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# UNIVERSAL COUNTER

## 5328A

## (Including Options 010, 011, 020, 021, 030, and 040)

USERS MANUAL

Unless otherwise specified by a Manual Change Sheet, this manual applies to all Hewlett-Packard Model 5328A Universal Counters and the Options described in Section I.

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# SAFETY CONSIDERATIONS

## GENERAL

This is a Safety Class I instrument. This instrument has been designed and tested according to IEC Publication 348, "Safety Requirements for Electronic Measuring Apparatus", and has been supplied in safe condition.

This manual contains information, cautions, and warnings which must be followed by the user to ensure safe operation and to retain the instrument in safe condition.

## WARNINGS

### SAFETY

If this instrument is to be energized via an autotransformer for voltage reduction, make sure the common terminal is connected to the earthed pole of the power source.

BEFORE SWITCHING ON THIS INSTRUMENT, the protective earth terminals of this instrument must be connected to the protective conductor of the (mains) power cord. The mains plug shall only be inserted in a socket outlet provided with a protective earth contact. The protective action must not be negated by the use of an extension cord (power cable) without a protective conductor (grounding).

Make sure that only fuses with the required rated current and of the specified type (normal blow, time delay, etc.) are used for replacement. The use of repaired fuses and the short-circuiting of fuse holders must be avoided.

Whenever it is likely that the protection offered by fuses has been impaired, the instrument must be made inoperative and be secured against any unintended operation.

### GROUNDING

Any interruption of the protective (grounding) conductor (inside or outside the instrument) or disconnecting the protective earth terminal is likely to make this instrument dangerous. Intentional interruption is prohibited.

### HIGH VOLTAGE

Any adjustment, maintenance, and repair of the opened instrument under voltage should be avoided as much as possible and, when inevitable, should be carried out only by a skilled, qualified person who is aware of the hazard involved.

Capacitors inside the instrument may still be charged even if the instrument has been disconnected from its source of supply.

Adjustments and service described herein are performed with power supplied to the instrument while protective covers are removed. Energy available at many points may, if contacted, result in personal injury.



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# CAUTIONS

## LINE VOLTAGE SELECTION

BEFORE SWITCHING ON THIS INSTRUMENT, make sure the instrument is set to the voltage of the power source. Verify that the power transformer primary is matched to the available line voltage. Verify that the correct fuse is installed.

## GROUNDING

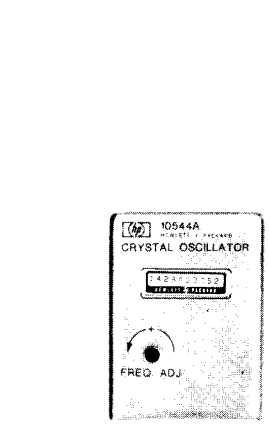
BEFORE SWITCHING ON THIS INSTRUMENT, ensure that all devices connected to this instrument are connected to the protective (earth) ground. (Grounding one conductor of a two-conductor outlet is not sufficient.)

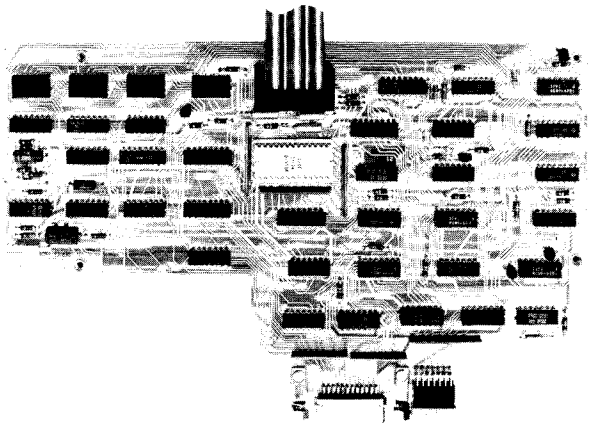
## ⚠ ATTENTION ⚠

This symbol:  , which appears on the instrument means: Read the instruction manual before operating the instrument. If the instrument is operated without reading the instructions, it may not operate correctly.



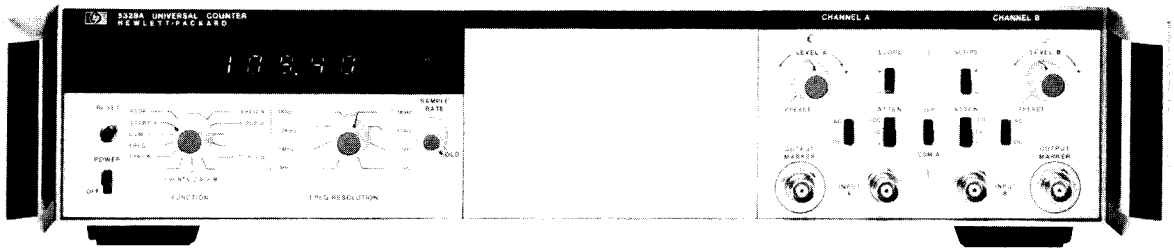
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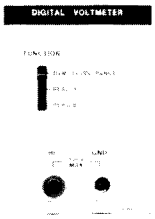


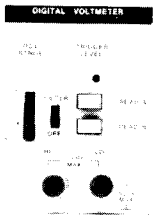
OPTION 010
OVEN
OSCILLATOR

OPTION 011
HP-IB
INTERFACE



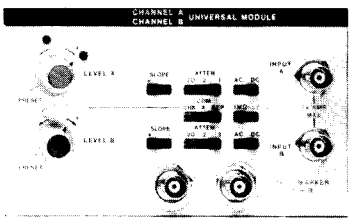

OPTION 020
DVM




OPTION 021
DVM




OPTION 030
CHANNEL C




OPTION 040
UNIVERSAL MODULE

*Figure 1-1. Model 5328A Universal Counter with Options*



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# SECTION I
# GENERAL INFORMATION

## 1-1. SCOPE OF MANUAL

1-2. This manual provides operating information for the Hewlett-Packard Model 5328A Universal Counter including all options. Maintenance information for the 5328A mainframe (without options) is covered in the 5328A Service Manual. A separate Installation and Service Manual is provided for each option supplied with the 5328A.

1-3. This manual is divided into five sections containing the following information:

SECTION I GENERAL INFORMATION covers a description of the counter, options, equipment supplied, accessories available, and specifications.

SECTION II INSTALLATION provides instructions for unpacking, inspection, preparation for use, shipment, and storage for the overall instrument. Installation instructions for the options are covered in separate Installation and Service Manuals for each option.

SECTION III OPERATION covers basic counter operation, sources of measurement error, time interval measurements, front and rear panel operation summaries for the standard instrument and each option, and descriptions of controls, connectors, indicators, inputs, and outputs.

SECTION IV APPLICATIONS contains information on how to use the 5328A to measure frequency, period, time interval, and ratio. DVM and totalizing measurements are also covered in this section.

SECTION V PROGRAMMING covers information for instruments equipped with Option 011. Included is an introduction to the Hewlett-Packard Interface Bus and instructions for setting the address switches, programming, using the program code set, triggering a measurement, reading a measurement, and program examples. Also included are bus commands, the ASCII codes and the measurement output format.

## 1-4. DESCRIPTION

1-5. The standard 5328A mainframe measures frequency, period, period average, time interval, time interval average, and ratio. A totalize function is also provided. The capabilities of the instrument are expanded (as shown in Table 1-3) by installing the options described in paragraph 1-17. The 5328A provides an 8-digit (9 with Option 030) LED display, display storage, and leading zero blanking. Decimal point and unit readouts are displayed automatically. Two independent selectable input channels are provided for time interval measurements. Each input channel has an attenuator, trigger slope selector, level control, ac-dc coupling, and an oscilloscope marker output. Rear panel connectors provide a gate output, a time base output and an input for an external frequency standard. An ARM switch on the rear panel allows arming by the signal being measured (switch OFF) or by another input signal (switch ON).

## 1-6. INSTRUMENT IDENTIFICATION

1-7. Hewlett-Packard instruments have a 2-section, 10-character serial number (0000A00000), which is located on the rear panel. The 4-digit serial prefix identifies instrument changes. If the serial prefix of your instrument differs from that listed on the title page of this manual, there are differences between this manual and your instrument. Instruments having higher serial prefixes are covered with a "Manual Changes" sheet included with this manual. If the change sheet is missing, contact the nearest Hewlett-Packard Sales and Service Office listed at the back of this manual.



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## 1-8. APPLICATIONS

1-9. Specific applications information is provided in Section IV. The general application features of the 5328A are described in the following paragraphs.

1-10. The high sensitivity, frequency range, and signal conditioning controls (see Table 1-3) make the 5328A ideally suited for a wide range of applications. The direct count feature of the 5328A means that prescaling techniques are not used to achieve the 100 MHz frequency range (up to 512 MHz with Option 030). Direct count speed is required in high-speed totalizing or system applications. The dynamic range, input attenuators and trigger level range (see Table 1-3) permit measurements to be made on virtually any signal.

