN/OUT signal). Zero scan (dialed delay) can be established at any time by depressing SCAN SELECT RESET pushbutton. Set FUNCTION switch to 'A' or 'B', whichever corresponds to module position. NOTE: If two Processor Modules are in use, FUNCTION switch should probably be set to 'A-B' or to one of the OPTION positions. Do not select an option unless unit in question is equipped with the option and the option function is understood. This includes DIGITAL STORAGE, which is selected with inner knob. NOTE: Baseline Sampling and Digital Storage can not be selected at the same time. When ready to begin, depress RESET pushbutton to zero scan and then release RESET pushbutton to begin scan of record. Recording device will proceed to scan out the input signal waveform. Additional noise reduction can be obtained by increasing main-frame Time Constant. However, too much main-frame Time Constant will degrade resolution unless scan time is slowed further (see preceding statements on Scan Time computation).

SCANNED ANALYSIS

Figure I-1. CONDENSED OPERATING INSTRUCTIONS

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SECTION II
CHARACTERISTICS

2.1 INTRODUCTION

The Model 162 Boxcar Averager can be combined with one or two Model 163 or 164 Processor Modules to form a gated signal-recovery system of exceptional versatility and utility. This system synchronously samples the input signal with an aperture that can be fixed at any point on, or slowly scanned across, the input signal. The signal passed through the aperture is applied to a variable time constant integrator, the output of which is the average of some number of repetitions of the input signal over the aperture duration. Because the average value of noise over a large number of repetitions is zero, an improvement in signal-to-noise ratio occurs. If the aperture is fixed on a single point of the input signal, the output of the Processor Module rises asymptotically toward the amplitude of the synchronous portion of the input signal at the sampled point. If the aperture is scanned across the input signal, the synchronous waveform is reproduced at the output.

The Model 162 Main Frame contains most of the timing and control functions, as well as the output signal-processing circuitry. There is provision for supplying the gated-and-averaged signal from either channel to the main-frame output. Alternatively, one can select the difference between the two gated-and-averaged signals as the main-frame output. With the addition of optional signal-processing circuit cards, the Model 162 can provide an output consisting of the product, ratio, or log of the ratio of the two averager channel outputs. Use of the optional digital storage option enables signals having extremely low duty factors to be averaged by providing both channels with virtually infinite output holding time. Prior to being made available at the Output connector, the main-frame output signal is smoothed by a low-pass filter with a time constant that is continuously adjustable from 100 μs to 100 s.

Main-frame delay controls permit the aperture in each channel to be delayed independently from about 3% to 100% of the Delay Range, selectable in 1-2-5 sequence from .1 μs to 50 ms. Pushbutton switches provide a choice of external, internal, or line triggering, and permit independent selection of manual or automatic scanning for each channel. The scan time, the time required to scan the aperture across 100% of the selected Delay Range, can be set to any value from 10^{-2} s to 10^{5} s.

Each of the Processor Module types provides a unique set of operating characteristics, allowing the input parameters of the Model 162 to be optimized to a very wide range of signal-recovery applications. The Model 163 Sampled Integrator module utilizes a Sampling Head to achieve aperture resolutions from 100 ps to 1 ns according to the Sampling Head selected. The input sensitivity is switch selectable from 100 mV to 1 V full-scale. There is provision for selecting the number of samples averaged and for baseline sampling. This latter function provides automatic compensation for dc drift and the effects of baseline wander.

The Model 164 Gated Integrator module offers a choice of aperture widths

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ranging from 5 ns to 5 ms. Pushbutton switches allow a choice of 50 Ω or 1 MΩ input impedance, ac or dc coupled, and the choice of either linear or exponential averaging. Both the module gain and aperture duration can be trimmed to provide an exact match between modules if two Model 164's are to be used in dual-channel operation.

Both the Model 163 and the Model 164 provide output and aperture monitors, output reset switches, and an Overload lamp to indicate overload. Both modules also provide a choice of the number of samples averaged. In the Model 163, a single switch selects the number of samples of which the output is the average. In the Model 164, the averaging Time Constant, together with the selected Aperture Duration, determines the number of samples of which the output is the average.

The built-in flexibility of the Model 162 makes it suitable for handling almost any application involving the examination of repetitive signals. Use of the ratio option in dual-channel operation, for example, permits automatic source compensation for fluctuations in the excitation power of pulsed lasers and transducers. Dual-channel operation also permits single-unit instrumentation in complex experiments such as time-shared dual-beam spectroscopy. As a single-channel or a dual-channel gated averager, the Model 162 is ideally suited to such applications as time-of-flight studies, plasma physics research, fluorescence and phosphorescence decay, non-destructive testing, and turbulence studies in fluid mechanics. The use of plug-in signal channel modules and plug-in optional signal-processing function cards, when combined with its many built-in operating features, makes the Model 162 Boxcar Averager the most versatile gated signal averager available.

2.2 DESCRIPTION

2.2A INTRODUCTION

In its simplest form, boxcar averaging is a process of controlled sampling and sample averaging. The process involves repeatedly measuring the amplitude of a specific point on a repetitive waveform while computing the average value of the measurements taken.

In some applications it is desirable to observe the shape of a repetitive waveform. This is accomplished in the Model 162 by time-scanning the sampling aperture across the waveform. The scanning rate is made slow enough to permit a sufficient number of samples to be taken in each segment of the waveform to assure accurate results. The output in the scanning mode is a reproduction of the input waveform slowed by the scan rate. An X-Y Plotter can be used to obtain a hard-copy record.

2.2B BLOCK DIAGRAM DISCUSSION (A more detailed diagram and discussion is provided in Section VI)

Timing and Manual Delay: Figure II-1 is a simplified block diagram of the Model 162 Boxcar Averager together with the Models 163 and 164 Processor Modules. Referring to this diagram, note that a trigger signal that is synchronous with the signal being examined activates the Aperture Delay Range timebase generator to produce a timing ramp (Figure II-2) that begins at time zero and continues to the end of the selected Aperture Delay Range.

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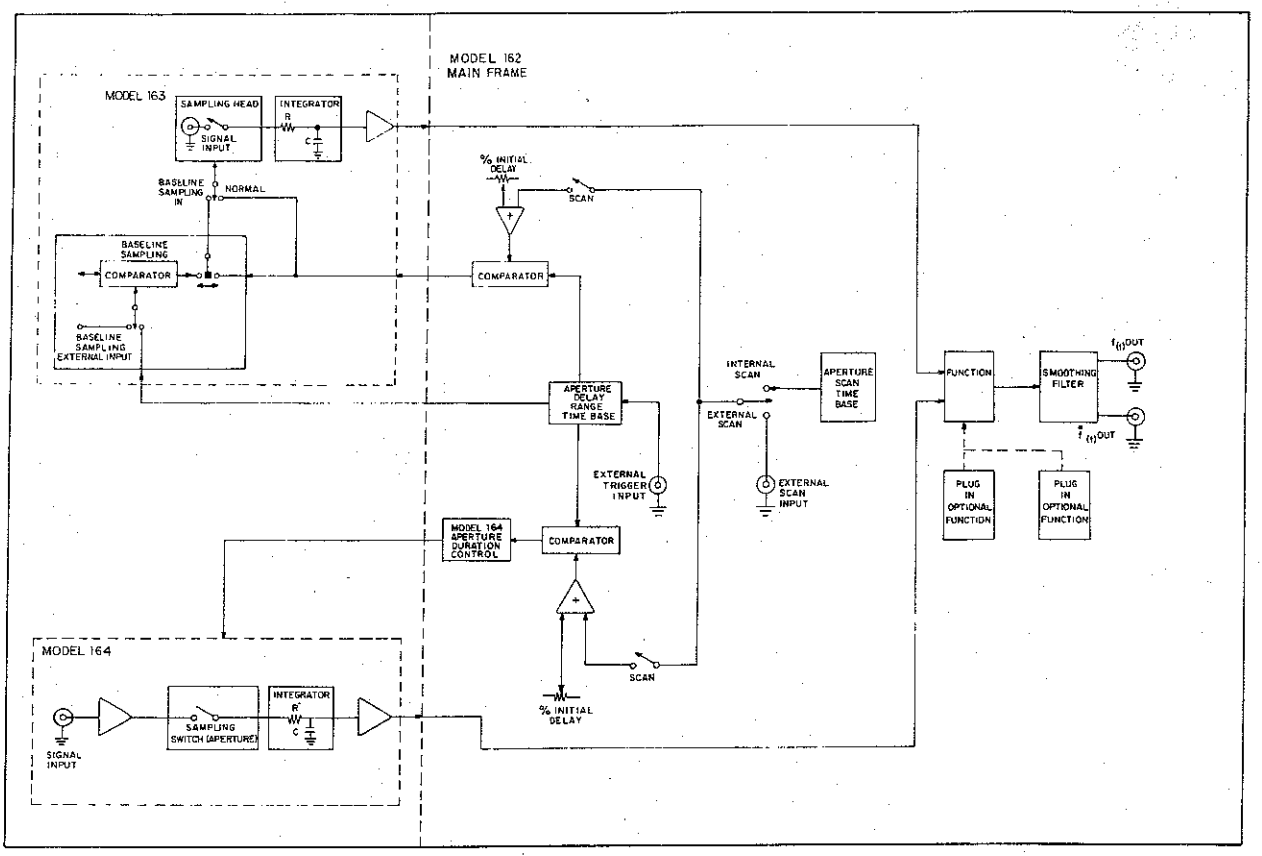


Figure II-1. SIMPLIFIED BLOCK DIAGRAM OF THE MODEL 162 WITH ONE M163 SAMPLED INTEGRATOR AND ONE M164 GATED INTEGRATOR INSTALLED

In manual operation, the Aperture Delay Range time-base voltage is compared with the corresponding % Initial Delay control voltage. The gate opens at the time set by the % Initial Delay control. Each channel is provided with a separate % Initial Delay circuit permitting the sampling switch of each channel to be operated at a different point on the Aperture Delay Range time base, if desired. Through the proper selection of the Aperture Delay Range and the setting of the % Initial Delay controls, any point on the repetitive waveform under study can be sampled.

Automatic Scan: When the Scan Select switches are set for automatic scanning, an internally generated scan ramp is also applied to the delay circuits. The % Initial Delay voltage and Scan Time ramp voltage are summed and sent to the Aperture Comparator which opens the gate. When the % Initial Delay control is set to its minimum position, the delay between the trigger and aperture position is determined solely by the Scan Ramp. Figure II-2 shows the time and amplitude relationships between the Aperture Delay Range time-base ramps, the Scan Ramp, and the aperture position. As the scan ramp ascends, the voltage applied to the Comparator rises, and the aperture opens slightly later relative to the trigger time with each repetition. In effect, with each repetition, the aperture is positioned slightly later on the Aperture Delay Range interval.

When the % Initial Delay control is adjusted to a setting other than minimum,

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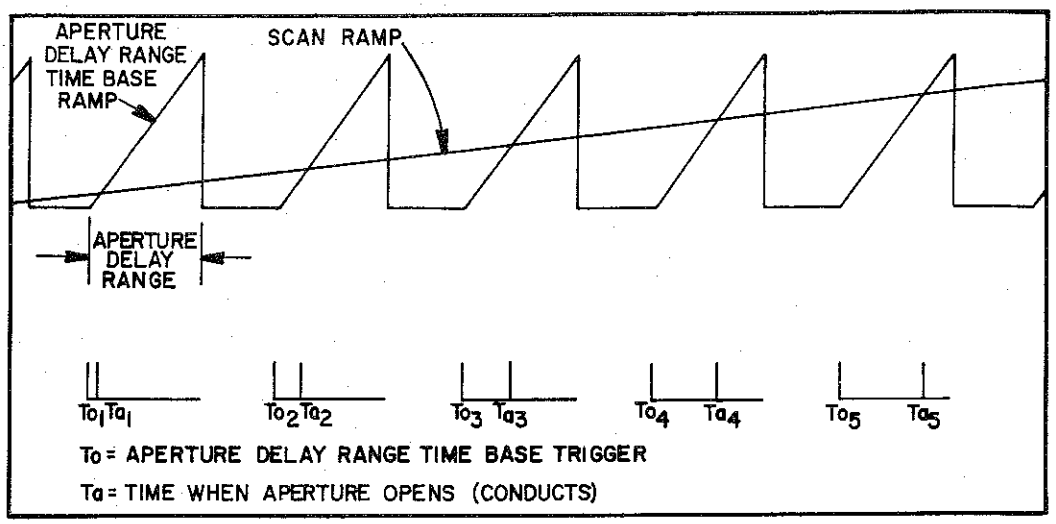


Figure II-2. TIME RELATIONSHIPS BETWEEN APERTURE DELAY RANGE, TIME BASE RAMPS, SCAN RAMP, AND APERTURE POSITION

the comparator input voltage is 'offset' by the amount of the dialed Initial Delay. As a result, the beginning of the aperture scan is time-shifted; the resulting scan is confined to an interval bounded at one end by the dialed Initial Delay, and at the other by the end of the selected Aperture Delay Range.

Aperture Duration and Averaging: The Aperture Duration (time for which the Sampling switch conducts with each repetition) depends on the Processor Module type. In the case of a Model 163, the aperture duration depends on the choice of Sampling Head. In the case of a Model 164, the aperture duration is determined by the main-frame Aperture Duration switch (this switch has no effect on the M163). For the interval that the gate conducts with each repetition, the input signal is applied to an integrating network, represented in Figure II-1 as a resistor-capacitor network. The capacitor charges towards the average potential over the aperture duration interval at a rate determined by the network time constant. When the gate is non-conducting, the input signal is disconnected, but the capacitor retains the charge acquired. With each successive aperture opening, the capacitor acquires additional charge. After a sufficient number of repetitions, the charge on the capacitor is essentially equal to the average value of the sampled signal segment. Noise is suppressed because its polarity and amplitude vary randomly in time, resulting in an average value of zero. The longer the network time constant and the shorter the aperture duration, the better the improvement in signal-to-noise ratio will be.

Digital Storage: Although the integrator circuitry is designed to retain the acquired capacitor charge, there is an inevitable slow discharge. This discharge is sufficiently low to be negligible in most applications. However, if the signal under study has a very low duty factor, the discharge can become a serious source of performance degradation. In such applications, it is advisable to equip the Model 162 with the Digital Storage Option. This option is basically a two-channel analog-to-digital-to-analog converter. When the Sampling switch opens at the end of each sample interval, the ac-

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quired charge is digitized and loaded into a digital storage register. The digital register contents are then read by a digital-to-analog converter which produces a dc voltage equal to the acquired charge on the capacitor. This dc voltage is fed back to the integrator to maintain its output potential at the same level until the next sample is taken, however long that may be.

Output Signal Processing: The output of each Processor Module is applied to the main-frame Signal Processing circuitry. The Model 162 is supplied with three standard signal processing 'functions', A only, B only, and A-B. In addition, there is provision for installing two plug-in optional function cards, if desired. Currently available options include A x B, A/B, and the log of A/B. User-designed and constructed optional functions can also be installed.

A front-panel switch selects the desired function. Whatever function has been selected is performed and the resulting signal applied to an output smoothing filter that provides additional noise suppression and meter damping. The smoothed signal is made available at the f(t) OUTPUT connector. A derivative output proportional to the rate of change of the output signal is also provided ($\dot{f}(t)$ OUTPUT). If one of the optional functions is selected and the option in question has not been installed (including digital storage), a front-panel OPTIONS indicator lamp lights and there is no output.