1-11. The controlled "arming" feature of the 5328A is useful in applications such as burst frequency measurements, and pulse amplitude measurements.

1-12. The optional integrating digital voltmeters measure trigger levels (critical in most time interval measurements) and external voltages. The hysteresis compensation feature of Option 040 means that the trigger level does not need resetting when the slope switch changes the polarity.

1-13. The standard 5328A single-shot resolution of 100 ns meets the requirements for applications such as mechanical and electromechanical device (relays) timing, time of flight measurements (ballistics), sonar ranging, radio ranging and navigation. The Option 040 provides increased resolution (to 10 ns) useful in applications such as computer/peripheral timing measuremnts, logic timing measurements, radar ranging and optical ranging. The delay feature of Option 040 allows unwanted signals to be ignored which would otherwise trigger the counter.

1-14. Using time interval averaging, time intervals as short as 100 ps, with resolution to 10 ps may be measured. Applications include cable length measurements, phase measurements, logic timing measurements, and integrated circuit propagation delay measurement.

1-15. Full bandwidth, sensitivity, and signal conditioning of the Channel A, B (and C for Option 030) input amplifiers is provided for ratio, totalizing, and scaling measurements.

1-16. The 5328A with Option 011 HP-IB Interface is able to output measurement data and be controlled (fully programmed) via the Hewlett-Packard Interface Bus (HP-IB). The 5328A is interfaced to HP-IB compatible instruments, calculators, or computers by simply interconnecting with an HP-IB cable.

## 1-17. OPTIONS

1-18. Several options are available with the 5328A, as listed below. If purchased as part of an initial order, options are installed at the factory and the instrument is ready for operation when received. Procedures for field installation of an option are described in the Installation and Service Manual supplied with each option (except for Option 010, Oscillator which is covered in the 5328A Service Manual). The following options are available:

a. Option 010, High Stability Time Base. Oven oscillator with aging rate $<5 \times 10^{-10}$/day.

b. Option 011, HP-IB Interface. Allows 5328A to output data and be controlled via the HP Interface Bus.

c. Option 020, Digital Voltmeter (DVM). Single ended DVM for trigger level and external dc voltage measurements.

d. Option 021, High Performance DVM. Floating high accuracy DVM for trigger level and external dc voltage measurements.



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e. Option 030, Channel C. Frequency measurements to 512 MHz; 15 mV rms sensitivity; direct count.

f. Option 040, High Performance Universal Module. Same as standard 5328A but with 10 ns single shot time interval; improved T.I. averaging; improved T.I. accuracy; measurements with delay; T.I. A→B marker; hysteresis compensation; switchable input impedance (1 MΩ/50Ω).

## 1-19. EQUIPMENT SUPPLIED AND ACCESSORIES AVAILABLE

1-20. Table 1-1 lists equipment supplied with the 5328A and Table 1-2 lists accessories available.

*Table 1-1. Equipment Supplied*

| DESCRIPTION | HP PART NO. |
|---|---|
| Detachable Power Cord 7½ ft (231 cm) long | 8120-1348 |

*Table 1-2. Accessories Available*

| DESCRIPTION | HP PART NO. |
|---|---|
| HP Interface Bus Interconnect Cable | 10631A, 3 ft long (914 mm)<br>10631B, 6 ft long (1828 mm)<br>10631C, 12 ft long (3656 mm) |
| Rack Mount Flange (for mounting 5328A with handles)<br>(for mounting 5328A without handles) | 5020-8873 (2 each)<br>5020-8861 (2 each) |

## 1-21. SPECIFICATIONS

1-22. Table 1-3 lists detailed specifications for the 5328A including all options.



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*Table 1-3. Specifications*

## INPUT CHARACTERISTICS

**Channel A and B (standard and option 040)**

**Sensitivity:**
25 mV rms, 0—40 MHz (dc coupled)
20 Hz—40 MHz (ac coupled)
200 kHz—40 MHz (ac coupled and 50Ω with Opt. 040)
50 mV rms, 40 MHz—100 MHz
Min. pulse width: 5 ns, 140 mV p-p

**Coupling:** Ac or Dc, switch selectable

**Impedance:** 1 MΩ ‖ <40 pF (switch selectable 1 MΩ or 50Ω nominal with Opt. **040**)

**Trigger Level:** Variable over ±2.5 volts times attenuator setting with 0 volt preset position.

**Trigger Slope:** independent selection of + or - slope

**Attenuators:** X1, X10, X100 (X1, X2, X20 with Opt. **040**)

**Dynamic Range:** 25 mV to 1 V rms x attenuator setting for 0—40 MHz; 50 mV to 500 mV rms x attenuator setting for 40—100 MHz

**Maximum input** (dc coupled):

| | |
|---|---|
| X1: | 250 V rms, dc—50 kHz<br>1.25 x $10^7$ V rms/freq., 50 kHz—2.5 MHz<br>5 V rms, 2.5—100 MHz |
| X10, X100: | 250 V rms, dc—5 MHz<br>1.25 x $10^9$ V rms/freq., 5—100 MHz |
| X2, X20: (Opt. **040**) | 250 V rms, dc—500 kHz<br>1.25 x $10^8$ V rms/freq., 0.5—25 MHz<br>5 V rms, 25—100 MHz |
| Ac coupled: | Vmax = 200 V (peak + dc) for dc—20 Hz; same as dc coupled for frequency greater than 20 Hz. |
| Opt. **040** 50Ω position: | 5 V rms, dc—100 MHz |

**Channel Input:** Common A or separate, switch selectable. In COM A position, sensitivity remains the same. Impedance becomes 1 MΩ ‖ <65 pF for the standard and 500 kΩ ‖ <65 pF for the Option 040 high impedance position. 50Ω position remains nominal 50Ω.

**Channel C (option 030)**

**Sensitivity:** 15 mV rms, 5 MHz—512 MHz
**Coupling:** dc
**Trigger Level:** 0 V, fixed
**Impedance:** 50Ω nominal
**Maximum Input:** 5 V rms
**Input Protection:** Fused

## FREQUENCY MEASUREMENTS

**Frequency A (standard and option 040)**

**Range:** 0 — 100 MHz direct count
**Resolution:** 1 MHz to 0.1 Hz in decade steps
**Accuracy:** ±1 count ± timebase error
**Display:** kHz, MHz

**Frequency C (option 030)**

**Range:** 5 — 512 MHz direct count
**Resolution:** 1 MHz to 0.1 Hz in decade steps
**Accuracy:** ±1 count ± timebase error
**Display:** kHz, MHz

*Trigger error is <0.3% of one period for sinewaves of 40 dB S/N or better and amplitude equal to sensitivity of counter. For any waveshape, trigger error is less than

$$\frac{\pm 2 \times \text{peak noise voltage}}{\text{signal slope}}$$

(or $\frac{\pm .0025\ \mu\text{sec}}{\text{signal slope in V/}\mu\text{sec}}$ for 40 dB S/N.)

## PERIOD MEASUREMENTS

**Period A (standard and option 040)**

**Range:** 0 — 10 MHz
**Resolution:** 100 ns to 1 s in decade steps (10 ns to 0.1 s with opt. **040**)
**Accuracy:** ±1 count ± timebase error ± trigger error*
**Display:** ns, μs, ms, s

**Period Average A (standard and option 040)** — the period of the signal at the A input is averaged over the number of periods, N, indicated by the resolution switch (N=1 to $10^7$).

**Range:** 0 — 10 MHz
**Resolution:** 100 ns to .01 ps in decade steps (10 ns to .001 ps with opt. **040**)
**Accuracy:** ±1 count displayed ± timebase error

$$\pm \frac{\text{trigger error}^*}{\text{no. periods averaged}}$$

## TIME INTERVAL MEASUREMENTS

**Time Interval A to B (standard and option 040)**

**Range:** 100 ns — $10^8$ s (10 ns — $10^7$ s with opt. **040**)
**Resolution:** 100 ns to 1 s in decade steps (10 ns to 0.1 s with opt. **040**)
**Accuracy:** ±1 count ± timebase error ± trigger error*

**Time Interval Average A to B (standard and option 040)** — The time interval between a start signal at A and a stop signal at B is averaged over the number of time intervals, N, indicated by the resolution switch (N=1 to $10^7$).

**Range:** 0.1 ns — 10 s (0.1 ns — 1 s with opt. **040**)

**Resolution:** $\frac{\pm 100\ \text{ns}}{\sqrt{\text{no. intervals averaged}}} \pm 10\ \text{ps}$

( $\frac{\pm 10\ \text{ns}}{\sqrt{\text{no. intervals averaged}}} \pm 10\ \text{ps}$ with opt. **040**)

**Accuracy:** $\frac{\pm 100\ \text{ns} \pm \text{trigger error}^*}{\sqrt{\text{no. intervals averaged}}} \pm 4\ \text{ns} \pm \text{timebase error}$

( $\frac{\pm 10\ \text{ns} \pm \text{trigger error}^*}{\sqrt{\text{no. intervals averaged}}} \pm 2\ \text{ns} \pm \text{timebase error}$

with opt. **040**. The opt. **040** has a "jittered" clock in time interval averaging for those cases when the input is coherent with the 5328A's clock frequency.)