Baseline Sampling: The Model 163 Processor Module is provided with a special baseline sampling function. When baseline sampling is selected, the sampling gate alternately samples the signal and then the baseline. The signal aperture position is determined by the % Initial Delay dial setting and Scan Ramp voltage as explained previously. However, the position of the baseline sample is determined solely by the M163 Baseline Sampling Delay control. A separate integrating circuit is provided to average the sampled segment of the baseline. In baseline sampling operation, the Model 163 output is the difference between the average value of the signal sample and the average value of the baseline sample. As a result, automatic compensation is provided for baseline wander.

2.3 APPLICATIONS

2.3A PICOSECOND DOMAIN FLUORESCENCE STUDIES

Interest in the study of fluorescence decay processes has grown rapidly in recent years, and efforts to study such processes in the picosecond region have become desirable. Such processes yield information about molecular and crystal structure and provide insight into excitation processes which can help in defining reaction mechanisms.

The natural noise-producing processes and the usual extremely low light levels involved in picosecond time domain studies dictate the use of signal averaging techniques. In addition, the use of a boxcar averager permits the 'time-translation' of the event under study from the picosecond domain to millisecond or second ranges where display on an oscilloscope or x-y plotter is feasible. The Model 162 with one or two Model 163 Processor Modules meets this need with resolution as high as 100 ps, depending on the choice of sam-

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pling head. Moreover, the baseline sampling mode built into the Model 163 enables it to automatically compensate for dc drifts in the detector or in the associated electronics. In dual-channel operation with the optional 'ratio' function installed, the Model 162 can automatically compensate for fluctuations in the excitation source so that they do not include error in the resultant measurement. When the optional 'log ratio' function is installed, the decay plot will appear as a straight line, or as a series of connected straight-line segments with different slopes if the spectra is complex. In applications involving low repetition rates, use of the digital storage option allows results to be obtained that are as good as those one would normally consider to be achievable at high repetition rates only.

2.3B FLUORESCENCE AND PHOSPHORESCENCE DECAY STUDIES

Many fluorescence and phosphorescence studies fall well outside the picosecond domain and therefore do not require ultra-fast instrumentation. The Model 162 with one or two Model 164 Processor Modules is an economical approach to these studies. Gating resolution is continuously variable from 5 ns to 5 ms. Dual-channel operation with the optional 'ratio' function installed provides automatic compensation for fluctuations in source power. Dual-channel operation also permits automatic compensation for baseline wander. In applications where the availability of only a few samples of the decay waveform make exponential averaging impractical, the Model 164 plug-in module offers a switch-selectable choice of exponential or summation averaging.

2.3C PULSED ULTRASONICS

The Model 162 can also be used in pulsed ultrasonics studies. Applications of pulsed ultrasonics to the study of materials and the examination of their internal structure are widespread. In this and other pulsed ultrasonic applications, the use of a boxcar averager permits separation of the echo originating in the region of interest from all other spurious signals while providing marked improvement in the signal-to-noise ratio.

2.3D PULSED RESONANCE EXPERIMENTS

In all applications of pulse-excited resonance, for both nuclear and electron resonance studies, application of a suitable signal averager permits the recovery of free induction decay waveforms and allows examination of the transitions induced by complex pulse sequences. Even though signals in these experiments are often extremely weak, and noise pickup by detectors is often a major problem, the boxcar averager easily separates the resonance signal from any obscuring influence.

2.3E LASER DEVELOPMENT

The use of pulse techniques in laser development continues to gain acceptance as a practical and convenient method of determining operating parameters, even when the laser is being developed for continuous operation. This growing acceptance is due in part to the accuracy obtainable by this technique and in part to the simplifications in prototype laser construction made possible by the reduced heat dissipation of pulsed operation. The boxcar integrator, with its variable gate width and automatic scanning capability, is

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ideally suited to laser research. When extremely narrow pulses are being generated and very fine resolution is required, the Model 162 Boxcar Averager with the Model 163 Processor Module can provide resolution to 100 ps with built-in automatic baseline compensation that eliminates the effects of dc drifts. The use of two plug-in modules permits the Model 162 to simultaneously measure the output of two lasers and read out the difference, or optionally, the product, ratio, or log of the ratio. If a two-pen X-Y recorder is available, the output waveform of each laser can be plotted simultaneously for visual comparison. In addition, in some applications, particularly those involving high-power lasers, low duty factors are a must. The digital storage option, which provides virtually infinite holding time for each channel, permits the Model 162 to accurately average signals having an extremely low duty factor.

2.3F OPTICAL ABSORPTION STUDIES

Pulsed excitation is an attractive technique for making optical absorption measurements. This is due in part to the higher excitation powers, made possible by the reduced heat generated in the sample by pulsed excitation as compared to continuous excitation. The Model 162 operated dual channel can also monitor the output of the pulsed exciter and automatically compensate for power fluctuations. If Model 163 plug-in modules are employed, automatic compensation for dc drifts in the detectors will also be provided so that the output is an accurate representation of the signal, free from outside influence. If Model 164 modules are employed, the continuously variable gatewidth permits the averaging parameters to be optimized to the signal source.

2.3G SAMPLING SCOPE

When used with an accessory oscilloscope, the Model 162 becomes a high-performance, variable-gatewidth, sampling scope. Actual performance parameters depend on the plug-in modules utilized. The Model 163 module offers a resolution from 100 ps to 1 ns, depending on the Sampling Head used, with automatic baseline compensation for ultra-fast drift-free sampling. The Model 164 module offers continuously variable gatewidths ranging from 5 ns to 5 ms, enabling the sampling time to be optimized to the signal under study. Dual-channel operation employing a pair of either type modules can provide simultaneous display of two waveforms if a dual-beam/dual-trace oscilloscope is available.

2.3H OTHER APPLICATIONS

Princeton Applied Research Corporation's Boxcar Averagers have already proven their worth in applications such as electro-reflectance, pulsed Raman spectroscopy, measurement of non-linear electro-optical properties of materials using high-power pulsed-laser techniques, dual-beam magnetic resonance, phonon relaxation time studies, spin-echo measurements, and ion-drift velocity investigations.

2.4 SPECIFICATIONS

2.4A MODEL 162 BOXCAR AVERAGER (MAIN FRAME)

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TIMING AND CONTROL

TRIGGER MODES:

(1) EXTERNAL: Unit can be triggered on either positive or negative going edge of external signal applied to a front-panel BNC connector. Trigger level is adjustable over a range of ±15 V. Input impedance is 50 kΩ. Maximum input is ±100 V. Minimum trigger duration is 10 ns. Minimum amplitude is 0.5 V baseline-to-peak.

(2) INTERNAL: Automatic repetitive triggering with period approximately equal to the selected Aperture Delay Range plus retrace time.

(3) LINE TRIGGERING: Unit can be triggered on either the positive or negative going slope of ac power line voltage.

MAXIMUM SYSTEM TRIGGER RATE: For the Model 163, 10 kHz. For the Model 164, 5 MHz.

APERTURE DELAY: The interval between triggering and the beginning of the aperture opening can be independently adjusted for each channel from about 3% to 100% of the selected Aperture Delay Range by means of calibrated ten-turn % INITIAL DELAY dials (aperture may not open below 3%). Resultant delay will be that dialed plus a minimum delay of nominally 75 ns (max. 100 ns). There is also provision for automatically scanning the aperture time position from the set % delay to the end of the Aperture Delay Range. Nominal 75 ns minimum delay applies in scanned operation as well.

(1) APERTURE DELAY RANGE: Selectable in 1-2-5 sequence from 0.1 µs to 50 ms. There is also provision for a special user-installed range which allows one to obtain an Aperture Delay Range intermediate to, or longer than, those provided. The Aperture Delay Range setting is accurate to ±2% of range. Accuracy of a specific dialed delay must take 75 ns (nominal) minimum delay into account as well.

(2) % INITIAL DELAY LINEARITY: Controls are linear to ±0.25% of range or ±3 ns, whichever is greater.

(3) DELAY JITTER: 50 ps rms or 0.05% of the selected Aperture Delay Range, whichever is greater.

APERTURE DURATION: A function of the type of Processor Module used.

(1) MODEL 163: Choice of 25 ps, 30 ps, 75 ps, 350 ps, or 1 ns fixed aperture as determined by the type of plug-in Sampling Head used. Resolution is limited to 100 ps by the delay jitter.

(2) MODEL 164: Aperture continuously variable from 5 ns to 5 ms. Aperture Duration control is located on front panel of main frame. There is also a 'special' range which can be used to achieve AD's intermediate to, or longer than, those provided. Minimum "special" AD is nominally 50 ns. A M164 Trim adjustment having a total range of 20%

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of the set aperture duration allows aperture duration matching in dual channel operation. Aperture duration selected at main frame is obtained with TRIM set to center of range.

APERTURE POSITION: Independent selection of manually adjusted delay or automatic scanning provided for each channel.

(1) MANUAL: Aperture position (delay between trigger and aperture) independently adjusted for each channel by % Initial Delay dials with full-scale delay being 100% of the selected Aperture Delay Range. NOTE: Reliable operation is uncertain with dialed delays of less than 3%. Also, total delay is dialed delay plus minimum of 75 ns nominal (max. is 100 ns).

(2) SCAN: Aperture position automatically scanned from dialed delay to 100% of selected Aperture Delay Range. One or both channels can be scanned, but scan rate is same for both. There is provision for scanning from internally or externally derived control signal. NOTE: If dial setting is less than 3%, aperture may not open while the first 3% of the Delay Range is being scanned. Normal operation over the remaining 97% is assured. Minimum 75 ns (nominal) delay applies in scanned operation as well as in manual.

(a) INTERNAL: Time required to scan aperture over entire Aperture Delay Range is that selected by SCAN TIME control, which allows scan times from 0.01 s to 100,000 s to be selected. Actual experimental time will be less if scan is restricted to only a portion of the Aperture Delay Range by using % INITIAL DELAY dials (scan always begins at dialed delay, not at '0'). Accuracy of selected Scan Time is ±15% (multiplier to CAL. position).

(b) EXTERNAL: Scan time determined by external program applied to rear-panel SCAN IN/OUT connector. Sensitivity is 10% of Aperture Delay Range per +1 V applied. Maximum program dV/dt is 10 V/ms. Input impedance is 10 kΩ. Maximum input without damage is +20 V.

SIGNAL PROCESSING

FUNCTIONS: The Model 162 is supplied with three standard output functions. Any two of four additional optional functions can be incorporated into the instrument, if desired. The optional function circuits are contained on plug-in circuit cards for which two mating connectors have been provided in the instrument, allowing the instrument to be equipped with no more than two options at one time. A front-panel OPTIONS light glows if an option is selected which has not been installed. NOTE: Limit of two options does not include Digital Storage.

(1) STANDARD FUNCTIONS

(a) Channel A Output only (A).

(b) Channel B Output only (B).

(c) Channel A Output minus Channel B Output (A-B).

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(2) OPTIONAL FUNCTIONS

(a) Model 162/95, AxB: Channel A Output multiplied by Channel B Output. AxB Option has two modes of operation, AxB and A/|B|, as selected by switch on the Option Board. In the AxB mode, transfer function is E_{out} = 0.1 AxB. Product accuracy is ±0.3% of full scale. In A/|B| mode, transfer function is E_{out} = 10 (A/|B|). Ratio accuracy is ±0.3% of full scale for |B| = 10 V (full scale), and ±0.7% for |B| = 1 V (10% of full scale). NOTE: Accuracy specifications are for option only. Error introduced in option will be in addition to any error introduced elsewhere in instrument.

(b) Model 162/97, A/|B|: Channel A Output divided by Channel B Output. Transfer function is E_{out} = 10 (A/|B|). Ratio accuracy is ±0.3% of full scale for |B| = 10 V (full scale) and ±0.5% of full scale for |B| = 200 mV (2% of full scale). NOTE: Accuracy specifications are for option only. Error introduced by option will be in addition to any error introduced elsewhere in instrument.

(c) Model 162/96, log (|A|/|B|): Logarithm of Channel A Output divided by Channel B Output. Transfer function is 4.00 $\log_{10}$ (|A|/|B|). Typical accuracy is as shown below. NOTE: Errors introduced by option will be in addition to any errors originating elsewhere in system. Note that scale factor is 4 V per decade.

RATIO	OUTPUT	ERROR IN OUTPUT VOLTAGE AS A FUNCTION OF B MAGNITUDE		
|A|/|B|	4 $\log_{10}$ (|A|/|B|)	B = 10 V	B = 1 V	B = 100 mV
1.0	0 V	10 mV	10 mV	40 mV
0.316	-2.000 V	10 mV	20 mV	150 mV
0.10	-4.000 V	10 mV	40 mV	400 mV
0.0316	-6.000 V	10 mV	150 mV	--
0.01	-8.000 V	20 mV	400 mV	--
0.00316	-10.000 V	60 mV	--	--

(d) User designed and constructed function (SPECIAL). Blank circuit boards can be purchased from Princeton Applied Research Corporation.

DIGITAL STORAGE OPTION: The Model 162/99 Digital Storage modification (option) provides the analog integrators with virtually infinite storage (holding) time. As installed (factory or field), two single channel processor modules (Models 163, 164) may be accommodated with a single addi-

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tional printed circuit board added to the main frame (Model 162). Each channel comprises a unique Analog-to-Digital-to-Analog converter whose output reinforces the integrator's output and prevents loss of memory. Note that the Digital Storage Option can be installed in addition to any two of the previously described optional functions.

(1) ENCODE TIME: 1 ms ±10%.

(2) ACCURACY: ±.1% of full scale (Dig. Storage only; will be in addition to any other errors).

(3) SHORT TERM HOLDING TIME: ±0.02%/minute, typical.
±0.2%/minute, maximum.

(4) LONG TERM HOLDING TIME: Virtually infinite for a ±1.0% full-scale error.

TIME CONSTANT: Output smoothing filter with time constant adjustable in decade steps from 0.1 ms to 100 s. Continuously adjustable multiplier allows selected time constant to be increased by as much as X10.

OUTPUTS:

(1) ANALOG PANEL METER: Taut-band construction; ±2% of full scale accurate; center-zero standard.

(2) DIGITAL PANEL METER (Option 162/98): 3½ digit display with digital output in BCD format provided at rear-panel connector. Meter accuracy is ±0.1% ±1 count. BCD output is in positive sense logic. Logic 0 = 0 V ±0.2 V, 5 mA maximum sinking current. Logic 1 = +3.5 V ±1 V, 100 μA maximum sourcing current.

(3) ANALOG OUTPUT: Smoothed output of function selected. ±10 V corresponds to full scale. Output impedance is 1 kΩ. Taking the signal at the Processor Module OUT pinjack as E_{in}, and that at this connector as E_{out}, the transfer function is:

$$\frac{E_{out}}{E_{in}} = \frac{-1}{1 + j\omega T}$$

where ω is 2πf and T is the main-frame Time Constant.

(4) ANALOG TIME DERIVATIVE: Output proportional to rate of change of Analog Output. Maximum out is ±10 V. Output impedance is 1 kΩ. NOTE: Taking the signal at the Processor Module OUT pinjack as E_{in}, and that at this connector as E_{out}, the transfer function is:

$$\frac{E_{out}}{E_{in}} = \frac{kA}{9} \frac{1}{1 + 1/j\omega T}$$

where ω = 2πf and T is the main-frame Time Constant. A is a variable

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gain factor dependent on the setting of the inner knob of the Time Constant switch, and varies from X10 (CAL. position) to X1 (X10 position). Note that A is also a component of T. k is another gain factor set by internal adjustment with range of X1 to X50. Factory setting for k is $10/2\pi$.

NOTE: No more than ±20 V can be applied to the Analog or Analog Time Derivative Outputs without damaging circuitry.

SYSTEM GAIN STABILITY: Less than 0.01%/°C and less than 0.1%/week.

SYSTEM DC DRIFT: A function of the Processor Module. After a one hour warmup the dc drift referred to the input is as follows.

(1) MODEL 163: 200 µV/°C typical. 10 µV/°C if Sampling Head is remotely operated and maintained at a constant temperature.

(2) MODEL 164: Less than 20 µV/°C.

GENERAL

SIZE: 17-1/8" W x 7" H x 18-1/4" D (43.6 cm W x 17.8 cm H x 46.5 cm D).

WEIGHT: 27 lb (12.3 kg).

POWER REQUIREMENTS: 105-125 or 210-250 V ac, 50-60 Hz, 50 VA maximum with typical loading.

FUSES: Rear-panel line fuse, 1.0 A SLOW-BLOW, 125 V, for operation from 105-125 V ac; 0.5 A SLOW-BLOW, 250 V, for operation from 210-250 V ac. Also, there are two internal fuses, 1/4 A, 125 V, SLOW-BLOW, that protect the ±50 V supplies.

2.4B MODEL 163 SAMPLED INTEGRATOR

HOLD TIME

Hold Time is defined in terms of the minimum trigger repetition rate that will result in no more than 1% of full-scale error. For the Model 163 the rate is 5 Hz in "normal" mode and 50 Hz in Baseline Sampling mode. In sampling scope applications, larger errors are generally tolerable, allowing lower minimum trigger rates to be used. If the unit is equipped with the digital storage option, lower trigger rates without performance degradation due to hold-time limitations can be accommodated (see Digital Storage Option specifications).

BASELINE SAMPLING

(1) FREQUENCY: Every other repetition; signal sampling cycles and baseline sampling cycles alternate.

(2) BASELINE SAMPLE DURATION: Same as for signal sample.

(3) BASELINE SAMPLING AVERAGING: Same as for signal sampling averaging.

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(4) M163 OUTPUT: Difference between average of signal sample and average of baseline sample. With Baseline Averaging not operative, output is difference between average of signal sample and ground.

(5) BASELINE SAMPLE POSITION: As set by front-panel uncalibrated control that allows baseline sample to be positioned over the range of about 5% to 100% of the Aperture Delay Range. Alternatively, position of baseline aperture can be set by externally derived voltage applied to M163 front-panel pin jack. NOTE: Control that sets position of baseline aperture also turns baseline sampling function on or off. Note that 75 ns (nominal) minimum delay applies to baseline sampling aperture delay as well as to signal sampling aperture delay.

(6) COMMON MODE REJECTION RATIO: >100:1 for signals <50% of full scale.

INPUT CHARACTERISTICS

(1) SENSITIVITY (full-scale): ±100 mV, ±250 mV, or ±1 V, switch selectable. Accuracy at each setting is ±2%.

(2) MAXIMUM SAFE INPUT: ±5 V. NOTE: Limit due to Sampling Head. Maximum input level can be raised by use of appropriate input attenuators.

(3) PARAMETERS THAT VARY AS FUNCTION OF SAMPLING HEAD TYPE

Sampling Head Type	Input Impedance	Coupling	Aperture Duration*	Pk-pk Sampling Noise (Sam.Av. set to 1)
S-1	50 Ω	dc	350 ps	5 mV
S-2	50 Ω	dc	75 ps	10 mV
S-3A	built-in probe; 100 kΩ shunted by 2.3 pF	dc	350 ps	20 mV
S-4	50 Ω	dc	25 ps	10 mV
S-5	1 MΩ shunted by 15 pF	ac/dc	1 ns	2 mV
S-6	50 Ω	dc	30 ps	10 mV

*NOTE: Effective Aperture Duration limited to 100 ps by delay jitter of Model 162/163.

Table II-1. SAMPLING HEAD PARAMETERS

SIGNAL-TO-NOISE IMPROVEMENT

Dependent on number of samples of which the M163 output is the average.

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This number, selectable in decade steps from 1 to 10 by front-panel SAMPLES AVERAGED switch, applies when the actual number of repetitions is large relative to the selected SAMPLES AVERAGED. Improvement in signal-to-noise ratio varies as the square root of the selected SAMPLES AVERAGED. When using baseline sampling, baseline samples are averaged in the same manner as signal samples.

LINEARITY

The deviation of the output from: (f.s.) x (IN), where f.s. is the output with a full-scale input applied and IN is the input expressed as a fraction of a full-scale input, is typically ±0.25%. This spec. is degraded at low duty factors.

COHERENT PICKUP

Less than 1 mV pk-pk referred to input. Varies with delay.

OVERLOAD CAPABILITY

If total input (coherent plus non-coherent signal) is full scale or smaller, spurious output will be less than 1% of full scale. Overload level signals at inputs to both signal and baseline sampling gates trigger front-panel Overload indicator lamp.

ZERO

Zeroing is provided by a front-panel control. Full-scale total range with Baseline Sampling turned OFF. Total range with Baseline Sampling turned ON is nominally 20% of full scale. Zero range is not necessarily symmetrical with respect to "0" output.

CLEAR

Pushbutton switch resets output of all processor modules and digital storage option, if installed, to zero. Corresponds to CLEAR pushbutton in a Model 164.

OUTPUTS

(1) SIGNAL MONITOR OUTPUT: Inverted ±10 V full-scale module output available at front-panel pin jack. Output impedance is 1 kΩ. NOTE: No more than ±20 V can be applied to this output without damaging instrument.

(2) GATE OUT: 0.5 μs marker pulse to indicate aperture position. If baseline sampling is used, two 0.5 μs marker pulses are provided, one to show the position of the signal sampling aperture, the other to show the position of the baseline sampling aperture. There is typically 10 ns delay between the time the aperture opens and the leading edge of the corresponding marker pulse. Marker pulse amplitude is nominally +1 V into 50 ohms; + 3 V into open circuit. NOTE: No more

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than ±20 V can be applied to this output without damaging the instrument.

(3) TRIGGER TAKEOFF: Limited rise-time replica of input signal available at this output. With noise-free input, this output can be used to trigger main frame or other peripheral apparatus. The amplitude is twice that of the input signal. The source impedance is 50 Ω and the baseline is at +2 V.

GENERAL

(1) SIZE: 2-5/8" W x 6-5/8" H x 15" D (7.3 cm W x 17.5 cm H x 38.1 cm D).

(2) WEIGHT: 5 lb (2.3 kg) maximum.

(3) POWER REQUIREMENTS: Power is supplied by Model 162 Main Frame.

2.4C MODEL 164 GATED INTEGRATOR

INPUT CHARACTERISTICS

(1) SENSITIVITY (full scale): ±100 mV. Accuracy is ±2%.

(2) MAXIMUM SAFE INPUT: ±10 V.

(3) INPUT COUPLING: ac or dc, switch selectable. Ac coupling time constant is one second. Pushbutton allows input circuit to be internally grounded for convenient zero adjustment.

(4) INPUT IMPEDANCE: 50 Ω or 1 MΩ shunted by 25 pF, switch selectable.

(5) OVERLOAD CAPABILITY: If total input (coherent plus non-coherent signal) is 400 mV (either polarity with respect to ground) or smaller, spurious output will be less than 1% of full scale. Overload level signals at gate input will trigger front-panel Overload light.

APERTURE DURATION

Continuously variable from 5 ns to 5 ms by means of front-panel switch and multiplier. Also provision for user-installed 'special' range for achieving aperture durations longer than, or intermediate to, those provided, down to a minimum of nominally 50 ns. M164 front-panel control allows aperture duration to be trimmed for matching aperture durations in dual-channel operation. Total range of trim is 20% of selected Aperture Duration. Selected aperture is obtained with TRIM set to center of range.

SAMPLING NOISE

With minimum M164 Time Constant, pk-pk sampling noise referred to input varies with Aperture Duration as follows.

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AD	PK-PK SAMPLING NOISE
10 ns < AD < 100 ns	< 2 mV
100 ns < AD < 1 µs	< 1 mV
1 µs < AD < 10 µs	< 500 µV
10 µs < AD	< 200 µV

HOLD TIME

Hold time is defined in terms of the minimum trigger repetition rate that will result in no more than 1% of full-scale error. For the Model 164, this rate depends on the setting of the Aperture Duration switch and on the actual aperture duration (aperture duration will be longer than switch setting if Multiplier is not in CAL. position). If the Aperture Duration switch is set to 5, 50, or 500 µs, the trigger rate can be as low as 2×10^{-7} divided by the actual aperture duration. If the Aperture Duration switch is set to any position below 5 µs, the trigger rate can be as low as 2×10^{-5} divided by the actual aperture duration. In sampling scope application, 5% aberrations are generally acceptable, allowing a factor of five further reduction in the minimum trigger rate. NOTE: If the unit is equipped with the digital storage option, lower trigger rates can be accommodated without performance degradation.

SIGNAL-TO-NOISE IMPROVEMENT

(1) SUMMATION (LINEAR) AVERAGING

Varies as the square root of the number of repetitions of the applied signal. Model 164 Time Constant and Aperture Duration have no effect on signal-to-noise improvement.

(2) EXPONENTIAL AVERAGING

Varies as the square root of the number of samples of which the output is the average. Output is the average of 2TC/AD samples, where TC is the M164 Time Constant and AD is the Aperture Duration, and providing enough repetitions have occurred for a total analysis time (repetitions x aperture duration) of at least 5TC.

TIME CONSTANT

Front-panel switch allows choice of decade-spaced time constants from 1 µs to 10 ms plus SPECIAL, in which a Time Constant intermediate to, or larger than, those provided can be set by user-installed internal capacitor.

LINEARITY

When system has been zeroed and gain-calibrated, the deviation of the output from (f.s.)x(IN), where f.s. = full scale and IN = input expressed as fraction of full scale, is typically ±0.1% of full scale. This spec. is degraded at low duty factors.

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COHERENT PICKUP

(1) Delay-variable pickup: Less than 2 mV pk-pk referred to input.

(2) Delay-independent pickup: With 1 mΩ input Z selected, pickup can be as large as 20% of full scale. Because this pickup appears as dc offset which does not vary with delay, it can be cancelled with ZERO control.

ZERO

Zeroing provided by front-panel control with total range of 100 mV relative to input of M164. Range not necessarily symmetrical with respect to "0".

CLEAR

Pushbutton switch resets output of all Processor Modules and Digital Storage Option, if installed, to zero. Corresponds to M163 CLEAR pushbutton.

OUTPUTS

(1) SIGNAL MONITOR OUTPUT: Inverted ±10 V full-scale module output available at front-panel pin jack. Output impedance is 1 kΩ. NOTE: No more than ±20 V can be applied to this output without damaging instrument.

(2) GATE OUT: Marker pulse equal in duration to selected Aperture Duration is provided at front-panel BNC connector. There is a 10 ns delay (nominal) between actual aperture opening and leading edge of marker pulse. Amplitude is nominally +1 V into 50 Ω; +5 V into open circuit. Width of marker pulse tracks aperture duration down to about 50 ns if terminated in 50 ohms.

GAIN CALIBRATION

100 mV ±0.25% internally developed voltage is available for calibrating M164 gain using front-panel Gain Adjustment which has range of ±10% of full scale. Permits gain matching in dual-channel operation.

GENERAL

(1) SIZE: 2-5/8" W x 6-5/8" H x 15" D (7.3 cm W x 17.5 cm H x 38.1 cm D).

(2) WEIGHT: 2 lb (0.9 kg) maximum.

(3) POWER REQUIREMENTS: Power is supplied by Model 162 main frame.

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SECTION III
INITIAL CHECKS

3.1 INTRODUCTION

The following procedure is provided to facilitate initial performance checking of the Model 162 Boxcar Averager and its associated Processor Modules. This procedure should be performed after inspecting the instrument for shipping damage (any noted to be reported to the carrier and to Princeton Applied Research Corporation), but before using it to make measurements. Should any difficulty be encountered in carrying out these checks, contact the factory or one of its representatives, a list of whom appears at the end of the manual. It might be mentioned that it is not the purpose of these checks to demonstrate that the instrument meets its specifications, but rather simply to show that it has arrived in good working order. Each instrument receives a painstaking alignment and checkout before leaving the factory and users can have a high degree of confidence that their Model 162 will meet or exceed all specifications if no shipping damage has occurred. The following checks will usually reveal any such damage.

Note that the checkout procedure calls for operating the Model 162 in conjunction with either a Model 163 or a Model 164. If the customer has two modules, either of different types or both the same type, they should be checked out one at a time. Once each has been checked, dual-channel checks can be performed as indicated.

3.2 EQUIPMENT NEEDED

(1) Square-wave source capable of furnishing 0-to-100 mV 1 kHz square waves and 0-to-1 V 1 kHz square waves, the two to be synchronous. It should be possible to set the 100 mV level to within a few percent of the desired level. The 1 V level, however, is not critical as long as the amplitude is high enough to trigger the M162 (±0.5 V minimum). This is most easily done by using a 1 V source followed by a 10:1 attenuator, arranged such that the 1 V square wave can be applied to the Ext. Trigger input of the Model 162 and the 100 mV square wave can be applied to the Signal Input of either the Model 163 or the Model 164. The 100 mV source should be such that the amplitude will be 100 mV when loaded with 50 ohms. The 1 V source will be driving the 50 kΩ input impedance of the Trigger Input so that loading considerations for the 1 V signal shouldn't be critical. NOTE: If the Processor Module is a Model 163 equipped with either a Type S-3A or S-5 Sampling Head, the signal input impedance will be high (100 kΩ and 1 MΩ respectively), simplifying input loading considerations for the 100 mV source as well. If the Processor Module is a Model 164, plan to use the 50 Ω input impedance. The TEKTRONIX type 114 Pulse Generator is a suitable signal source.

(2) Oscilloscope suitable for monitoring 1 μs 5 V pulses.

(3) Watch with second hand, or a stop watch.

(4) Coaxial cables having a characteristic impedance of 50 ohms and fitted with BNC connectors.

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3.3 PRELIMINARY STEPS

(1) Check the position of the rear-panel Line Voltage Selector switch. For operation from a line voltage in the range of 105-125 V ac, '115' should show in the switch window. For operation from a line voltage in the range of 210-250 V ac, '230' should show.

(2) Plug the Processor Module into the 'A' (lefthand) module receptacle. If the module is a Model 163, first plug the Sampling Head (TEKTRONIX S-1, S-2, S-3A, S-4, S-5, or S-6) into the module. NOTE: If the Sampling Head is other than a Model S-5, it will be necessary to mount the Head on an Extender (supplied) to give access to the DC BALANCE adjustment (left side facing unit from front). In the case of an S-5, the DC BALANCE adjustment is on the front and use of the extender is not required. Most Sampling Heads also have a right-side adjustment. This right-side adjustment ABSOLUTELY SHOULD NOT BE DISTURBED. Next plug in the line cord and turn the Power switch on. If Sampling Head is an S-5, select dc coupling. The meter reading may be either on or off scale, depending on the setting of the front-panel controls. The front-panel Indicator lamps may or may not be on. Allow about five minutes for the instrument to warm up before proceeding.