**Minimum pulse width:** 25 ns (10 ns with opt. **040**)

**Minimum dead time:** 150 ns (140 ns with opt. **040** and maximum repetition rate of 10 MHz) ("dead time" is the time between the preceding time interval's stop event and the current time interval's start event).

## RATIO MEASUREMENTS

**B/A and C/A (standard and option 040)** — The ratio of the frequency at B (or C for C/A function when option 030 is installed) to the frequency at A is measured for N counts of A where N is selected by the resolution switch (N=1 to $10^7$).

**Range:** A: 0 — 10 MHz
B: 0 — 100 MHz
C: 5 — 512 MHz

**Resolution:** 1 part in $\frac{B}{A} \times N$ (or $\frac{C}{A} \times N$)

**Accuracy:** ± 1 count of B (or C) ± trigger error* of A x freq. of B (or C) (N >1)
For N = 1, add ± 120 ns x freq. of B (or C)
(± 12 ns x freq. of B (or C) with **Opt. 040**)



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*Table 1-3. Specifications (Continued)*

## DIGITAL VOLTMETER MEASUREMENTS

**DVM (option 020 and 021)** — Trigger levels of input channels A and B and external voltages may be measured.†

| **Maximum Sensitivity:** | **OPT. 020** | **OPT. 021** |
|---|---|---|
| Meas. Time (N=): | | |
| 10 s (N=$10^7$) | 1 mV | 10 μV |
| 1 s (N=$10^6$) | 1 mV | 100 μV |
| 0.1 s (N=$10^5$) | 2 mV | 1 mV |
| 10 ms (N=$10^4$) | 20 mV | 10 mV |
| 1 ms (N=$10^3$) | 200 mV | 100 mV |
| **Range:** | 0 to ±125 Vdc | ±10, ±100, ±1000 Vdc, and AUTORANGE |
| **Full range display resolution** (1 sec measurement time): | ±0.9999, ±9.999, ±99.99, ±125.0 | ±12.5000, ±125.000, ±1000.00 |
| **Accuracy:** (20 min. warm-up) | ±.5% reading ±4 mV | ±.03% reading ±.004% range; for 1000 V range: ±.087% reading ±.004% range |
| **Temp. Coefficient:** (0 to 40°C) | ±.05% reading/°C ±0.5 mV/°C | ±.002% reading/°C ±.001% range/°C |
| **Input Terminals:** | Single ended | Floating pair |
| **Input Impedance:** | 10 MΩ | 10 MΩ |
| **Normal Mode Rejection Ratio:** | >60 dB at 60 Hz (50 Hz) ±0.1% | >80 dB at 50 Hz or greater with filter on |
| **Effective Common Mode Rejection Ratio** (1 kΩ unbalance): | — | DC: >120 dB AC: >120 dB for multiples of 60 Hz (50 Hz) with filter on |
| **Response Time** (step input): | 70 ms | 10 ms (filter off) |
| **Maximum Input:** | ±500 V | HI to LO: ±1100 V all ranges; LO to chassis ground: ±500 V |
| **Trigger Level Measurements:** | 2 mV display resolution | 1 mV display resolution; trigger level reading automatically multiplied by setting of attenuator switch if using option **040** universal module |

## TOTALIZING AND SCALING MEASUREMENTS

**Start A (standard and option 040)** — The number of counts at the A input are totalized for N=1 on the resolution switch. For N >1, A/N is totalized and the scaled output (A/N) is available at the Timebase Out rear panel connector.

**Range:** 0 — 100 MHz for N=1
0 — 10 MHz for N >1

**EVENTS C, A TO B (standard and option 040)** — The number of events at the C input are totalized during the synchronized time interval (i.e., a multiple of 100 ns, or 10 ns for opt. 040) defined by inputs to channel A and B.

**Accuracy:** ±1 count of C ± trigger error* of A and B ± freq. of C x 120 ns
(±1 count of C ± trigger error* of A and B ± freq. of C x 12 ns with opt. **040**)

## MEASUREMENTS WITH DELAY (Option 040)

Delay mode is activated by inner concentric knob on LEVEL A control of option 040 Universal Module (red LED indicates delay is activated). In delay mode, Channel A triggers and is then disabled from triggering again until the delay times out (disabled state occurs within 1 μs after triggering). Channel B is continuously disabled until the delay times out. After the delay, both A and B are enabled. The delay time may be measured by placing the counter in T.I. A→B and the Universal Module in check (CHK).

**Delay range:** 20 μs to 20 ms continuously adjustable

**Minimum Dead Time:** 1 μs between stop and next start (T.I. average measurements only)

**Meaningful Functions:** FREQ. A, PER A, PER AVG A, T.I. A→B, T.I. AVG A→B, RATIO C/A, START A, EVENTS C, A→B

## HP-IB INTERFACE (Option 011)

Provides digital output of measurement data ("talker") as well as input for remote program control ("listener").

**Programmable Functions:** Function, Resolution, Sample rate (max, or manual control), Arming, Display modes, Measurement modes, Output modes, and Reset commands

**HP-IB commands:** responds to the following bus commands (see HP-IB Users Guides for definitions) — Unlisten, Untalk, Local Lockout, Device Clear, Serial Poll Enable, Serial Poll Disable, Go to Local, Selected Device Clear, and Group Executive Trigger.

**Service Request (SRQ):** if enabled, indicates end of measurement.

**Maximum data output rate:** 500 readings/sec



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Table 1-3. Specifications (Continued)

## GENERAL

**Display:** 8 digit (9 with Opt. 030) LED display

**Blanking:** Suppresses display of unwanted zeros to left of most significant digit

**Storage:** Holds reading between samples; can be overridden by rear panel switch.

**Sample rate:** Variable from less than 2 ms between measurements to HOLD which holds display indefinitely.

**Gate output:** Rear panel output; TTL levels; high when counter gate open

**Timebase output:** Rear panel output; TTL levels

**Check signal:** With function switch in CHECK, counter should display 10 MHz ±1 count. (With opt. **040**, place function switch in Freq A and universal module in CHECK (CHK) — counter should display 100 MHz ±1 count.)

**Timebase:**

**standard crystal**

Aging rate: $<3 \times 10^{-7}$/month
Temperature: $<2.5 \times 10^{-6}$ 0° to 50°C
Line voltage: $<1 \times 10^{-7}$ for 10% change

**Opt. 010 over oscillator**

Aging rate: $<5 \times 10^{-10}$/day after 24-hour warm-up
Short term: $<1 \times 10^{-10}$ rms/sec
Temperature: $<7 \times 10^{-9}$ 0° to 50°C
Line voltage: $<\pm 5 \times 10^{-9}$ for 10% variation
Warm-up: $<\pm 5 \times 10^{-9}$ in 20 min.

**Ext. Freq. Std. Input:** 30 kHz to 10 MHz signal of amplitude >1.0 V rms into 1 kΩ. Maximum input: 5 V p-p. For opt. **040** only, the following constraints apply: ext. freq. std. must be 10 MHz for Period Avg., T.I. Avg., Period (N=1), and T.I. (N=1).

**Trigger Lights:** Light is ON when input is above trigger level; OFF when input is below trigger level; BLINKING when channel is triggering. Operative over frequency range 0—100 MHz.

**Marker Outputs:** Inverted channel A and channel B Schmidt trigger outputs available on front panel; 0 to -100 mV levels into 50Ω;<20 ns delay. (With Opt. **040**, inverted channel A Schmidt trigger and T.I. A→B marker outputs (0 to -50 mV) available on front panel—T.I. A→B is high during the time interval measured by the counter). Outputs protected from inadvertently applied voltage to ± 5 Vdc.

**ARM:** Rear panel switch turns arming ON or OFF. With arming ON, the measurement is armed by an input other than the input involved in the measurement. The following are armed by an event at B: FREQ A, PERIOD A, PERIOD AVG A, FREQ C, DVM, C/A; the following are armed by an event at C: T.I. A→B, T.I. AVG A→B, EVENTS C, A→B, B/A.

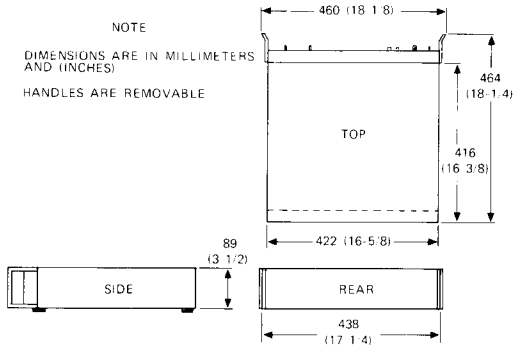
**Operating Temperature:** 0° to 50°C

**Power Requirements:** 100/120/220/240 V rms, +5%, -10% (switch selectable), 48—66 Hz; 150 VA max.

**Accessories Furnished:** Power cord, 200 cm (7½ ft.)

**Weight:** Net 8.5 kg (18 lb, 12 oz). Shipping 11.2 kg (24 lb. 12 oz)

**Dimensions:**




**Available Accessories**

HP Rack Mount Ears (2 each required)

(for use with handles) ..... 5020-8873
(for use without handles) ..... 5020-8861



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# SECTION II
# INSTALLATION

## 2-1. INTRODUCTION

2-2. This section provides instructions for unpacking, inspection, preparation for use, shipment, and storage.

## 2-3. UNPACKING AND INSPECTION

2-4. If the shipping carton is damaged, inspect the counter for visible damage (scratches, dents, etc.). If the counter is damaged, notify the carrier and the nearest Hewlett-Packard Sales and Service Office immediately (offices are listed at the back of this manual). Keep the shipping carton and packing material for the carrier's inspection. The HP Sales and Service Office will arrange for repair or replacement of your instrument without waiting for the claim against the carrier to be settled.

## 2-5. PREPARATION FOR USE

**CAUTION**

**BEFORE CONNECTING THIS INSTRUMENT TO AN AC POWER LINE, BE SURE THAT THE 100-, 120-, 220-, 240-VOLT LINE SELECTOR SWITCHES ON THE REAR PANEL ARE SET TO THE PROPER POSITIONS AND PROPER LINE FUSE IS INSTALLED.**

### 2-6. Power Requirements

2-7. This instrument can be operated on single phase 100, 120, 220, or 240 (-10% +5%) volts ac. Power required is approximately 150 VA maximum. To avoid instrument damage, the rear-panel line selector switch must be set to the correct position ("100V, 120V, 220V, or 240V") and the correct fuse (as labeled on the rear panel) must be installed. See Section III for rear-panel features photograph. When shipped, the switch is set for 120-volt ac operation.

### 2-8. Fuse Replacement and Installation

2-9. Two fuses are supplied with the instrument. The instrument is shipped with a 2.0 amp fuse installed for 100 or 120 volt operation. To configure the instrument for 220 or 240 volt operation disconnect the ac power cable, set the line selector switch and install the 1.0 amp fuse.

### 2-10. Power Cables

**WARNING**

**TO PROTECT OPERATING AND SERVICING PERSONNEL, THIS INSTRUMENT IS EQUIPPED WITH A THREE-PIN POWER RECEPTACLE. THE CENTER PIN OF THE RECEPTACLE CONNECTS THE INSTRUMENT CHASSIS AND PANELS TO EARTH GROUND WHEN USED WITH A PROPERLY WIRED THREE CONDUCTOR OUTLET AND POWER CABLE. IMPROPERLY GROUNDED EQUIPMENT CAN RESULT IN HAZARDOUS POTENTIALS BETWEEN EQUIPMENTS.**



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2-11. To accommodate the different power receptacles used throughout the world, this instrument is supplied with one of the power cables shown in Figure 2-1. The cable supplied for use in the United States meets the specifications established by the International Electrotechnical Commission (IEC). The male connector of this cable is a NEMA type and the female connector is a C.E.E. type.

2-12. Connect the power cable to a power source receptacle that has a grounded third conductor. If the line power receptacle is a two-pin type instead of a three-pin receptacle, use a two-to-three pin adapter (HP Part No. 8120-1348 for USA applications) and connect the green lead on the adapter to earth ground. See warning above. If your counter is to be operated with 220-240 Vac line power, an Underwriters Laboratories listed connector should be used to connect power.

### 2-13. Operating Environment

2-14. Maximum and minimum allowable operating temperatures are listed in Table 1-3. If these limits are exceeded at the installation site, auxiliary cooling or heating should be used to keep the environment within limits. A 1-inch space above the counter should be clear to allow cooling air circulation. The fan intake at rear is to be kept clear.

### 2-15. Bench Operation

2-16. The instrument cabinet has plastic feet and foldaway tilt stands for convenience in bench operation. The tilt stands permit inclining the instrument for ease in using front-panel controls and indicators.

### 2-17. Rack Mounting

2-18. The counter is ready for bench operation as shipped from the factory. To mount the counter in a rack, it is necessary to attach side flanges at the front of the counter. The side flanges may be ordered from the factory. For rack installation of counters with handles, use Flange, Part No. 5020-8873. For installation of counters without handles use Flange, Part No. 5020-8861. To convert to rack installation, proceed as follows:

a. Remove tilt stand.

b. Remove feet (press the foot-release button, slide foot toward center of instrument, and lift off).

c. Remove trim strips (and handles if desired) at front end of sides.

d. Attach flanges to front end of sides. Instrument is now ready to mount in standard rack.

**CAUTION**

**AMBIENT TEMPERATURE IN RACK DURING OPERATION SHOULD NOT EXCEED 122°F (50°C). BE SURE INSTRUMENT POSITION IN RACK PERMITS ADEQUATE AIR CIRCULATION AND THAT NEARBY EQUIPMENT DOES NOT DISCHARGE HOT AIR DIRECTLY ON THE INSTRUMENT.**

### 2-19. PACKAGING FOR RESHIPMENT

### 2-20. Original Packaging

2-21. The same containers and materials used in factory packaging can be obtained through the Hewlett-Packard Sales and Service Offices listed at the rear of this manual.



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2-22. If the counter is being returned to Hewlett-Packard for service, attach a tag indicating the type of service required, return address, model number, and full serial number. Mark the container FRAGILE to assure careful handling.

2-23. In any correspondence refer to the counter by model number and full serial number.

### 2-24. Other Packaging Methods

2-25. If factory packaging is not available, good commercial packing should be used. Contract packaging companies in many cities can provide dependable custom packaging on short notice. The following general instructions should be followed when repackaging with commercially available materials.

a. If shipping to a Hewlett-Packard Service Office or Service Center, attach a tag indicating the type of service required, return address, model number, and full serial number.

b. Wrap the counter in heavy paper or plastic.

c. Use a strong shipping container. A double-wall carton made of 350-pound test material is adequate.

d. Use enough shock-absorbing material (3- to 4-inch layer) around all sides of the counter to provide a firm cushion and prevent movement inside the container. Protect the control panel with cardboard.

e. Seal the shipping container securely.

## 2-26. STORAGE

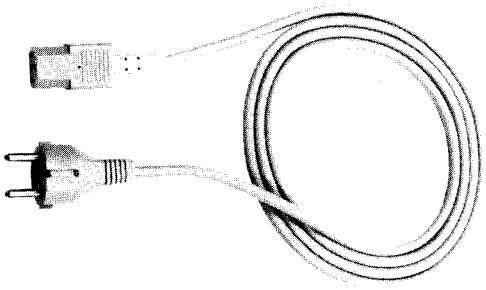
2-27. If the counter is to be stored for an extended period of time, it should be enclosed in a clean, dry, sealed container. See specifications in Section I for storage environmental limitations.

## 2-28. OPTIONS INSTALLATION

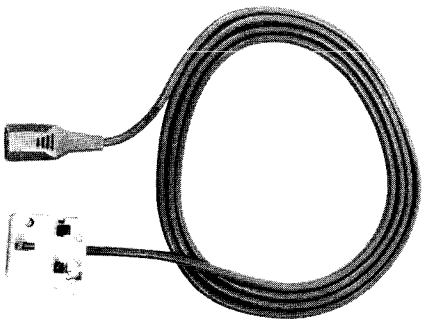
2-29. Instructions for field installation of each option (listed in paragraph 1-17) are contained in the Installation and Service Manual for each option, with the exception of Option 010, High Stability Time Base. Field installation instructions for Option 010 are provided in Section V of the 5328A Service Manual.



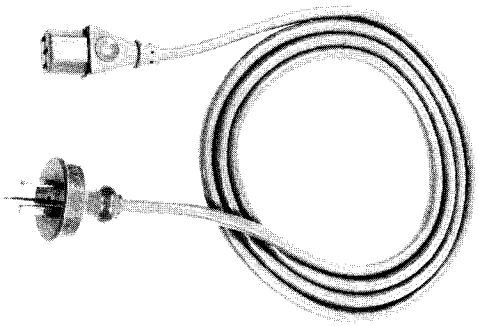
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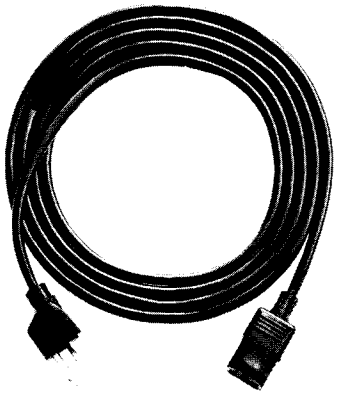
**POWER CABLE HP NO. 8120-1689**
(Germany, France, Sweden, Netherlands, Yugoslavia, Belgium, Norway, Finland)



**POWER CABLE HP NO. 8120-1351**
Great Britain



**POWER CABLE HP NO. 8120-1369**
Australia, New Zealand



**POWER CABLE NO. 8120-1348**
U.S.A., Canada

*Figure 2-1. Power Cables*



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# SECTION III
# OPERATION

## 3-1. INTRODUCTION

3-2. This section contains operating information necessary to understand operation and control of the instrument. A description of basic counter operation is provided, followed by a front panel operation summary for the standard mainframe (Figure 3-8) and a separate operation summary for each option (Figures 3-10 through 3-13). Rear panel controls and connectors are described in Figure 3-9. Detailed information is provided on the use of controls and indicators. Information on how to make measurements in the various measurement modes is provided in Section IV.