3.4 PROCEDURE IF PROCESSOR MODULE IS MODEL 163 (If Model 164, go to Subsection 3.5)

(1) Set the controls as follows.

MAIN FRAME

% INITIAL A	10% (one revolution from fully counterclockwise position)
% INITIAL B	fully counterclockwise
APERTURE DELAY RANGE	1 mSEC
APERTURE DURATION	setting immaterial
SCAN TIME	10 SEC (mul. to CAL)
FUNCTION	A (digital storage selector OFF)
TIME CONSTANT	.1 mSEC (mul. to CAL)
TRIGGER MODE pushbuttons	EXT depressed; all others released
SCAN SELECT pushbuttons	all released

MODEL 163

INPUT RANGE	1 V
SAMPLES AVERAGED	1
BASELINE SAMPLE DELAY	fully counterclockwise; center pushbutton depressed
COUPLING (sampling-head switch, if present)	DC

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(2) Triggering

(a) Connect the 0-to-1 V square wave at 1 kHz to the Trigger INPUT connector (main-frame front panel).

(b) Adjust the TRIGGER LEVEL control (main-frame front panel) as required to establish proper triggering as indicated by a steady glow of the TRIGGERED lamp (main frame).

(3) Zero and DC Bal.

(a) Adjust the M163 ZERO control for '0' panel meter indication.

(b) Change the setting of the INPUT RANGE switch to 100 mV. Then adjust the Sampling Head DC BAL adjustment for '0' on the panel meter.

(c) Return the INPUT RANGE switch to 1 V and adjust Zero again. Continue in this manner, alternating between the 1 V and 100 mV positions while adjusting the ZERO and DC BAL adjustments until no further improvement in the '0' indication can be made. Leave the INPUT RANGE switch set to 100 mV.

When the Zero Adjustment and DC Balance Adjustments are completed, remove the extender and return the Sampling Head to its normal position. The power should be off for this operation.

(4) Signal Processing - Manual Delay

(a) Connect the signal source (but with signal turned "off") to the Sampling Head input. Then adjust the M163 ZERO control for "0" panel meter indication.

(b) Turn on the 0-to-100 mV square wave (should already be connected from preceding step). NOTE: If the input impedance of the Sampling Head is 50 ohms, be sure to take the loading effect into account; the signal should be 100 mV when loaded with the Sampling Head input impedance.

(c) The panel meter indication should be nominally full-scale to the right. The tolerance will be that of the 100 mV input signal amplitude plus or minus the gain tolerance of the M162/163.

(d) Adjust the signal amplitude at the source to get the desired full-scale indication.

(e) Begin rotating the % INITIAL A dial clockwise. At about the 50% point the meter indication will drop to '0', indicating that the lower level of the 0-to-100 mV square wave is being sampled. The actual point where the crossover from full-scale to '0' occurs will vary according to the symmetry of the input square wave. From 50% to 100% delay (five revolutions to ten revolutions, the maximum), the '0' indication will be maintained. If the period

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of the input signal is a bit short, towards 100% delay the meter indication might rise again to full scale, indicating that the upper level of the next cycle is being sampled. After verifying the indicated behavior, leave the % INITIAL DELAY dial set to 10%.

(5) Signal Processing - Scanned Operation

(a) Depress the SCAN SELECT 'A' pushbutton.

(b) Hold in the SCAN SELECT RESET pushbutton. While the button is held down, the panel meter will indicate nominally full scale. At some convenient time, release the RESET pushbutton. The panel meter will continue to indicate full scale for about four seconds, indicating that the upper level of the input square wave is being scanned. Then the indication will drop to '0', where it will remain for about five seconds as the lower level of the square wave is scanned. These nine second (nominal) 'cycles' of four seconds of full-scale indication followed by five seconds of '0' indication will follow one another automatically.

(6) Baseline Sampling and Gate Out

(a) Connect the oscilloscope signal input to the M163 GATE OUT connector. The oscilloscope should be triggered on the positive edge of the same signal as is being used to trigger the Model 162. The sweep time should be 100 μs per cm.

(b) A 0.5 μs marker pulse should be visible on the oscilloscope. As the scan cycles repeat, this marker pulse will be observed to 'slide' across the trace, taking nominally nine seconds to complete each scan. At the end of each scan, the pulse position will reset to the sweep beginning and then start to scan again.

(c) Turn the BASELINE SAMPLE DELAY control (M163) clockwise. As soon as the control is rotated off the fully counterclockwise position, a second 0.5 μs pulse will be noted. This one will not scan. Its position is determined by the setting of the BASELINE SAMPLE DELAY control. With the control as far counterclockwise as it can be without turning the Baseline Sampling function off, the second pulse will be positioned near the beginning of the scope trace. With the control fully clockwise, this pulse will be at the end of the trace.

(d) Note the panel-meter indication as a function of the position of the two marker pulses. When both pulses are on the same half of the input square wave (both on the left half of the scope trace or both on the right half), the panel meter will indicate '0'. When both pulses are on opposite halves of the trace, the panel meter will indicate nominally full scale, either plus or minus. When the signal aperture marker is on the left half of the trace and the baseline aperture marker on the right, full-scale positive output is obtained. When their positions are reversed,

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full-scale negative output is obtained. If the oscilloscope has dual-sweep capabilities, it may prove instructive to monitor the input signal simultaneously so that the position of the apertures relative to the input square wave can be more easily seen.

NOTE: This completes the Initial Checks for a system consisting of a Model 162 and a single Model 163. If there is a second Model 163 to be checked, plug it into module receptacle 'B', and return to step 1, the only difference being that instead of setting the FUNCTION switch to 'A', set it to 'B'. Once the second one is checked out, go to Subsection 3.6 to check dual-channel operation.

3.5 PROCEDURE IF PROCESSOR MODULE IS MODEL 164

3.5A CHECKS IN THE EXTERNAL TRIGGER MODE

(1) Set the controls as follows.

MAIN FRAME

% INITIAL A	10% (one revolution from fully counterclockwise position)
% INITIAL B	fully counterclockwise
APERTURE DELAY RANGE	1 mSEC
APERTURE DURATION	5 µSEC (multiplier to CAL)
SCAN TIME	10 SEC (multiplier to CAL)
FUNCTION	A (digital storage OFF)
TIME CONSTANT	.1 mSEC (multiplier to CAL)
TRIGGER MODE pushbuttons	EXT depressed; all others released
SCAN SELECT pushbuttons	all released

MODEL 164

TIME CONSTANT	1 µSEC
Pushbuttons	EXP/SUM, CAL, GND, and DC/AC depressed; all others released

(2) Triggering

(a) Connect the 1 V square wave at 1 kHz to the Trigger INPUT connector (main-frame front panel).

(b) Adjust the TRIGGER LEVEL control as required to establish proper triggering as indicated by a steady glow of the TRIGGERED lamp (main frame).

(3) Zero and Gain Calibration

(a) Adjust the Model 164 ZERO control for '0' panel meter indication.

(b) Release the GND pushbutton. Then set the screwdriver adjustment associated with the CAL pushbutton for exactly full-scale panel meter indication.

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(c) Release the CAL pushbutton.

(4) Signal Processing - Manual Delay

(a) Connect the 0-to-100 mV square wave to the INPUT of the Model 164. NOTE: Be sure to take the loading effect of the 50 ohm input impedance into account; the signal should be 100 mV loaded with 50 ohms.

(b) Note the panel meter indication, which should be nominally full-scale to the right. The tolerance is simply that of the source signal amplitude. Adjust the source amplitude as required to get exactly full-scale meter indication.

(c) Begin rotating the % INITIAL A dial clockwise. At about the 50% point the meter indication will drop to '0', indicating that the lower level of the 0-to-100 mV square wave is being sampled. The actual point where the crossover from full-scale to '0' occurs will vary according to the symmetry of the input square wave. From 50% to 100% delay (five revolutions to ten revolutions), the '0' indication will be maintained. If the period of the input signal is a bit short, towards 100% delay the meter indication might rise again to full scale, indicating that the upper level of the next cycle is being sampled. After verifying the indicated behavior, set the % INITIAL DELAY dial to 10%.

(5) Signal Processing - Scanned Operation

(a) Depress the SCAN SELECT 'A' pushbutton.

(b) Hold in the SCAN SELECT RESET pushbutton. While the button is held down, the panel meter will indicate nominally full scale. At some convenient time, release the RESET pushbutton. The panel meter will continue to indicate full scale for about four seconds, indicating that the upper level of the input square wave is being scanned. Then the panel meter indication will drop to '0', where it will remain for five seconds as the lower level of the square wave is scanned. These nine-second (nominal) cycles of four seconds of full-scale indication followed by five seconds of '0' indication will follow one another automatically.

(6) Summation Averaging Checks

(a) Release the SCAN SELECT 'A' pushbutton and set the M164 Time Constant to 10 ms.

(b) Depress the M164 CLEAR pushbutton (meter indication will zero) and, while continuing to hold the CLEAR pushbutton down, release the M164 EXP/SUM pushbutton.

(c) At some convenient time, release the CLEAR pushbutton. The meter indication will begin rising linearly from zero and will reach full scale in about four seconds. It will not stop at full scale

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but will continue to rise until the stops are reached. NOTE: The exact timing is not very critical. Several factors affect the time required to reach full scale, among them the frequency of the input trigger signal, the tolerance of the Model 164 Time Constant, and the tolerance of the Aperture Duration. It should be noted that the trigger rate with a 1 kHz input trigger signal and a 1 ms Aperture Delay Range will be 500 Hz. (Because the cycle time with a 1 ms Aperture Duration Range is slightly longer than 1 ms, the unit triggers on every other cycle.) If the trigger repetition frequency is a bit high, the unit might trigger on every cycle, reducing to two seconds the time required to reach full scale.

(d) At some convenient time, depress the GND pushbutton (which latches) and the CLEAR pushbutton (which does not latch). The meter indication will instantly go to zero. When the CLEAR pushbutton is released, the meter indication will be observed to drift slowly away from zero. The rate of drift and its direction can be controlled by means of the M164 OUTPUT ZERO control.

(e) Depress the EXP/SUM pushbutton to restore exponential averaging.

3.5B INTERNAL TRIGGER MODE CHECKS

(1) Triggering

(a) Release the EXT. trigger pushbutton. The TRIGGERED lamp should extinguish.

(b) Depress the INT Trigger pushbutton. The TRIGGERED lamp should glow steadily again. NOTE: It could happen that the attempt to establish internal triggering will not succeed. If this is the case, alternately release and press in the INT. pushbutton until internal triggering, as indicated by the TRIGGERED lamp, is established.

(2) Signal Processing

(a) Set the APERTURE DELAY RANGE to 10 mSEC. Check that the M164 Time Constant is 10 ms (from step 6-a of preceding page).

(b) Check that the GND pushbutton is still depressed. The meter indication should be '0'.

(c) At some convenient time, depress the CAL pushbutton and release the GND pushbutton (in that order). The meter indication will begin rising, approaching full scale asymptotically. The observed charging time constant will be nominally 20 seconds, that is, the meter will reach 63% of full scale in 20 s (the actual time required can vary somewhat as determined by the tolerances of the circuits involved). After 40 s, the meter indication should be nominally 86%, after 60 s it should be 95%, after 80 s it should be 98%, and after 100 s it should be within 1% of full scale.

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The actual time required to reach full scale may vary somewhat from these numbers. The important thing is that the general behavior indicated is observed.

(d) Depress the GND pushbutton (leave CAL depressed). The meter indication will now decrease, asymptotically approaching zero.

(e) Momentarily depress the CLEAR pushbutton. The meter indication will quickly go to '0'.

3.5C HOLD CHECKS

(1) Zero Hold

(a) Decrease the M164 TIME CONSTANT to 100 μSEC.

(b) At some convenient time, release the INT trigger pushbutton. The TRIGGERED light will extinguish, showing that the unit is no longer triggering.

(c) Note the panel meter indication. For as long as the unit is not triggering the meter indication drift should be less than 1% of full scale per second.

(2) Full-Scale Hold

(a) Depress the EXT Trigger pushbutton to restore triggering. The meter indication will quickly go to '0'.

(b) Release the GND pushbutton (CAL should still be depressed). The meter indication will go to full scale in a few seconds.

(c) At some convenient time, release the EXT trigger pushbutton.

(d) Note the panel meter indication. For as long as the unit is not triggering, the meter indication drift should be less than 1% of full scale per second.

NOTE: This completes the Initial Checks for a system consisting of a Model 162 and a single Model 164. If there is a second Model 164 to be checked, plug it into module receptacle 'B', and return to step 1 of Subsection 3.5A, the only difference being that instead of setting the FUNCTION switch to 'A', set it to 'B'. Once the second Processor Module is checked out, go to Subsection 3.6 to check dual-channel operation.

3.6 DUAL-CHANNEL OPERATION

These checks presuppose that the operator has two M163's or two M164's, and that both have been checked out according to the previous procedures. In other words, the ZERO and DC BAL or CAL adjustments, whichever is appropriate, have been made.

(1) Procedure with two M163's.

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(a) Both modules should be plugged in and the controls should be set as indicated in step 1 of Section 3.4. The trigger input should be connected and the Trigger Level control adjusted for proper triggering. The 0-to-100 mV square wave should be connected to both inputs. NOTE: Take into account the change in loading caused by having the two inputs connected in parallel.

(b) Note the meter indication with the FUNCTION switch set to 'A'. Then set the FUNCTION switch to 'B'. The meter indication should be the same, plus or minus a few percent to allow for gain differences between the two modules.

(c) Set the FUNCTION switch to 'A-B'. The meter indication should go to '0', plus or minus a few percent of full scale.

This completes the dual-channel checks for a pair of Model 163's.

(2) Procedure with two M164's.

(a) Both modules should be plugged in and the controls should be set as indicated in step 1 of Subsection 3.5A. The trigger input should be connected and the Trigger Level control adjusted for proper triggering. There is no need to connect the 100 mV signal; the Model 164 Processor Modules are checked using the internal Calibrate level.

(b) Release the GND pushbutton. The CAL pushbutton should still be depressed (preceding step).

(c) With the FUNCTION switch set to 'A', the panel meter should indicate full scale.

(d) Transfer the FUNCTION switch setting to 'B'. The panel meter should continue to indicate full scale.

(e) Transfer the FUNCTION switch setting to 'A-B'. The meter indication should go to '0', plus or minus a percent or two of full scale (depends on how well the zero and calibrate operations were performed when the modules were checked out individually).

This completes the Initial Checks. If the indicated results were observed, one can reasonably conclude that the M162 and the Processor Modules with which it was furnished are working properly. Note that no dual-channel checks were furnished for the case where dual-channel operation is attempted with one M163 Processor Module and one M164 Processor Module. Operation with this combination is perfectly feasible and there should be little difficulty in adapting the preceding procedures to checking out dual-channel operation with one module of each type.

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SECTION IV
OPERATING INSTRUCTIONS

4.1 INTRODUCTION

This section of the manual begins with a discussion of several preliminary operating considerations, such as installation, cooling, warmup, and power requirements. These preliminary discussions are followed by a description, keyed to photographs, of the controls and connectors. The remainder, the largest part of Section IV, consists of the detailed operating instructions, which discuss in detail how to use the Model 162 and its associated processor modules to obtain the best measurement results possible.