## 3-3. BASIC COUNTER OPERATION

3-4. The operation of the frequency counter is best understood by describing how the counter performs a frequency measurement. If n is the number of cycles of a signal that occurs in a time period t, the average frequency f of that signal over the time period t is given by

$$f = \frac{n}{t} \qquad (1)$$

### 3-5. Frequency

3-6. The counter measures the frequency f by accumulating the number of cycles n of the input signal that occurs over the time period t. The basic counter elements necessary to perform this measurement are shown in Figure 3-1.

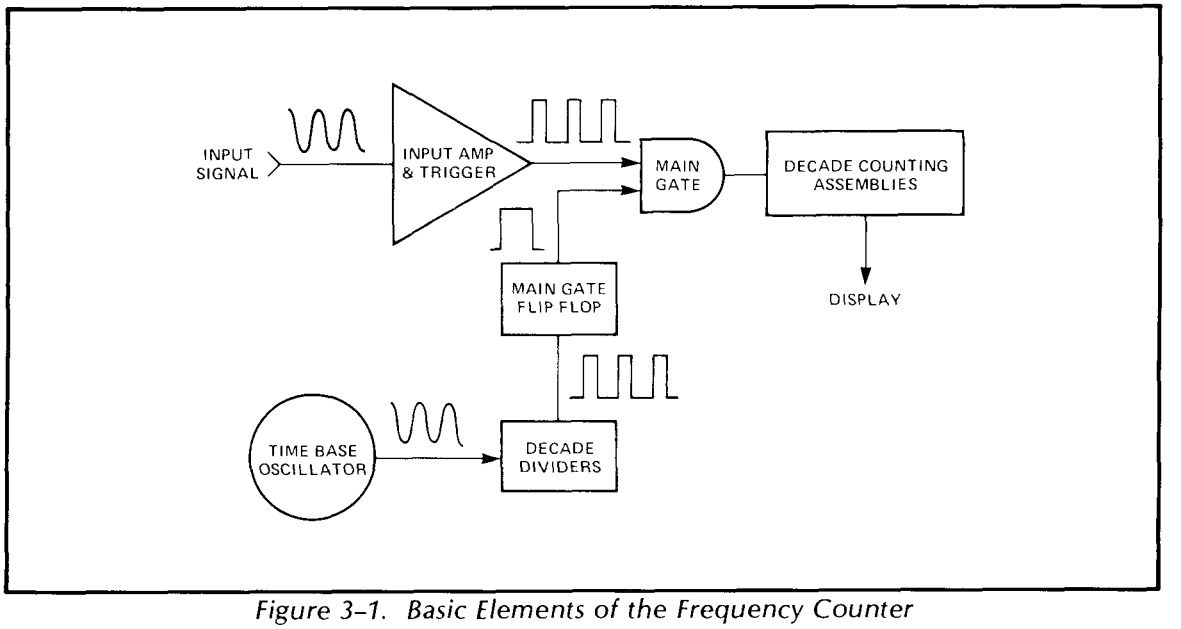



*Figure 3-1. Basic Elements of the Frequency Counter*

3-7. INPUT AMPLIFIER AND TRIGGER — essentially conditions the input signal to a form that is compatible with the internal circuitry of the counter. As Figure 3-1 indicates, the output of the amplifier/trigger is a pulse train where each pulse corresponds to one cycle or event of the input signal.



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3-8. TIME BASE OSCILLATOR — is that element of the counter from which the time t of Equation (1) is derived. From Equation (1) it may be seen that the accuracy with which t is determined has a significant effect on the measurement accuracy of the frequency f. Consequently the 5328A employs a 10 MHz precision crystal oscillator as the time base element.

3-9. DECADE DIVIDERS — takes the time base oscillator signal as the input and provide as an output a pulse train whose frequency is variable in decade steps. The operator can control this frequency with the FREQ RESOLUTION, N switch. The time t of Equation (1) is determined by the period of this pulse train.

3-10. MAIN GATE — is the heart of the counter. When this gate is opened, pulses from the amplifier/trigger are allowed to pass through. The opening and closing of the main gate is controlled by the decade divider output to the main gate flip-flop.

3-11. DECADE COUNTING ASSEMBLIES — totalizes the output pulses from the main gate and displays this total after the gate is closed. If, for example, the gate is open for precisely 1-second, the decade counting assemblies (DCA's) display the frequency, in Hertz, of the input signal.

3-12. Other basic measurements the counter can perform are described in the following paragraphs.

### 3-13. Period

3-14. Period, the inverse of frequency, can be measured by the counter by reversing the inputs to the main gate. Now the input signal controls the duration over which the main gate is open and the decade divider output is counted by the DCA's. The duration of the count is, of course, one cycle or period of the input signal (see Figure 3-2).

3-15. Unused decades in the decade divider chain can be used to divide the amplifier/trigger output so that the gate remains open for decade steps of the input period rather than a single period. This is the basis for **multiple period averaging**. Period and period averaging techniques are used to increase measurement accuracy on low frequency measurements as explained further in paragraph 4-9.

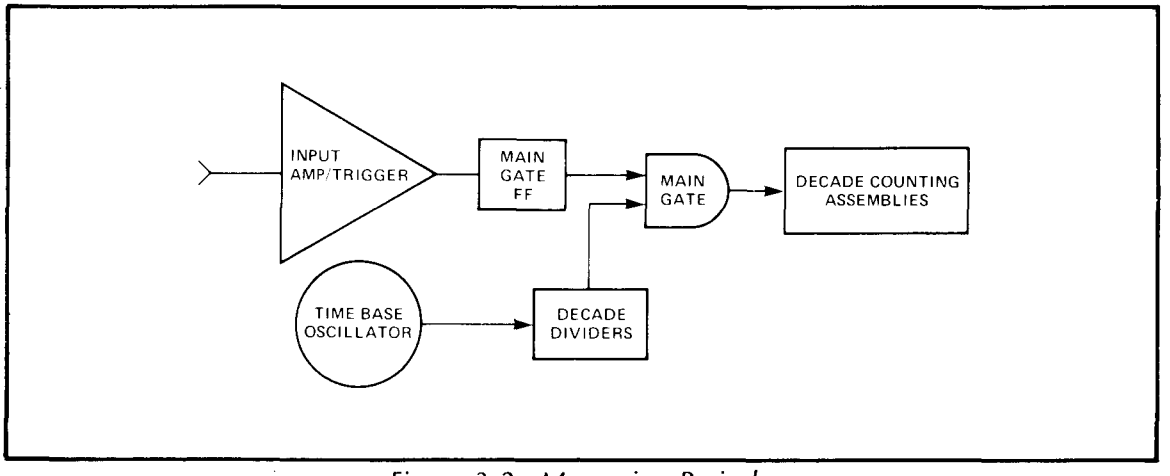



*Figure 3-2. Measuring Period*

**NOTE**

*The roles of the amplifer/trigger and decade divider outputs are reversed in measuring the period. This same configuration also serves for ratio measurements with the second input replacing the time base oscillator.*



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### 3-16. Ratio

3-17. By replacing the time base with a second input of frequency, $f_2$; the same configuration as in Figure 3-2 can be used to measure the ratio $f_2/f$. For higher resolution the signal at frequency f can be divided in decade steps in a manner identical to multiple period averaging.

### 3-18. Time Interval

3-19. Figure 3-3 shows the configuration for the measurement of time between two events or time interval. The main gate is now opened by the START input and closed by the STOP. The decade divider output is again counted and the display shows the elapsed time between START and STOP signals. The measurement of time interval is considered in more detail in paragraph 3-22.

### 3-20. Totalize and Scale

3-21. The 5328A also provides a totalizing/scaling mode where an input can be divided in decade steps and totalized to provide a low frequency output which is coherent with the input.