4.2 PRELIMINARY CONSIDERATIONS

4.2A INSTALLATION

The Model 162 Main Frame can be either bench or rack mounted. The rack-mounting angles, which are supplied as part of an optional accessory kit, are easily bolted to the side of the instrument immediately behind the front panel. To mount the angles, it is first necessary to remove the decorative cover strips which are secured by the same bolts as are used to mount the angles.

4.2B POWER REQUIREMENTS

When equipped with two processor modules and with typical loading, the Model 162 requires a maximum of 50 VA of either 105-125 V ac or 210-250 V ac, 50-60 Hz. A rear-panel switch enables transfer from one line voltage range to the other. The processor modules take their power from the Main Frame.

4.2C FUSING

There are three fuses in all, a rear-panel slow-blow type fuse (1.0 A for 117 V operation, 0.5 A for 220 V operation) in series with the ac input power, and two internal ¼ A slow-blow type fuses that protect the ±50 V regulators. These regulators supply power to the Tektronix Sampling Head when the Main Frame is operated in conjunction with a Model 163 Processor Module.

4.2D GROUNDING

The chassis of the Model 162 is internally connected to the 'third wire' or grounding pin of the input power connector. It is important that this grounding pin be connected to a good earth-ground connection, either through the power distribution system of the laboratory, or at least by running a separate ground wire to a cold water pipe, which in turn has a good ground connection. This precaution serves to prevent shock hazards and to prevent the entire chassis from being driven at some high ac voltage.

Should it be necessary to electrically isolate the input power to the instrument, use a good quality, electrostatically-shielded, isolation transformer. The chassis of the instrument should still maintain its earth-ground integri-

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ty by running a heavy wire (#18 AWG or larger) from the chassis to input neutral or to an earth-ground connection.

4.2E COOLING

No special cooling techniques are required. However, if the instrument is operated in an enclosed rack with other equipment, the ambient temperature within the rack should not exceed 40°C.

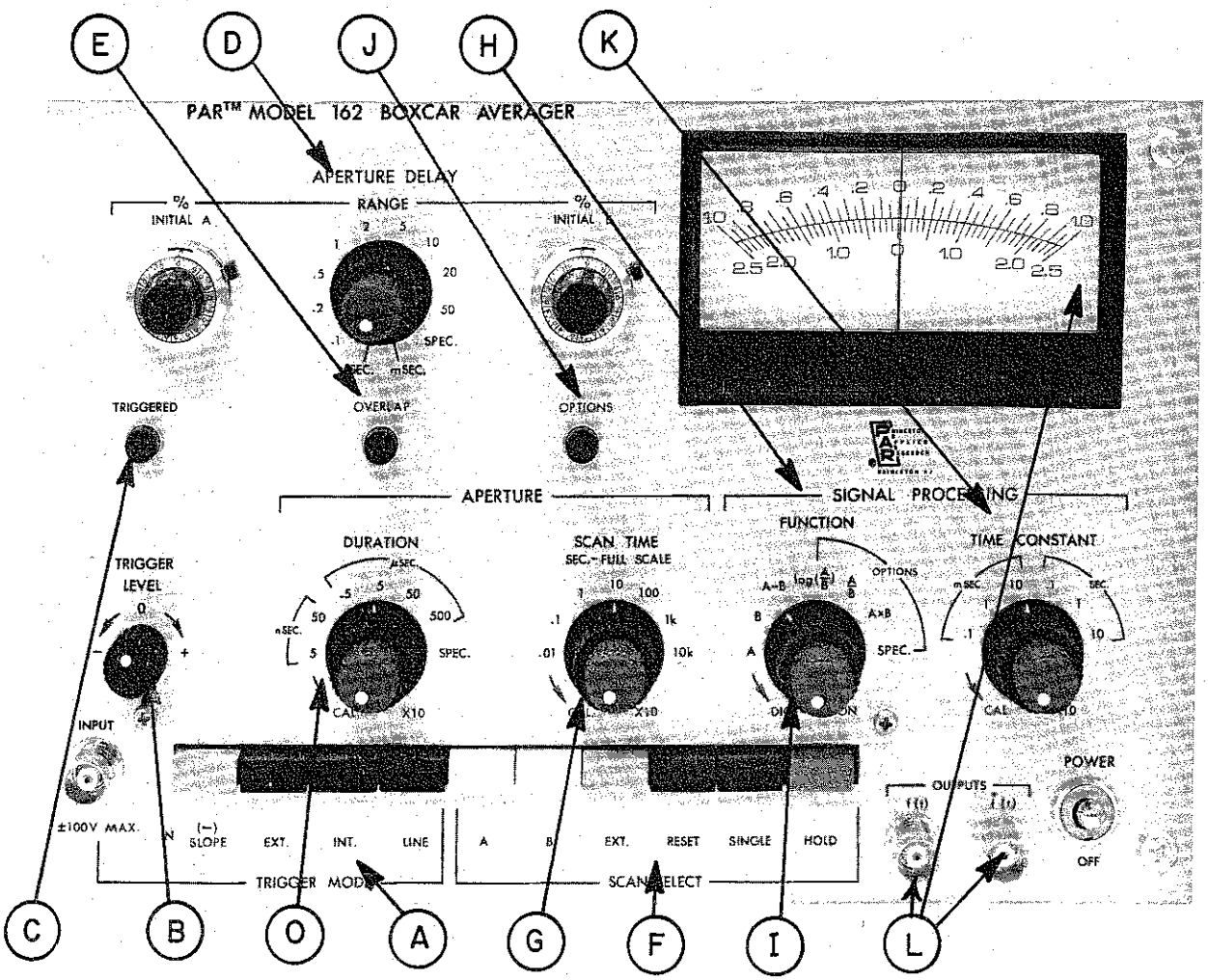


Figure IV-1. MAIN FRAME FRONT PANEL

4.3 CONTROLS, CONNECTORS, AND INDICATOR LAMPS

4.3A MAIN FRAME FRONT PANEL (Figure IV-1)
NOTE: Inasmuch as the APERTURE DURATION control affects the M164 only, that control is described in subsection 4.3C, which treats the M164 Module.

A. TRIGGER MODE - Four pushbuttons select instrument triggering mode.

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(1) EXTERNAL - With this pushbutton depressed, instrument is trigger-sensitive to external signal applied to Trigger Input connector. This is the most frequently used trigger mode in measurement applications.

(2) INTERNAL - With this pushbutton depressed, instrument is automatically self-triggering. Trigger rate is approximately the inverse of the selected Aperture Delay Range (plus retrace time). Useful mainly for servicing.

(3) LINE - With this pushbutton depressed, trigger signal is derived from power frequency signal. This trigger mode is used mainly in servicing.

(4) SLOPE - This pushbutton allows the operator the option of triggering on either the positive (pushbutton out) or negative (pushbutton depressed) slope of the applied trigger waveform in EXT and LINE TRIGGER operation.

B. TRIGGER LEVEL: This control determines where on the applied trigger waveform triggering will take place. Range of control is ±15 V.

C. TRIGGERED LAMP: This lamp flashes each time the Model 162 is triggered. The duration of the flash is long enough to be noticed independent of the selected operating parameters.

D. APERTURE DELAY RANGE: Dual-concentric switch and two associated ten-turn dials determine the Aperture Delay characteristics.

(1) RANGE: This switch determines the interval (beginning marked by trigger) over which the leading edge of the aperture opening can be positioned. In Internal Trigger operation, this switch also sets the trigger repetition rate, which is approximately the reciprocal of the selected Delay Range plus the retrace time.

(2) % INITIAL A and % INITIAL B: Function depends on whether aperture is to be manually positioned or scanned. If the aperture is to be manually positioned, these dials directly set the position of the aperture leading edge as a % of the selected Delay Range. As indicated, one dial affects the A Processor Module, the other the B Processor Module. In scanned operation, the interval over which the leading edge of the aperture will be scanned begins with the % Initial A & B Delay dial settings and finishes with the end of the selected Aperture Delay Range.

E. OVERLAP LAMP: This lamp lights whenever the trailing edge of the aperture opening extends beyond the end of the selected Aperture Delay Range. Overlap circuit not active for M163 Processor Module.

F. SCAN SELECT: Six pushbutton switches control the aperture scan characteristics.

(1) A & B: These pushbuttons allow the operator to select manual or scanned positioning of the aperture for each Processor Module. In

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the released position, the position of the aperture leading edge at the corresponding Processor Module is directly set by the % Initial Delay dial. In the depressed position, the aperture is scanned over the interval beginning with the % Initial Delay dial setting and ending at 100% of the selected Aperture Delay Range. NOTE 1: The RESET, SINGLE, and HOLD pushbuttons are relevant to scanned operation only. NOTE 2: If EXT. Scan pushbutton is depressed, A and B pushbuttons select channel(s) to be affected by external program (% Initial Delay dials always effective).

(2) EXT: With this pushbutton depressed, the aperture position is determined by the sum of the % Initial Delay dial setting plus any delay programmed by externally derived voltage applied to rear-panel SCAN IN/OUT connector. Note that with no program applied to rear panel connector, % Initial Delay dials set aperture position. A & B pushbuttons determine which channel(s) will be affected by applied program.

(3) SINGLE: Affects scanned operation only. When depressed, aperture position remains at 100% of selected Aperture Delay Range when a given scan ends. When released, aperture position automatically resets to delay determined by % Initial Delay dial setting to mark beginning of new scan. Scans follow one another with no operator action required. NOTE: If A and B are both depressed, one aperture will generally reach 100% of Aperture Delay Range before the other. Whichever reaches 100% of Delay Range first dominates, that is, as soon as one aperture or the other reaches 100%, both apertures will reset or both will scan no further according to position of SINGLE pushbutton.

(4) HOLD: When depressed, aperture position scan stops advancing. When button is released, scan continues from hold point.

(5) RESET: Depressing this momentary action switch causes the scan to reset immediately to the delay set by the % Aperture Delay dials. NOTE: Hold pushbutton over-rides reset.

G. SCAN TIME: Dual-concentric controls determine time required to scan leading edge of Aperture opening over the entire Aperture Delay Range.

H. FUNCTION: Seven position switch provides choice of three standard functions or four optional functions. A given instrument can only be equipped with two optional signal-processing functions at a time. This limit of two does not apply to the digital-storage option.

(1) STANDARD FUNCTIONS

A: Channel A output only.

B: Channel B output only.

A-B: Channel A output minus Channel B output.

(2) OPTIONAL FUNCTIONS: Circuitry is contained on plug-in printed cir-

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cuit cards for which two connectors have been provided inside the Model 162. Each connector accepts any of the option cards.

A/B: Channel A output divided by Channel B output (see specs. for transfer function).

AxB: Channel A output multiplied by Channel B output (see specs. for transfer function).

LOG A/B: Logarithm of Channel A output divided by Channel B output (see specs. for transfer function).

SPEC: User designed and constructed function. Blank circuit cards can be purchased from Princeton Applied Research Corporation.

I. DIGITAL STORAGE OPTION: Front-panel switch activates Digital Storage Option circuitry. Digital Storage Option allows virtually infinite hold times to be achieved.

J. OPTIONS LAMP: This lamp lights if the Function switch is set to a position for which a proper plug-in circuit card has NOT been installed. Also lights if Digital Storage is turned on without a Digital Storage card having been installed.

K. TIME CONSTANT: Output smoothing filter time constant in decade steps from .1 ms to 10 s. Continuously variable X10 multiplier extends range to 100 s.

L. OUTPUTS:

(1) ANALOG PANEL METER: Taut-band, center zero standard.

(2) DIGITAL PANEL METER: 3½ digit display with BCD output is available as extra cost option.

(3) ANALOG OUTPUT: ±10 V corresponding to full-scale output.

(4) ANALOG DERIVATIVE: ±10 V Scan-time derivative of averaged output (see specs.).

4.3B MODEL 163 PROCESSOR MODULE (Figure IV-2 on next page)

V. INPUT: Utilizes standard plug-in sampling head to achieve aperture widths as narrow as 100 ps. Can be operated remotely with optional Sampling Head Extender.

W. INPUT SENSITIVITY: Switch-selectable choice of 100 mV, 250 mV, or 1 V full scale.

X. SAMPLES AVERAGED: Switch allows selection of number of samples of which output is the average (assuming number of samples taken is very much larger than SAMPLES AVERAGED selected).

Y. BASELINE SAMPLING: When activated, alternate sampling apertures are time

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positioned as determined by associated Baseline Sampling Delay control or by external signal applied to adjacent pin jack. Model 163 output is the difference between averaged segment of input signal and averaged segment of baseline, thereby providing automatic compensation for dc drifts and baseline wander.

Z. OUTPUT MONITOR: Processor Module output is provided at this pin jack. Adjacent control permits baseline zero adjustment.

AA. APERTURE MONITOR: 0.5 µs marker pulse. Leading edge of marker pulse occurs about 10 ns after leading edge of aperture opening. Note that aperture duration is determined by choice of Sampling Head and is otherwise invariable.

BB. TRIGGER TAKEOFF: Risetime-limited replica of input signal provided at this connector. Baseline is nominally +2 V. Amplitude is twice input amplitude.

CC. OVERLOAD LAMP: Lights to indicate overload condition in M163.

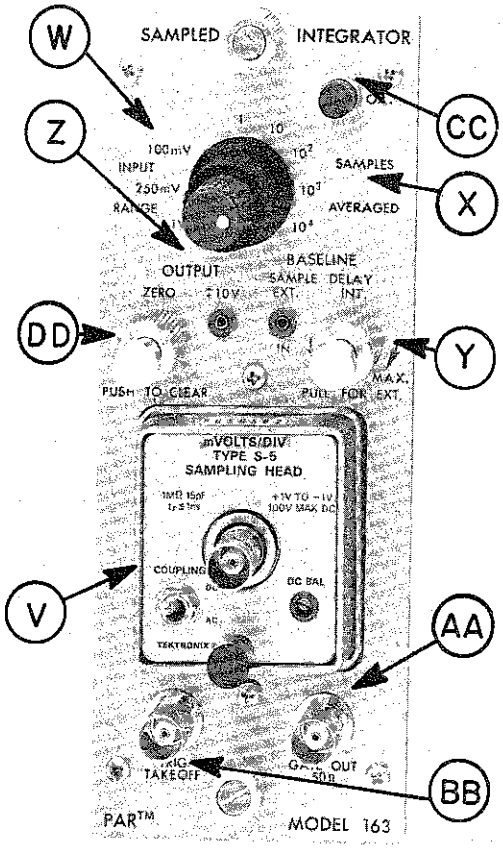


Figure IV-2. MODEL 163 PROCESSOR MODULE

DD. CLEAR: Pressing this pushbutton zero-sets all instrument integrators, including those in the Model 164. If the instrument is equipped with the digital storage option, the digital storage memory contents will be erased as well. NOTE: The Model 164 Processor Module is also equipped with a Clear pushbutton that performs exactly the same function.

4.3C MODEL 164 PROCESSOR MODULE (Figure IV-3 on next page)

M. INPUT CONTROLS: Three pushbutton switches provide a choice of high or low input impedance and ac or dc coupling. Also provided is a means of internally grounding the input to facilitate zeroing.

N. CALIBRATE: When depressed, this pushbutton causes an internally derived 100 mV signal to be applied to the input. Adjacent gain-trim control permits output to be adjusted to full scale with calibrated input. Trim control can be used to match the gain of one M164 to the gain of another in dual-channel operation.