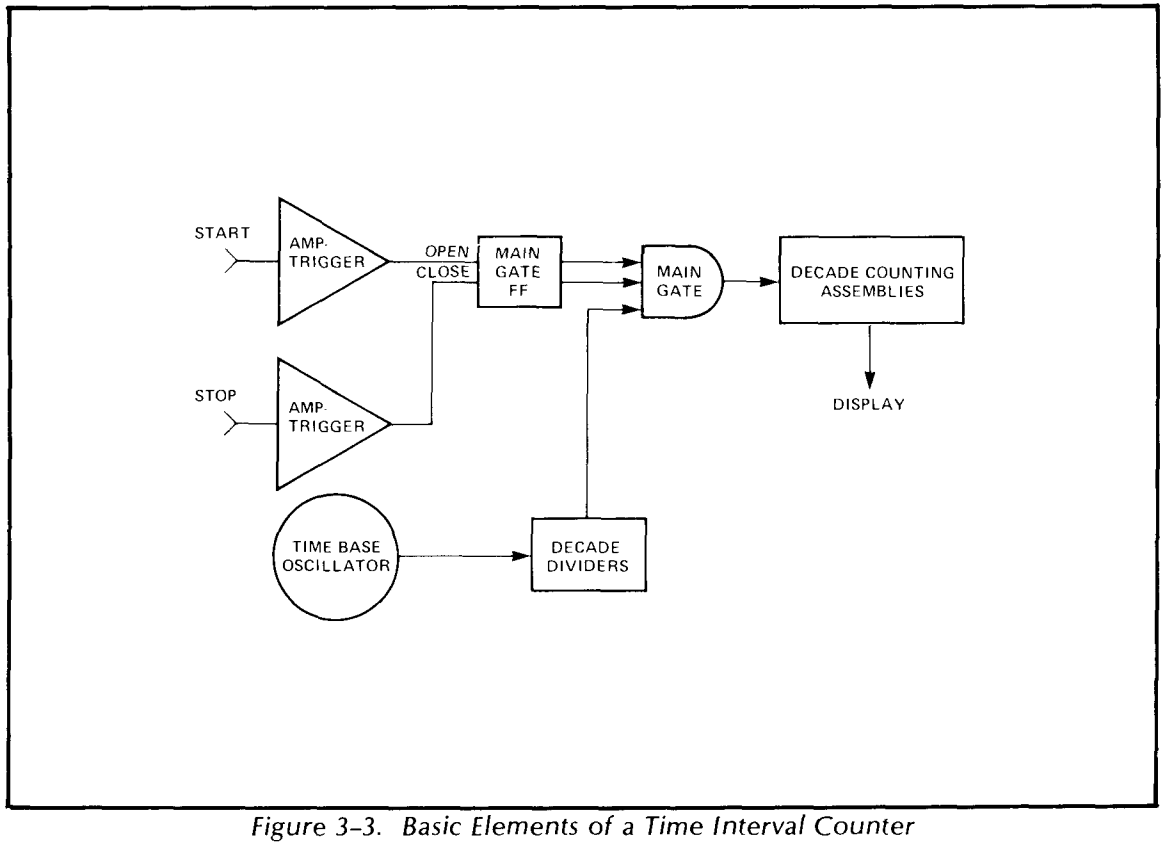



*Figure 3-3. Basic Elements of a Time Interval Counter*

### 3-22. TIME INTERVAL, RESOLUTION, AND AVERAGING TECHNIQUES

3-23. Time interval, the measurement of the time between two events, is shown in the block diagram shown in Figure 3-3. The main gate is now controlled by two independent inputs, the START input opening the gate and the STOP input closing it. Clock pulses are accumulated for the duration the gate is open and this accumulated count represents the time interval between START and STOP. This is shown by Figure 3-4.



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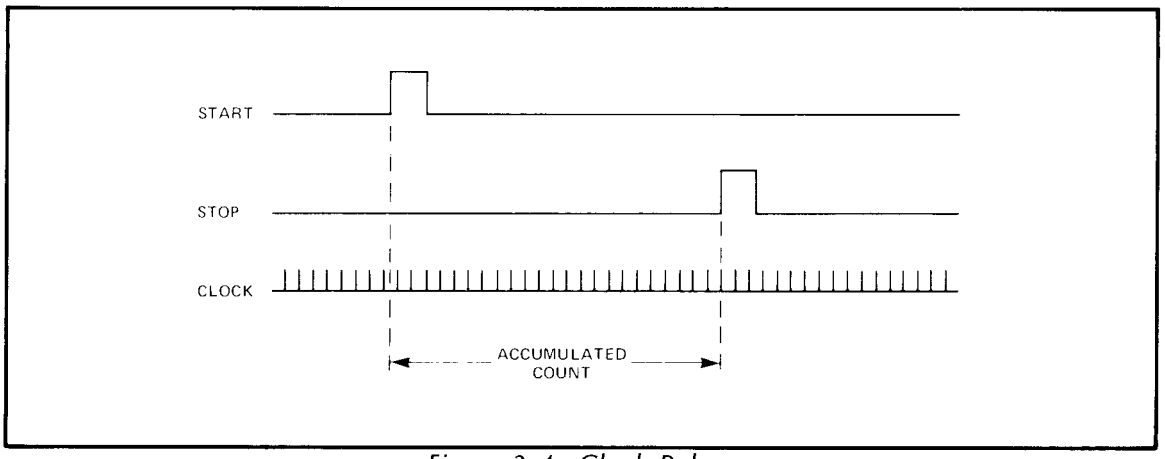



*Figure 3-4. Clock Pulses*

**NOTE**

*In a time interval measurement, clock pulses are accumulated for the duration the main gate is open. The gate is opened by one event, START and closed by the other, STOP.*

### 3-24. Resolution

3-25. The resolution of the measurement is determined by the frequency of the counted clock (e.g., a 10 MHz clock provides 100 nsec resolution). Clearly, the elements within the time interval counter (input amplifier, main gate, DCA's) must operate at speeds consistent with the clock frequency, for otherwise the instrument's resolution would be meaningless. The standard Universal Module of the 5328A counts a 10 MHz clock. The Option 040 Universal Module counts a 100 MHz clock to give 10 ns single-shot resolution.

3-26. Clock frequencies of 1, 10, 100 MHz, etc., are preferred since the accumulated count, with the appropriate placement of decimal point, gives a direct readout of the time interval. This explains why the conventional time interval counter is at present limited to 10 nsec, a clock frequency of 100 MHz. 1 GHz is beyond reach and a clock frequency of 200 MHz would require some arithmetic processing of the accumulated count in the DCA's to enable time to be displayed directly.

### 3-27. Time Interval Averaging

3-28. This technique is based on the fact that if the ±1 count error is truly random it can be reduced by averaging a number of measurements. The words "truly random" are significant. For time interval averaging to work the time interval must (1) be repetitive and (2) have a repetition frequency which is asynchronous to the instrument's clock. Under these conditions the resolution of the measurement is:

$$\frac{\pm 1 \text{ count}}{\sqrt{N}}$$

where N = number of time intervals averaged.

3-29. With averaging, resolution of a time interval measurement is limited only by the noise inherent in the instrument. Ten picoseconds resolution can be obtained with the 5328A. This is not the whole story, however, since most time interval averaging suffers one severe limitation; namely, the minimum measurable time interval is limited to the period of the clock. This limitation is removed by circuits known as synchronizers which are employed in the 5328A to measure intervals as small as 100 ps.



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3-30. The 5328A synchronizers operate as in Figure 3-5. The top waveshape shows a repetitive time interval which is asynchronous to the square wave clock. When these signals are applied to the main gate, an output similar to the third waveform results (no synchronizers). Note that much of this output results in transitions of shorter duration than the clock pulses. DCA's designed to count at the clock frequency are unable to accept pulses of shorter duration than the clock. The counts accumulated in the DCA's will therefore approximate those shown in the fourth trace—the exact number of counts is indeterminant since the number of short duration pulses actually counted by the DCA's cannot be known. Since the time interval to be measured is slightly greater than the clock period, the fourth waveshape shows that the average answer will be in error, having been biased, usually low, because of the DCA's requirement of having a full clock pulse to be counted.

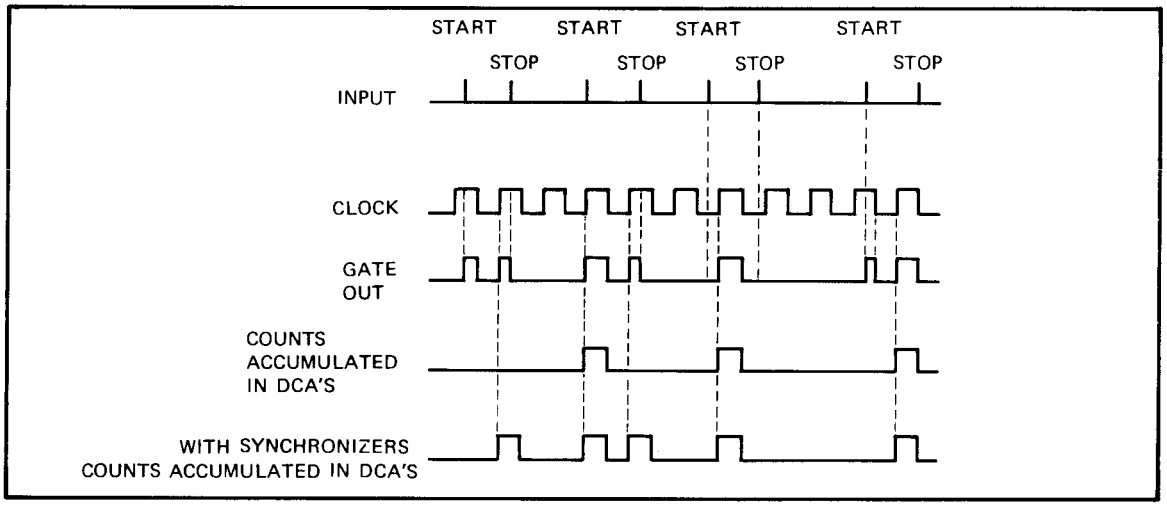



*Figure 3-5. Synchronizer Operation with Time Interval Averaging*

3-31. This problem is alleviated by the synchronizers which are designed to detect leading edges of the clock pulses that occur while the gate is open. The waveshape applied to the DCA's, when synchronizers are used, is shown by the fifth waveform. The leading edges are detected and reconstructed, such that the pulses applied to the DCA's are of the same duration as the clock.

3-32. Synchronizers are a necessary part of time interval averaging; without them the averaged answer is biased. In addition, it may easily be seen that with synchronizers involved, time intervals of much less than the period of the clock can be measured. This technique is only as good as the synchronizers, however. The 5328A's high-speed synchronizers enable intervals as small as 100 picoseconds to be measured.

3-33. There are occasional situations where time interval averaging cannot be performed on a periodic signal. This problem occurs when the input time interval repetition rate is synchronous with the internal clock. The Option 040 avoids this problem by modulating the clock with white noise whenever the 5328A is in the Time Interval Average function, to minimize the synchronous lock-up associated with this measurement.

## 3-34. SOURCES OF MEASUREMENT ERROR

3-35. The major sources of measurement error are the ±1 count ambiguity, the time base error and trigger error. These are discussed in the following paragraphs.

### 3-36. ±1 Count Ambiguity

3-37. Since the signal input to the main gate of the counter and the clock input are not coherent, an inherent ±1 count ambiguity exists in the count accumulated in the decade counting assemblies. This is illustrated by Figure 3-6.



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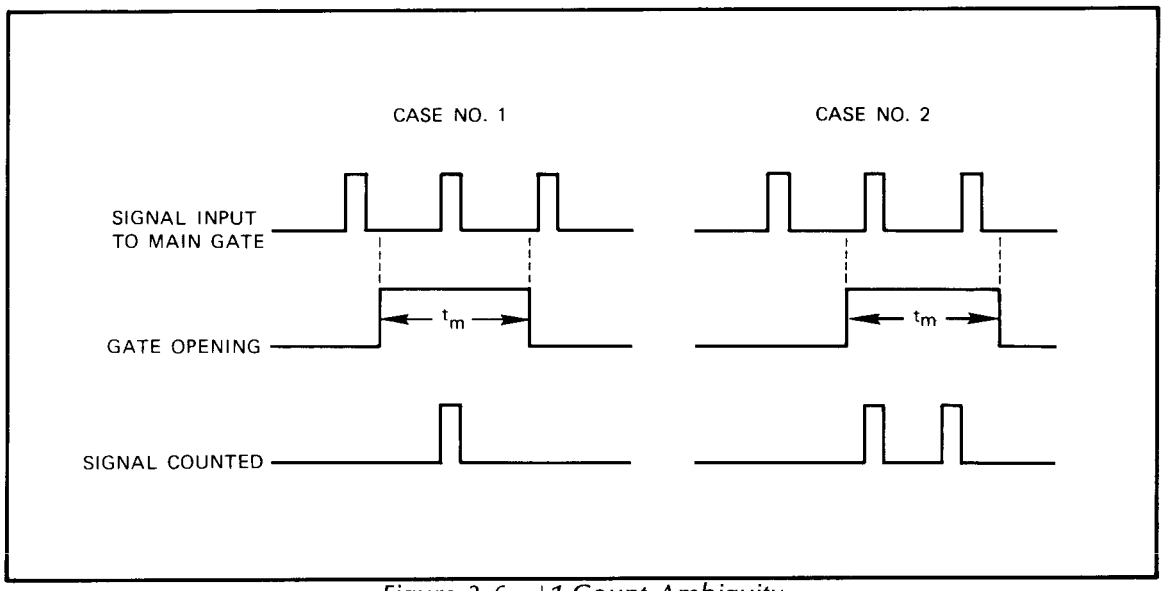



*Figure 3-6. +1 Count Ambiguity*

**NOTE**

The main gate is open for the same time $t_m$ in both cases. Incoherence between the clock and the input signal can result in two different counts which for this example are 1 for case No. 1 and 2 for case No. 2.

3-38. FREQUENCY MEASUREMENT ERROR. The error caused by the ambiguity is in absolute terms, ±1 of the accumulated count. For a frequency measurement the signal counted is the input signal of frequency $f_{in}$. Thus the relative error is given by

±1 count error, relative frequency measurement error

$$\frac{\Delta f}{f} = \frac{\pm 1}{f_{in}} \qquad (2)$$

3-39. PERIOD MEASUREMENT ERROR. For period measurement, on the other hand, the signal counted is the internal time base clock of period $t_c$. Hence the relative error becomes

±1 count error; relative period measurement error

$$\frac{\Delta T}{T} = \frac{\pm t_c}{T_{in}} \qquad (3)$$

3-40. MAIN GATE REQUIREMENTS. The ±1 count error described above assumes the main gate itself does not contribute any error. As with any gate, however, the main gate does exhibit propagation delays and takes finite times to both switch on and off. Any differential between the times taken for the main gate to switch on and off show up as uncertainties in the length of time the gate is open. This uncertainty in turn translates into a measurement error that increases the ±1 count. However, the uncertainty in the main gate of the 5328A is substantially less than the period of the highest frequency counted, so this error is not appreciable.

### 3-41. Time Base Error

3-42. Any error in the time base oscillator directly translates itself into a measurement error. Thus, if the total of all the oscillator errors amount to $1 \times 10^{-6}$, the total error contributed by the



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time base in the measurement of a 10 MHz signal is $1 \times 10^{-6} \times 10^{7} = 10$ Hz. Similarly, for the measurement of a 100 msec period, the error would be $1 \times 10^{-6} \times 10^{-1} = 1 \times 10^{-7}$ or 100 nsec.

### 3-43. Trigger Error

3-44. Noise on the input signal will cause uncertainties in the point at which the Schmitt trigger switches. Provided the noise is not large enough to cause false triggering (i.e., cross both limits of the hysteresis band which would produce more pulses out of the Schmitt trigger than input cycles to it) no significant error is introduced in a frequency measurement.

3-45. For period measurements, however, this uncertainty produces like error in the time the gate is open since it is this signal that controls the gate. It can be shown that with essentially low frequency noise and a signal to noise ratio of 40 dB, the resultant worst case trigger error is .32% of the period. Thus, the trigger error in the measurement of the period of a 1 kHz signal is $3.2 \times 10^{-3} \times 10^{-3} = 3.2$ $\mu$sec worst case. For 60 dB S/N, worst case error is .032% while for a 20 dB S/N signal it is 3.2%.

3-46. For an arbitrary waveshape (but constant slew rate through the hysteresis band), the trigger error takes on a different expression. In Figure 3-7, it is shown that for this case, the trigger error is

$$\frac{\pm 2 \times \text{peak noise voltage}}{\text{signal slew rate}}$$

For a 40 dB S/N, this translates to

$$\frac{\pm .0025\ \mu\text{sec}}{\text{signal slew rate (V/}\mu\text{sec)}}$$

3-47. For time interval measurements, trigger error is generally negligible when compared to the systematic error introduced by the uncertainty in the setting of trigger levels. For an uncertainty in trigger level of ±10 mV and a peak noise voltage of 1 mV, trigger error is a factor of 5 less than the error caused by trigger level uncertainty, regardless of signal slew rate. For example, trigger level uncertainty of ±10 mV on a 100 mV/ns signal introduces an error in the time interval measurement of ±0.1 ns. The trigger error for such a signal, with 1 mV peak noise, is less than ±.02 ns, a factor of five less. Averaging reduces the trigger error still further (but not the trigger level uncertainty error). The error is reduced by $\sqrt{N}$ for time intervals averaging and by N for period averaging.