O. APERTURE DURATION: Dual-concentric controls located at the MAIN FRAME determine the M164 Aperture width. Aperture can be set at any width over the range of 5 ns to 5 ms plus 'special' user installed range. Aperture Duration controls have no effect on M163 Processor Module.

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P. GATE OUT: Pulse coincident with aperture provided at this connector. Tracks accurately down to 50 ns aperture durations when terminated in 50 Ω. Adjacent Trim control permits aperture duration to be trimmed, useful in matching the aperture characteristics of two Model 164's. Selected Aperture Duration is obtained with Trim set to center of range.

Q. TIME CONSTANT: Enables averaging time constants from 1 μSEC to 10 mSEC to be selected (plus 'SPECIAL' user installed range).

R. AVERAGING MODE: Two pushbuttons.

(1) EXP-SUM: Gives choice of exponential or summation (linear) averaging.

(2) CONT. GATE: When this pushbutton is depressed, unit is locked into continuous-aperture state. Useful mainly for servicing.

S. OUTPUT MONITOR: Processor Module output is available at this pin jack. Adjacent Zero control permits baseline zero adjustment.

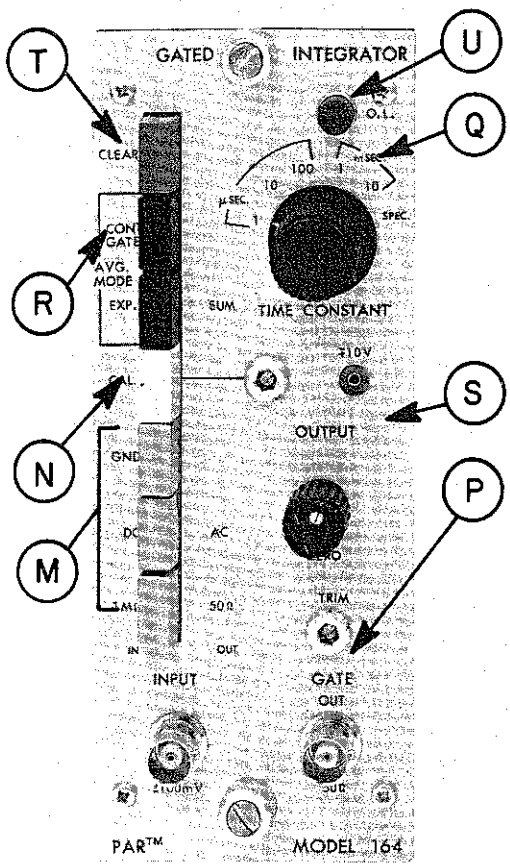


Figure IV-3. MODEL 164 PROCESSOR MODULE

T. CLEAR: Pressing this pushbutton zero sets all instrument integrators, including those in the Model 163. If the instrument is equipped with the digital storage option, the storage-option memory contents will be erased as well. NOTE: The Model 163 Processor Module is also equipped with a CLEAR pushbutton that performs exactly the same function.

U. OVERLOAD INDICATOR LAMP: This indicator glows when the Model 164 amplifiers are overdriven.

4.3D REAR PANEL

BNC CONNECTORS

(1) SCAN IN/OUT: Function depends on setting of front-panel Scan Select EXT. pushbutton. If this pushbutton is depressed, aperture position is determined by % Initial Delay dials plus voltage program applied to this connector. Sensitivity is 10% of selected Aperture Delay Range per +1 V applied. A and B pushbuttons determine which channel(s) are affected by externally derived program. Z_{in} = 10 kΩ. If pushbutton is in released position, positive Scan Ramp is provided at this connector. Ramp is referenced to 0 V. Peak amplitude is pro-

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portional to setting of % Initial Delay dial with a maximum of +5 V. Z_{out} = 600 Ω.

(2) CHANNEL A SCAN: When Channel A is being scanned, sum of scan ramp and % Initial Delay A voltage is provided at this connector. Ramp is referenced to dialed % Initial Delay voltage (maximum of +5 V at 100%). When ramp plus dialed delay voltage reach +5 V, ramp either maintains five volt level (Single pushbutton depressed) or resets to start another ramp (Single pushbutton released). Z_{out} = 1 kΩ. NOTE: In EXT. Scan operation, output is sum of EXTERNAL PROGRAM plus % Initial Delay A voltage (A pushbutton depressed).

(3) CHANNEL B SCAN: Same as for Channel A, except that % Initial Delay B dial sets reference voltage.

NOTE: If both A and B are being scanned, reset (or end-of-scan hold) occurs for both when either aperture opening reaches 100% of delay range position, corresponding to +5 V level being reached at either of the Channel Scan BNC connectors.

(4) SPARE: Customer specified signal or level can be made available at this connector.

SIGNAL/CONTROL INTERFACE, P101 (Mating connector is 3M#3415)

Pins	Function or Signal
1, 50	-E OUT (B): ±10 V f.s. Channel B Module Out.
2, 49	-E OUT (A): ±10 V f.s. Channel A Module Out.
3, 48	F (E OUT): Main Frame analog derivative output.
4, 47	F (E OUT): Main Frame analog output.
5, 46	SCAN IN/OUT: Same as for SCAN IN/OUT BNC connector.
6, 45	SCAN SUPPRESS: Externally derived voltage applied to this point can be used to vary scan rate plus or minus relative to that selected by the Scan Time controls.
7, 44	CHANNEL B SCAN: Same as for CHANNEL B SCAN BNC connector except that $Z_{out} \simeq 0$ Ω.
8, 43	CHANNEL A SCAN: Same as for CHANNEL A SCAN BNC connector except that $Z_{out} \simeq 0$ Ω.
9, 42	SCAN RESET: Logic 0 applied to this input parallels function of front-panel SCAN RESET pushbutton.
10, 41	SIGNAL RESET: Logic 0 applied to this input parallels function of front-panel CLEAR pushbutton (provided on both Models 163 and 164).
11, 40	SCAN HOLD: Logic 0 applied to this input parallels function of front-panel HOLD pushbutton.
12, 39	TRIGGER HOLDOFF: Logic 1 applied to this input inhibits instrument from being triggered. Source must provide 500 µA.
13, 38	SCOPE BLANKING: This output is at logic 0 when a scan is in progress. It is at +50 V (10 kΩ source) when scan is NOT in progress.

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14, 37	------	$\overline{\text{SCOPE}}$ $\overline{\text{BLANKING}}$: This output is at +50 V (10 kΩ source) when scan is in progress. It is at logic 0 when scan is NOT in progress.
15, 36	------	spare
16, 35	------	PENLIFT (NO): Normally open 1 A contact of pen-lift relay.
17, 34	------	+15 V ±15 mV; 100 mA capacity.
18, 33	------	PENLIFT (W): Wiper of pen-lift relay (rated at 1 A).
19, 32	------	-15 V ±15 mV; 100 mA capacity.
20, 31	------	PENLIFT (NC): Normally closed 1 A contact of pen-lift relay.
21, 30	------	+5 V ±50 mV; 300 mA capacity.
22, 29	------	spare
23, 28	------	GND (ground return).
24, 27	------	GND (ground return).
25, 26	------	HIGH QUALITY (SIGNAL) GROUND

Table IV-1. P101 INTERFACE (REAR PANEL)

NOTE: Mating connector with short length of ribbon cable is supplied.

BCD OUTPUT INTERFACE CONNECTOR (Mating connector is Amphenol Blue Ribbon #57-30360)

Pin	Function	Function when Applied to 131 System Model 262
1	Polarity (logic 1 = 1)	1 = Polarity +
2	+4 V	Not Used
3	Overload Output (Logic 1 = Overload)	Digit 1, A
4	Overload Output (Logic 1 = Overload)	Digit 1, C
5	DVM Most Significant Digit, A	Digit 2, A
6	DVM Most Significant Digitk C (always ground)	Digit 2, C
7	DVM 2nd Most Significant Digit, A	Digit 3, A
8	DVM 2nd Most Significant Digit, C	Digit 3, C
9	DVM 3rd Most Significant Digit, A	Digit 4, A
10	DVM 3rd Most Significant Digit, C	Digit 4, C
11	DVM Least Significant Digit, A	Digit 5, A
12	DVM Least Significant Digit, C	Digit 5, C
13	Spare	
14	Spare	
15	Spare	
16	Spare	
17	DVM Least Significant Digit, D	Digit 5, D
18	Conversion Complete (inverted)	EXECUTE
19	Conversion Complete	Not Used
20	External Trigger Input	TTL Logic 0 (min. 1.5 µs; max. 2 ms)*
21	Spare	
22	Spare	
23	NOT BUSY input (Output data will remain fixed when this line is at logic 0. Must be 1 or open for conversions to continue)	$\overline{\text{BUSY}}$

(cont'd on following page)

*For external triggering of digital display, there must first be a 5.1 kΩ resistor connected between pins R and 15 of J2 (upper connector at rear of panel meter).

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(cont'd from preceding page)

24	Exponent, A (always ground)	Digit 6, A
25	Exponent, C (always ground)	Digit 6, C
26	Exponent, B (always ground)	Digit 6, B
27	Exponent, D (always ground)	Digit 6, D
28	DVM Overload Output (Logic 1 = Overload)	Digit 1, B
29	DVM Overload Output (Logic 1 = Overload)	Digit 1, D
30	DVM Most Significant Digit, B (always ground)	Digit 2, B
31	DVM Most Significant Digit, D (always ground)	Digit 2, D
32	DVM 2nd Most Significant Digit, B	Digit 3, B
33	DVM 2nd Most Significant Digit, D	Digit 3, D
34	DVM 3rd Most Significant Digit, B	Digit 4, B
35	DVM 3rd Most Significant Digit, D	Digit 4, D
36	DVM Least Significant Digit, B	Digit 5, B

NOTE: Logic 1 = +3.5 V ±1 V, Logic 0 = 0.2 V ±0.2 V.

Table IV-2. DIGITAL OUTPUT CONNECTOR (REAR PANEL)

The DVM used in the Model 162 has a '3½' (4 digits) display. Each digit is represented at the rear panel connector in Binary Coded Decimal (BCD) format. The most significant digit is the leftmost of the four digits displayed. The Teletype digit #1 (? for overload) is 1 digit to the left of the Most Significant Digit. The notation A, B, C, and D after the digit notation refers to column headings of the truth table. The value of each of these outputs when at a logic 1 is 1, 2, 4, and 8 respectively. For each digit, the A, B, C, and D outputs, taken together, represent a number (0 to 9) in BCD format.

PROCESSOR MODULE INTERFACE OUTPUTS (12 pins out provided with M163 only; used primarily for establishing MASTER/SLAVE operation with two M163's; Mating connector is CINCH 251 06 30 160). NOTE: This interface is available on special order only (consult factory).

When operating a Model 163 with Baseline Sampling selected, baseline sampling cycles and signal sampling cycles alternate. If two M163's are in use, it could happen that a given cycle will be a baseline sampling cycle in one unit but a signal sampling cycle in the other. Ordinarily, this would not matter. However, if desired, it is possible to assure that a given cycle will have the same function (signal sample or baseline sample) in both units. This is done by establishing MASTER/SLAVE operation as described in the following table.

Pin	Function
A	External Baseline Sample Delay. Parallels M163 front-panel External Baseline Sample Delay pin-jack. Input requirement is +0.225 V to +4.5 V, corresponding to 5%-to-100% of Aperture Delay Range. Z_{in} = 5 kΩ.
B	Not used.

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C --------	SIGNAL MASTER OUT. In MASTER/SLAVE operation with two M163's, connect this pin of MASTER unit to pin F of SLAVE unit.
D --------	BASELINE MASTER OUT. In MASTER/SLAVE operation with two M163's, connect this pin of MASTER unit to pin 4 of SLAVE unit.
E --------	GND
F --------	BASELINE SLAVE INPUT. In MASTER/SLAVE operation with two M163's, connect this pin of SLAVE unit to pin C of MASTER unit.
1 --------	+5 V
2 --------	GND
3 --------	Not used.
4 --------	SIGNAL SLAVE INPUT. In MASTER/SLAVE operation with two M163's, connect this pin of SLAVE unit to pin D of MASTER unit.
5 --------	GND
6 --------	SLAVE INHIBIT. Logic 0 (ground) must be applied to this pin of SLAVE unit in MASTER/SLAVE operation with two M163's.

Table IV-3. M163 PROCESSOR MODULE INTERFACE (Rear Panel)

4.4 DETAILED OPERATING CONSIDERATIONS

4.4A INTRODUCTION

In most applications, the Model 162 is used to determine the exact shape of a repetitive waveform that is obscured by noise. By sliding an aperture over the interval of interest and averaging the signal that passes through the window, the waveform can be reproduced at the output. In general, the recovery of any given input waveform is accomplished as follows.

(1) The Model 162 is synchronized with the signal of interest. This is usually done by applying an externally derived trigger signal to the Trigger Input connector of the Model 162.

(2) The signal is applied to either the Model 163 or the Model 164, and the module controls are adjusted for optimum processing of the signal.

(3) The Aperture Delay and Scan controls are adjusted as required.

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(4) The proper function is selected and the actual signal recovery performed.

In the following pages, each of these steps is discussed in detail.

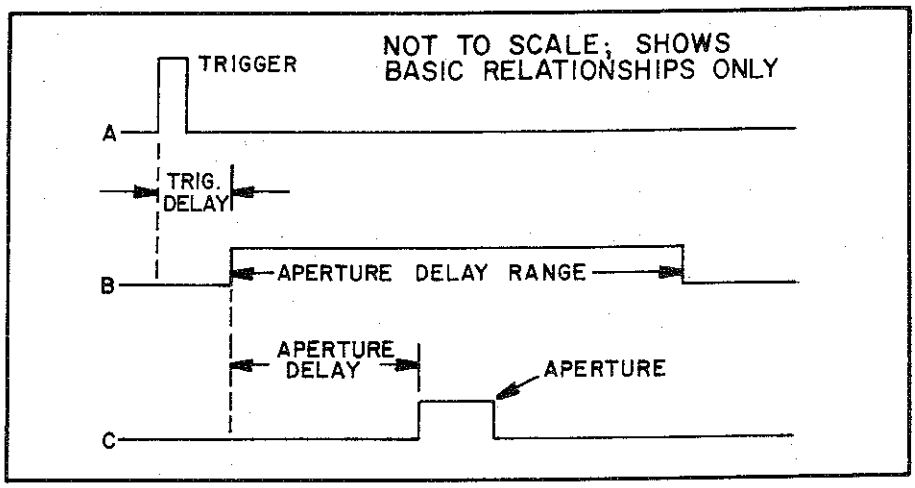


Figure IV-4. BASIC MODEL 162 TIMING RELATIONSHIPS

4.4B SYNCHRONIZATION

INTRODUCTION: Figure IV-4 illustrates the basic timing relationships in the Model 162 Boxcar Integrator. Each time the unit is triggered (triggering on the positive edge of an externally derived trigger is indicated in the figure), there occurs a fixed Trigger Delay of nominally 20 ns, at the end of which the selected Aperture Delay Range begins. (For convenience in illustration, the Aperture Delay Range is shown as a pedestal, although from an operating point of view, it is simply a selected time interval.) At some time after the beginning of the Aperture Delay Range interval, but before it ends, an aperture opening occurs. The duration of the aperture opening can extend beyond the end of the Aperture Delay Range, but normally does not. Usually, the aperture opening is very short relative to the selected Delay Range. In single-point analysis, the aperture opens at the same time after each trigger. In scanned operation, with each repetition it opens a bit later with the incremental increase in Aperture Delay normally being small relative to the duration of the aperture opening itself. Note that in both scanned and single-point analysis, internal fixed-delays act to prevent positioning the aperture any closer to the trigger than 75 ns (nominal).

A gated integrator is made to 'see' the input signal for the duration of each aperture opening. If the same point is sampled for many repetitions, the integrator output gradually assumes the average level of the input signal at the sampled point. In scanned operation, if the scan is slow enough, each point will be sampled enough times to be 'captured' by the integrator, so that, if the integrator output is used to drive the 'Y' axis input of a recording device, the input waveform will be reproduced at the scan rate.

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In any case, whether doing single-point or scanned analysis, it is absolutely essential that the timing of the aperture opening be known and controlled relative to the timing of the input signal. In short, the signal and the Model 162 timing sequence must be synchronized. This is normally done by operating the Model 162 in the External Trigger mode and applying a trigger signal having a fixed time relationship to the waveform being examined. Frequently it may be possible to trigger the Model 162 from the same stimulus as initiates the signal to be processed. Operation of the Model 162 in each of the Trigger modes is discussed in the following paragraphs.

EXTERNAL TRIGGER MODE: As long as the EXT Trigger Mode pushbutton is depressed, a timing sequence is initiated each time an appropriate externally derived trigger signal is applied to the Trigger INPUT connector. The SLOPE pushbutton and TRIGGER LEVEL control determine when, in terms of the fine structure of the trigger pulse, the Aperture Delay Range begins. However, regardless of how these controls define the trigger detection point, there is always a minimum delay of nominally 20 ns between the trigger detection point and the beginning of the subsequent Aperture Delay Range. Other internal delays add to this, with the result that the aperture can follow the trigger by no less than 75 ns (nominal). Thus, when operating with a short Delay Range, it may prove advantageous to pre-trigger the M162 or to delay the signal to be recovered by means of an appropriate delay line. The Trigger Level control allows triggering over a range of ±15 V and the Slope pushbutton allows triggering on either the positive-going or negative-going edge of the applied trigger. For reliable operation the applied triggers should be at least 0.5 V in amplitude and have a duration of no less than 10 ns. Trigger pulses larger than 100 V (zero-to-peak) should not be applied because such pulses may damage the trigger detection circuitry. Z_{in} = 50 kΩ.

Figure IV-5 shows the variation in trigger detection point for two arbitrarily determined trigger levels and for both slopes. The main criterion in setting these controls is to select a point which gives a stable trigger point for each input trigger pulse.

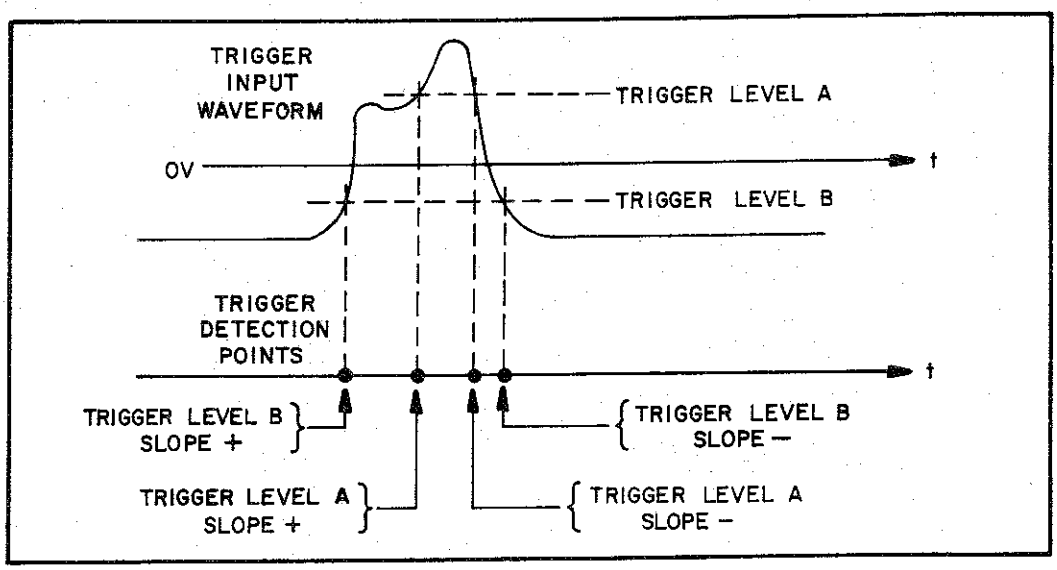


Figure IV-5. TRIGGERING AS A FUNCTION OF SLOPE AND TRIGGER LEVEL

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Proper triggering is indicated by the front-panel TRIGGERED indicator lamp. Each time the unit is triggered, this lamp glows briefly. The duration of the glow is independent of instrument operating parameters. As a result, even with a very short trigger pulse and Aperture Delay Range, the glow lasts long enough to be noticed. With relatively low trigger rates, the individual triggers are clearly distinguishable by separate flashes of light. With fast trigger rates, the flashes blend together into a steady glow.

While a timing sequence is in progress, the instrument remains trigger insensitive. The trigger insensitive state extends somewhat beyond the selected Aperture Delay Range to allow the involved circuits time to reset. Trigger inhibiting also occurs for the duration of an aperture opening that extends beyond the end of the Aperture Delay Range. If a Model 163 Processor Module is being used, the maximum trigger rate is limited to 10 kHz.

Trigger inhibiting is provided because it is frequently neither necessary nor desirable that every trigger pulse initiate a timing sequence. Consider the case where the experiment is triggered by an oscillator, with the oscillation period shorter than the duration of the waveform being investigated. In such a case, it would be awkward (to say the least) to start a new timing sequence while another is still in progress.

Internal to the instrument, there is an Aperture Delay Range ramp which is on the order of five to ten percent longer in duration than the selected Aperture Duration Range. This five to ten percent overhang has to be considered in addition to the reset time. For Aperture Delay Ranges from 100 ns to 50 µs, the reset time is 100 ns. For Aperture Delay Ranges from 100 µs to 50 ms, the reset time is 100 µs. Thus, depending on the choice of Aperture Delay Range, the reset time may be either short or long relative to the Delay Range overhang. In any case, there is trigger inhibiting beyond the end of the Aperture Delay Range equal to the sum of the reset plus overhang.

To illustrate the effects of trigger inhibiting in an experimental application, consider the following example. Suppose one were operating with an Aperture Delay Range of 20 µs and a trigger repetition period of 23 µs. Further suppose the Aperture Duration to be 5 µs and that the aperture position is to be scanned over the Aperture Delay Range. Early in the scan, the aperture opening terminates well before the end of the Aperture Delay Range, so there is no trigger inhibiting as a consequence of aperture opening overlap. With a reset time of 100 ns and a Delay Range overhang of nominally 2 µs, these two factors can also be neglected as far as trigger holdoff considerations are concerned. Thus, assuming the system does not include a Model 163 (maximum trigger rate of 10 kHz), the information early in the scan will be one sample per 23 µs. At the end of the scan, however, the situation changes. Before the aperture delay reaches 100%, it will extend far enough beyond the end of the Aperture Delay Range to overlap the next trigger. However, because the instrument is rendered trigger insensitive whenever the aperture extends beyond the Aperture Delay Range (indicated by glowing of the front-panel OVERLAP indicator lamp), the trigger falling in the Overlap interval is ignored and the information rate at the end of the scan decreases to one sample per 46 µs. If the scan rate had been selected according to the higher information rate, the resolved output waveform would be 'blurred' towards the end of the scan. The simplest solution would be to increase the

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trigger period to about 30 µs. In that way, the controls could be idealized to an information rate that would remain constant over the scan time.

LINE TRIGGER MODE: Line Trigger operation is actually a variation of External Trigger mode operation. A signal derived from the ac power line is applied to the same point internally as is the regular external trigger signal. The Slope pushbutton and Trigger Level controls remain effective; operation is the same as if one were operating in the External Trigger mode, and using a 1.2 V pk-pk square wave input at the line frequency as the trigger signal. Line trigger operation is mainly used in servicing the Model 162. However, there is no reason why it could not be used in experimental applications where the event under study is synchronized with the line. Generally speaking, it is better to operate asynchronous with the line to reduce the possibility of bothersome pickup and interference at the line frequency and its harmonics.

INTERNAL TRIGGER MODE: With the INT Trigger pushbutton depressed, the Model 162 becomes self triggering and free runs. The interval between successive aperture openings equals (at least) the Aperture Delay Range, plus the Delay Range overhang (nominally 5% to 10% of the selected Aperture Delay Range), plus the reset time (100 ns or 100 µs as explained in the preceding discussion of trigger inhibiting with External Trigger operation). If the system includes a Model 163 Processor Module, the 10 kHz trigger rate limit still applies. In other words, assuming the system includes a Model 163, the interval between successive apertures will be at least 100 µs, no matter how short an Aperture Delay Range is selected.

Internal trigger mode operation is intended for servicing use. Unless one is willing to go to a great deal of trouble, there is no way of synchronizing the Model 162 with the experiment. Almost always, it will prove more convenient to trigger both the experiment and the Model 162 from an external trigger source. NOTE: When the INT. pushbutton is depressed, triggering may not begin. If this happens, the remedy is simply to alternately release and depress the INT. pushbutton until proper triggering is established as indicated by the triggered lamp.

4.4C INPUT SIGNAL PROCESSING

The Model 162 can be operated with either one or two Processor Modules. Mixing of the module types is allowed, that is, the 'A' module can be either a Model 163 or a Model 164, and the same is true for the 'B' module. Because of the considerable difference in operating controls provided on the two modules, they are discussed separately.

MODEL 164

The Model 164 can be operated in either position. Installation consists simply of sliding the Module into one of the two slots, and then securing it by means of the two knurled locking screws provided, one at the top and the other at the bottom of the module panel. The main frame power should be off when a module is being inserted or removed. A discussion of each of the Model 164 controls follows.

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INPUT IMPEDANCE: This pushbutton selects the input impedance, either 1 MΩ (pushbutton depressed) or 50 Ω (pushbutton released). For operation from source impedances high enough to result in significant attenuation with a 50 Ω input impedance, one should choose the 1 MΩ input impedance. However, bear in mind that as the source impedance becomes higher, the high-frequency attenuation introduced by the Model 164 input shunt capacitance will increase as well. This input shunt capacitance is typically 25 pF. It may happen, such as when one wishes to use certain external attenuator probes, that a higher shunt capacitance will be desirable so that the overall attenuator response (probe resistance shunted by compensation adjustment in series with Model 164 input resistance shunted by its input capacitance) will be within range of the compensation adjustment. Unused pads have been provided on the Model 164 circuit board to facilitate adding this capacitance. The M164 Parts Location Diagram (Section IX) indicates exactly where the capacitor should be installed.

In those applications calling for the highest possible resolution, and where the source impedance is fifty ohms, use of the 50 Ω input is mandatory. Also, 50 Ω cables must be used to interconnect the signal source and the Model 164. Suitable cable types include RG58C/U, RG188A/U, and many others. In many situations, the source impedance may be other than 50 Ω (93 Ω, 110 Ω, etc.). Where this is the case, the cable characteristic impedance should be that of the source and a series resistor should be provided at the input of the Model 164 to achieve impedance matching. The resistance of the series resistor is determined by:

$$R_{series} = Z_{source} - 50\ \Omega$$

The attenuation resulting from this resistor is given by:

$$\text{Attenuation} = \frac{R_{series}}{Z_{source}}$$

COHERENT PICKUP AND INPUT IMPEDANCE

Part of the aperture-gate signal is coupled by stray paths to the input of the Model 164. This pickup is self-rectified and appears as dc offset at the output of the Processor Module. With a 50 ohm input impedance, the pickup is negligible. With a one megohm input impedance, the pickup can be as large as 20% of full scale. Because this pickup manifests itself as a dc offset which does not vary with delay, it can be cancelled easily by means of the M164 ZERO control. However, it does complicate the zeroing and gain-calibration process where operation with the 1 MΩ input impedance is intended.

Once proper triggering has been established and the instrument timing parameters adjusted, the zeroing and gain-calibration adjustments are made. For operation with the 50 Ω input impedance, one has only to depress GND and adjust for "0" out, followed by releasing GND, depressing CAL, and setting the associated screwdriver adjustment for full-scale output. For operation with the 1 MΩ input impedance, a second zeroing adjustment, to be performed after the CAL adjustment, is required. This one is made with the signal source im-

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pedance connected (but with the signal "off"), and with the GND pushbutton NOT depressed.

To get a quick idea of the offset amplitude, simply alternately select 50 Ω and 1 MΩ. Another way is to alternately press and release the GND pushbutton when the 1 MΩ input impedance is selected. NOTE: The offset magnitude will vary with the Aperture Duration and Time Constant. If these parameters are changed, the "second zeroing" will have to be repeated.

INPUT COUPLING: This pushbutton allows the operator to choose either DC coupling (pushbutton depressed) or AC coupling (pushbutton released). DC coupling is preferred when measuring low-frequency phenomena. Where dc drift at the signal source is a consideration, especially over long analysis intervals, ac coupling might be preferred.

The use of ac coupling prevents input dc offsets from being included in the analysis. However, low frequency components which may be of interest are lost. The input network used gives a 3 dB down low frequency response of 0.16 Hz. Below this frequency the response goes down at the rate of 6 dB/ octave. Note that the internal connections differ according to the choice of input impedance. As shown in Figure IV-6, dc components are blocked altogether with the 1 MΩ input impedance. With the 50 Ω input impedance, the dc components are blocked with respect to the input amplifier, but they are applied to the 50 Ω input resistor. Consequently, when operated with the 50 Ω input impedance, whether ac or dc coupled, the applied dc should be limited to 5 V (equivalent to half a watt dissipation in the 50 Ω input resistance).

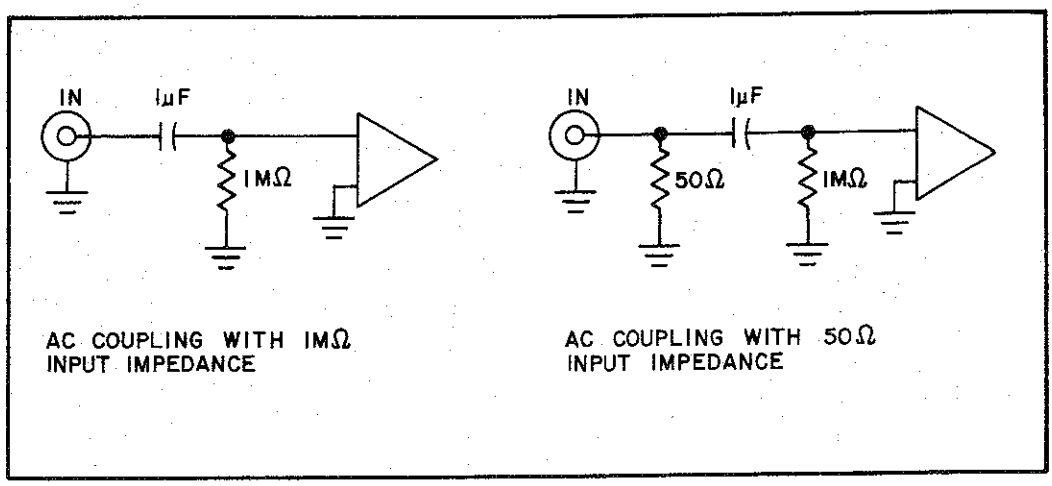


Figure IV-6. INTERNAL COUPLING CONNECTIONS AS A FUNCTION OF SELECTED INPUT IMPEDANCE IN AC COUPLED OPERATION

GND PUSHBUTTON: This pushbutton, when depressed, grounds the input of the first amplifier, useful when zeroing. Note that the Input connector is NOT grounded. If the 1 MΩ input impedance is selected, an applied input signal simply sees an open circuit. If the 50 Ω input impedance is selected, an applied input signal sees 50 Ω to ground, regardless of whether one is operat-

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ing ac coupled or dc coupled. NOTE: See COHERENT PICKUP AND INPUT IMPEDANCE on page IV-16.

CAL. PUSHBUTTON: When this pushbutton is depressed, the externally derived input signal is disconnected from the input amplifier and an internally 0.25% accurate full-scale dc level applied in its place. An associated screwdriver adjustment allows the gain of the instrument to be precisely set by monitoring for -10 V at the front-panel Output Monitor pin jack, providing the instrument is being triggered or the CONT. GATE pushbutton is depressed. The total range of the adjustment is about 20% of full scale. Note that, for the gain to be accurately set, the module must first be zeroed with the GND pushbutton depressed (independent of selected input impedance). NOTE: See COHERENT PICKUP AND INPUT IMPEDANCE on page IV-16.

ZERO CONTROL: This multi-turn, high-resolution control allows the module output to be precisely adjusted to 0 V with zero applied to the input (GND pushbutton). The total range of the control is nominally 100 mV relative to the input of the Model 164. The following procedure can be used in making a zero adjustment. NOTE: To obtain a valid zero adjustment, it is necessary that the unit be triggering, and that the Aperture Duration and M164 Time Constant be set to their signal recovery values. In particular, one should NOT do a zero adjustment with the CONT. GATE pushbutton depressed unless CONT. GATE operation is intended.

(1) Establish proper triggering from an external source. If preparing to examine an externally derived signal, all instrument controls should be set as they will be when recovering the actual signal.

(2) Depress the GND. pushbutton.

(3) Monitor the level at the Model 164 front-panel pin jack or at the main-frame output (Output connector or panel meter). Then adjust the Zero control for 0 V at the monitored point. Note that the observed rate of response will depend on the selected Model 164 Time Constant. If the aperture is locked open (CONT. GATE pushbutton depressed), five times the selected Model 164 Time Constant will be required for the level at the pin jack to reach within 1% of its final value (at the main frame output the effect of the final 'Signal Processing' Time Constant will be seen as well). Even with the maximum available time constant of 10 ms, the slowing effect of the M164 Time Constant will be scarcely noticeable at the M164 IN jack. However, if the instrument is being triggered, and the CONT. GATE pushbutton is not depressed, then the response time as determined by the M164 Time Constant is increased by one over the aperture duty factor. With a narrow aperture and low repetition rate, the response time can become very long. Note that the effect of the final 'Signal Processing' Time Constant is independent of duty factor.

NOTE: A GND depressed zero adjustment is usually followed by a CAL depressed gain adjustment. Also, if operating with the 1 MΩ input impedance selected, a second GND released zeroing will be required as explained under COHERENT PICKUP AND INPUT IMPEDANCE on page IV-16.

There may also be instances when one would wish to deliberately introduce

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offset with the Zero control, such as when a non-zero baseline could give a more convenient display. When operating dc coupled, the Zero control can be used to null out dc offsets accompanying the input signal.

EXP./SUM PUSHBUTTON: This pushbutton allows the operator to select either exponential (weighted) or true (linear or summation) averaging. When operated in the exponential averaging mode, the output signal asymptotically approaches 'G' times the input signal level, where 'G' is the gain. The time required for the output to reach its final level is five times the observed time constant (selected Model 164 time constant divided by the aperture duty factor). Once the output reaches 'G' times the input signal, there is no further change in the output level, regardless of how many repetitions of the input signal occur. After a large number have occurred, at least enough to give five time constants of analysis time, the output of the Processor Module can be considered to be the average of 2TC/AD repetitions of the input signal, where TC is the selected Model 164 Time Constant and AD is the selected Aperture Duration, both in seconds. The SNIR (signal-to-noise improvement ratio) achieved in the M164 then is $\sqrt{2TC/AD}$. Note that this is a weighted average, that is, the most recent repetition has more influence on the output level than the one preceding it which has more influence than the one preceding it, and so forth, on back to the early repetitions which have negligibly small influence. The advantages of exponential averaging are that the final output level bears a simple fixed relationship to the input signal level, and that any arbitrary amount of SNIR can be obtained by appropriately selecting the Time Constant and Aperture Duration. The main-frame Signal Processing time constant gives additional improvement in the signal-to-noise ratio as explained in Subsection 4.4I.

With the pushbutton in the released position, the instrument becomes a linear averager, that is, one in which all repetitions of the signal contribute equal volt-second pieces of information to the output. As a consequence, the output does not asymptotically approach G times the input, but rather increases by the same amount with each repetition of the input until output overload occurs. In linear averaging operation, the output is simply the average of N repetitions, where N is the actual number that have occurred. The M164 SNIR then is simply $\sqrt{N}$. Note that the SNIR is independent of both the time constant and the aperture duration. These parameters do, however, affect the rate of growth of the output level, that is, the size of the volt-second piece of information contributed with each repetition.

Figure IV-7 shows the M164 output response as a function of time for the two averaging modes. Note that in exponential averaging, the output response is given by the standard RC charging curve. After an analysis time equal to one time constant, the output reaches 63% of its final value. After five time constants of analysis time, the output is within one percent of its final value. Operated as a linear averager, the output reaches the same level after an analysis interval of only one time constant. This level is not final. If subsequent repetitions occur, the output will continue to rise until overload occurs.

From a practical point of view, the principal difference between linear and exponential averaging is that linear averaging gives a better SNIR for a given number of repetitions of the event under study. However, in most in-

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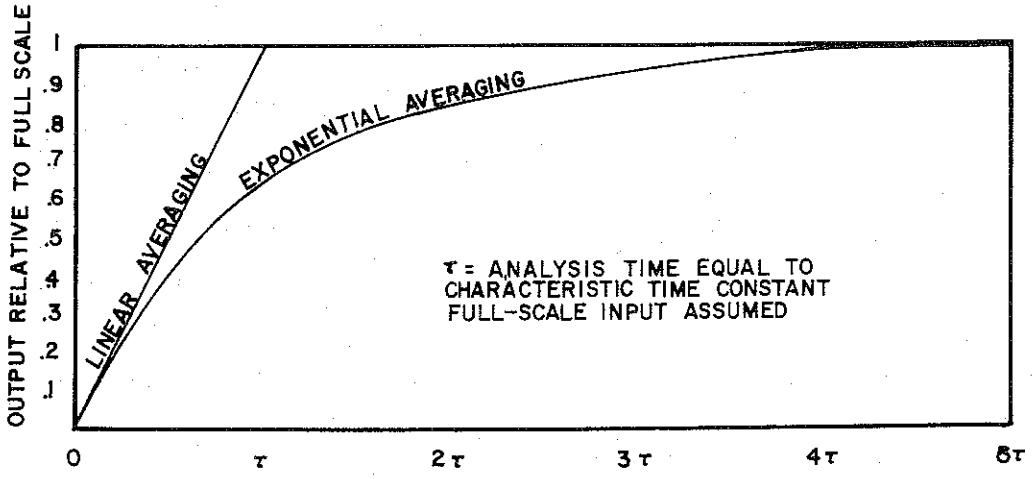


Figure IV-7. OUTPUT RESPONSE AS A FUNCTION OF ANALYSIS TIME FOR BOTH EXPONENTIAL AND SUMMATION AVERAGING

stances, one is not limited with regard to the number of repetitions. By simply extending the experiment somewhat longer, exponential averaging yields results equal to those obtainable with linear averaging and with the advantage that the output level reached bears a simple direct relationship to the input signal level. Consequently, exponential averaging is used in most applications. Nevertheless, situations where the absolute number of allowable repetitions is limited do occur, and in such an application, one would do better to use linear averaging. Consider the following example.

Suppose that the effect under study in a given application deteriorates with repeated stimulation so that the maximum number of useful repetitions is limited to 500. Further suppose that the resolution requirement is 1 μs and that an aperture duration of 1 μs is used. Consider the comparative results of recovering this signal, first with exponential averaging, and second with linear averaging.

For the output to reach its final value in exponential averaging, it is necessary that five time constants of analysis time occur. In the example at hand, there are 500 repetitions, each having a duration of 1 μs, giving a total analysis time of 500 μs. For full output response, the time constant cannot exceed one fifth the analysis time. For maximum SNIR, the time constant wants to be as large as possible. Thus the optimum time constant in this application is 500/5 or 100 μs. The SNIR achieved by the M164 with a time constant of 100 μs and an aperture duration of 1 μs is $\sqrt{2TC/AD} = 14.1$.

Now consider the same example with linear averaging. The M164 SNIR will simply be $\sqrt{N} = \sqrt{500} = 22.4$, regardless of the time constant selected (we assume that resolution requirements dictate the 1 μs aperture duration). The time constant will, however, affect the size of the volt-second increments. Since the analysis time is 500 μs, a time constant of exactly 500 μs will result in full-scale output after 500 repetitions. With a lower time constant, the output level will exceed full scale, resulting in overload. If the time constant is very long, the final level will be very small, perhaps even so small as to make the drift and noise of the main frame output amplifiers significant in comparison. Ideally, the time constant selected should give as much

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output as possible consistent with avoiding output overload. In the case of the Model 164, the proper choice would be 1 ms, the next time constant larger than the ideal (but unavailable) 500 μs time constant.

It should be noted that all of this is with reference to single-point analysis. If the input signal is being scanned, the only possible choice is exponential averaging. Also, note that one must be operating with exponential averaging to perform the earlier mentioned zeroing and gain-calibration operations.

CONT. GATE PUSHBUTTON: When this pushbutton is depressed, the instrument is no longer a gated integrator. Instead, the aperture is 'locked' open, and the instrument functions as a gain of X100 amplifier having its upper frequency response set by the Model 164 and Main Frame Time Constant switches. Although there may be laboratory applications for the instrument operated in this manner, this function primarily serves to simplify servicing.

CLEAR: This pushbutton allows the operator to reset the various instrument integrators to zero. If the unit is equipped with the digital storage option, the data stored in the option memory circuits is wiped out and replaced with all zeros as well. Each processor module is furnished with a Clear pushbutton and all work in parallel. Thus, if the Main Frame in question is equipped with two Model 164's, two Model 163's or one of each, it doesn't matter which Clear pushbutton is activated. Activating any one of them clears and zero-sets all integrators. Usually, clearing is done just prior to starting an analysis. If the analysis has to be terminated prior to its completion, use of the Clear function will shorten the time required to get started again. From an operational point of view, the clearing action is virtually instantaneous and doesn't depend on the instrument's being triggered.

TIME CONSTANT: The choice of time constant is particularly important with regard to obtaining good measurement results in the minimum possible time. Not only does Time Constant directly affect the SNIR (signal-to-noise improvement ratio), but it also influences the time required to recover a given point or waveform. As explained previously, in exponential averaging, the SNIR achieved in the Processor Module is given by the expression

$$\text{SNIR} = \sqrt{2TC/AD}$$ (white input noise having upper frequency limit of 1/2 AD assumed)

where the Time Constant and Aperture Duration are given in seconds. By making the time constant large and the aperture duration narrow, any arbitrary amount of SNIR can be achieved. However, there is a tradeoff in that operating time is increased. Each point on the recovered waveform must be analyzed for at least five time constants for that point to be represented at the output with an amplitude of G (G = instrument gain) times the input amplitude. Thus the experimental time required to do an analysis varies directly with the time constant, while the improvement in SNIR varies with the square root of the time constant. Clearly, in an application where minimizing operating time is an important consideration, the time constant should be no longer than is required to reduce the noise to an acceptable level. Additional SNIR can be obtained in the main frame by means of the Signal Processing Time Constant.

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Besides allowing the choice of time constants from 1 μs to 10 ms, the Time Constant switch also has a special position to allow time constants greater than, or intermediate to, the time constant values provided. With the switch set to SPEC, the time constant is determined by a user installed capacitor mounted on normally unused terminals of the Time Constant switch. Figure IV-8 shows the mounting terminals for the special time constant capacitor. The relationship between capacitance and time constant is:

$$C = \frac{TC}{2 \times 10^4}$$

where: C is the required capacitance in farads, and
TC is the desired time constant in seconds.

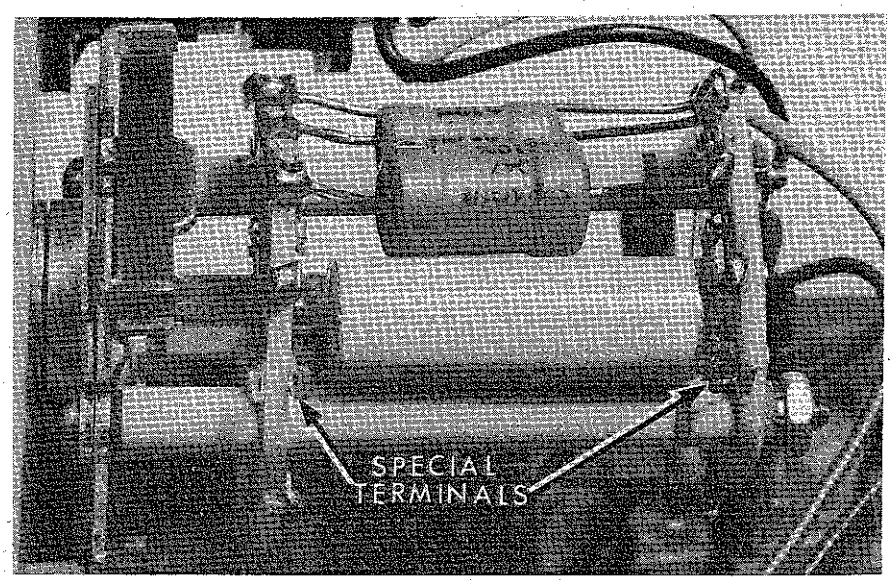


Figure IV-8. TIME CONSTANT SWITCH TERMINALS TO BE USED FOR INSTALLATION OF "SPECIAL" TIME CONSTANT CAPACITOR

Only low leakage capacitors should be used. Film capacitors such as Mylar, polystyrene, polycarbonate, or Teflon are all suitable. Specifically to be avoided are electrolytics and tantalum capacitors. The high leakage of such capacitors will severely degrade the hold-time (minimum trigger rate) capabilities of the Model 164 when operated with the Time Constant switch in the SPECIAL position. With no capacitor, the time constant will be nominally 1 μs.

It is important to realize that the observed response time depends on the aperture duty factor as well as on the time constant. Five time constants of analysis time are required to fully 'capture' one amplitude point. Because the analysis proceeds only during the aperture open times, the output response is 'slowed' by one over the aperture duty factor. For example, suppose one were doing a single point analysis with a one microsecond aperture duration. Further suppose the repetition rate to be 1 kHz and the selected

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