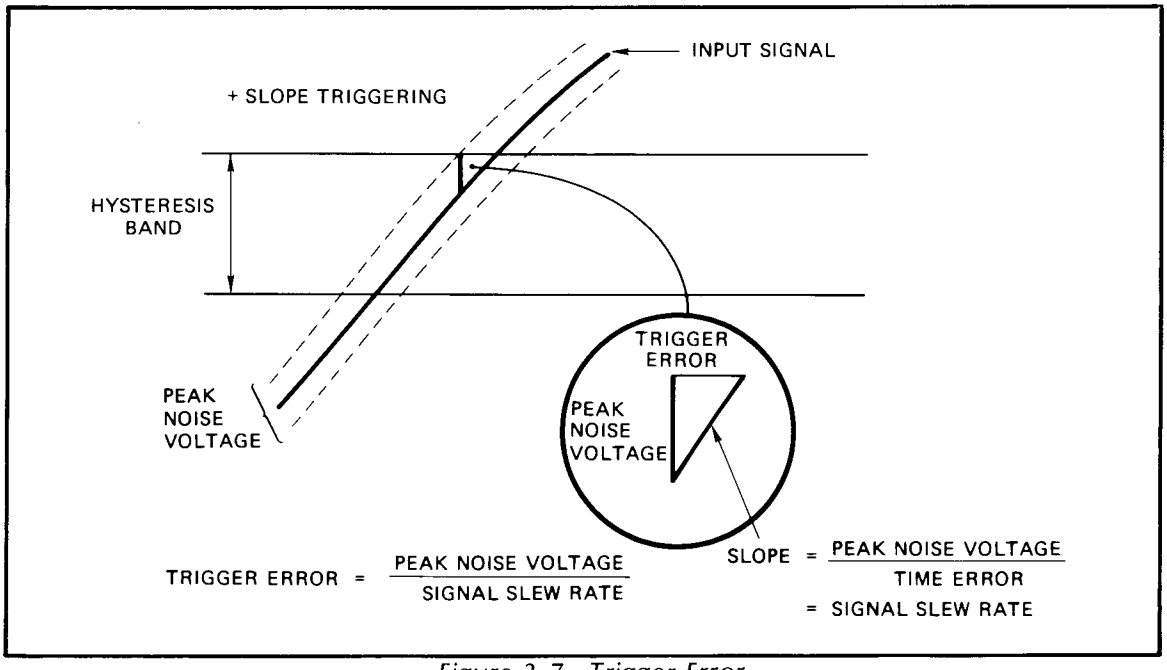
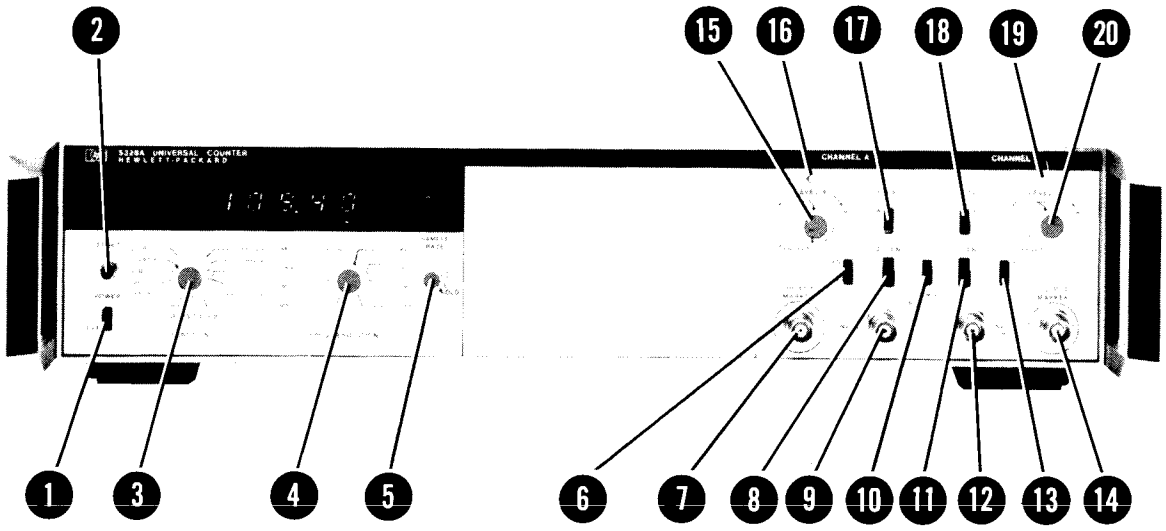



*Figure 3-7. Trigger Error*



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1. POWER switch ❶. In off (up) position, supplies power to oven of the Option 010 high stability time base to maintain a constant temperature for the crystal. In ON position, supplies normal operating power to the instrument.

**WARNING**

**THE AC POWER INPUT CIRCUITS TO TRANSFORMER T1 AND THE UNREGULATED DC VOLTAGE ARE STILL ON, EVEN WHEN THE POWER SWITCH IS OFF. CONTACT WITH THESE CIRCUITS CAN RESULT IN INJURY TO PERSONNEL OR DAMAGE TO EQUIPMENT.**

2. RESET button ❷. Resets display and internal count to zero. When continuously depressed, lights all segments of the LED display and all annunciator LED's for LED test. Returns 5328A to LOCAL CONTROL when Option 011, HP-IB Interface is in use.

3. FUNCTION selector ❸. Selects mode of operation.

   a. RATIO C/A. Sets counter to measure the ratio of the frequency at channel C (Option 030 channel C installed) to the frequency at channel A.

   b. CHECK. Applies 10 MHz to decade counting assemblies. Verifies operation of SAMPLE RATE control, RESOLUTION switch, and RESET.

   c. FREQ C. Sets counter to measure the frequency at the channel C input.

   d. DVM. Sets counter to measure the voltage applied to the terminals of the Option 020 or 021 digital voltmeter.

   e. START A, STOP. Sets the counter to totalize the number of events at the A input until STOP is selected, for N=1 on the RESOLUTION switch. For N>1, the number of counts divided by N is totalized. The scaled output (i.e., frequency of A÷N) is available at the Time Base Out rear panel connector.

*Figure 3-8. Standard 5328A Front Panel Operation Summary*



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*f. START CLOCK. A "phantom" function located 1 switch position clockwise from STOP. Totalizes the internal 10 MHz clock ÷N where N is selected by the RESOLUTION switch (N≥10). The scaled output (i.e., 10 MHz ÷N) is available at the Time Base Out rear panel connector.

*g. DVM/A. A "phantom" function located 2 switch positions clockwise from STOP. Used for scaling DVM measurements. Counter displays DVM/freq. A where freq A ≤10 MHz. N selects the number of events at A over which the measurement is made.

*h. DVM, A→B. A "phantom" function located 3 switch positions clockwise from STOP. The voltage at the DVM terminals is integrated over the synchronized time interval defined by events at channels A and B. Units of the displayed reading are volt•seconds.

i. FREQ A. Sets counter to measure frequency at channel A.

j. PER A. Sets counter to measure period at channel A.

k. PER AVG A. Sets counter to make a period average measurement of the signal at channel A. The number of periods over which the average measurement is made is determined by N, selected by the RESOLUTION switch.

l. RATIO B/A. Sets counter to measure the ratio of the frequency at channel B to the frequency at channel A.

m. T.I. A→B. Sets counter to make a time interval measurement. Start signal is applied to channel A and the stop signal is applied to channel B.

n. T.I. AVG A→B. Sets counter to make a time interval average measurement of the time interval from A to B. The number of time intervals over which the average measurement is made is determined by N, selected by the RESOLUTION switch.

o. EVENTS C, A→B. Sets the counter to totalize the number of events at the channel C input during the synchronized time interval determined by inputs to channels A and B.

*"phantom" functions which, due to relatively limited use, are not labeled on the 5328A front panel.

4. RESOLUTION, N selection ❹. Selects resolution in frequency measurements and N for totalizing and averaging measurements. Determines how long the main gate is open for frequency measurements:

| N | GATE TIME | RESOLUTION |
|---|---|---|
| 1 | 1 μs | 1 MHz |
| 10 | 10 μs | 100 kHz |
| 100 | 100 μs | 10 kHz |
| $10^3$ | 1 ms | 1 kHz |
| $10^4$ | .01 s | 100 Hz |
| $10^5$ | .1 s | 10 Hz |
| $10^6$ | 1 s | 1 Hz |
| $10^7$ | 10 s | .1 Hz |

5. SAMPLE RATE control ❺. Varies time between measurements continuously from less than 2ms to HOLD which holds display indefinitely.

Figure 3-8. Standard 5328A Front Panel Operation Summary (Continued)



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6. OUTPUT MARKERS ❼, ⓮. Inverted channel A and B Schmitt trigger outputs indicate when a channel has triggered; 0 to -100 mV levels into 50Ω with less than 20ns delay.

7. Coupling switch AC-DC ❻, ⓭. Selects ac or dc coupling for input signal. When input amplifier control switch ❿ is in COM A, channel B coupling is determined by setting of channel A coupling switch.

8. ATTEN switch ❽, ⓫. Selects attenuation of input signal. Signal amplitude is reduced by 10 in X10 and by 100 in X100. When input amplifier control switch ❿ is in COM A, channel B attenuation is determined by setting of channel A attenuation switch.

9. Channel inputs ❾, ⓬. Input channels A and B.

10. Input amplifier control switch ❿. Selects independent operation of channels A and B in SEP (separate) position. In COM A (common A) position, the signal at A is also applied to channel B. (The B input is disconnected from the input circuitry; channel B coupling and attenuation are determined by the channel A settings.)

11. See 9.

12. See 8.

13. See 7.

14. See 6.

15. Trigger lights ⓰, ⓳. Light blinks when its channel is triggering. Light is OFF when input signal is below the trigger level. Light is ON when input signal is above trigger level.

16. LEVEL control ⓯, ⓴. Used in conjunction with ATTEN switch to select voltage at which triggering occurs. With X1 attenuator, level is variable ±2.5 volts. In X10, ±25 volts. In X100, ±250 volts.

17. SLOPE switch ⓱, ⓲. Selects triggering on either positive or negative slope of input signal.

18. See 17.

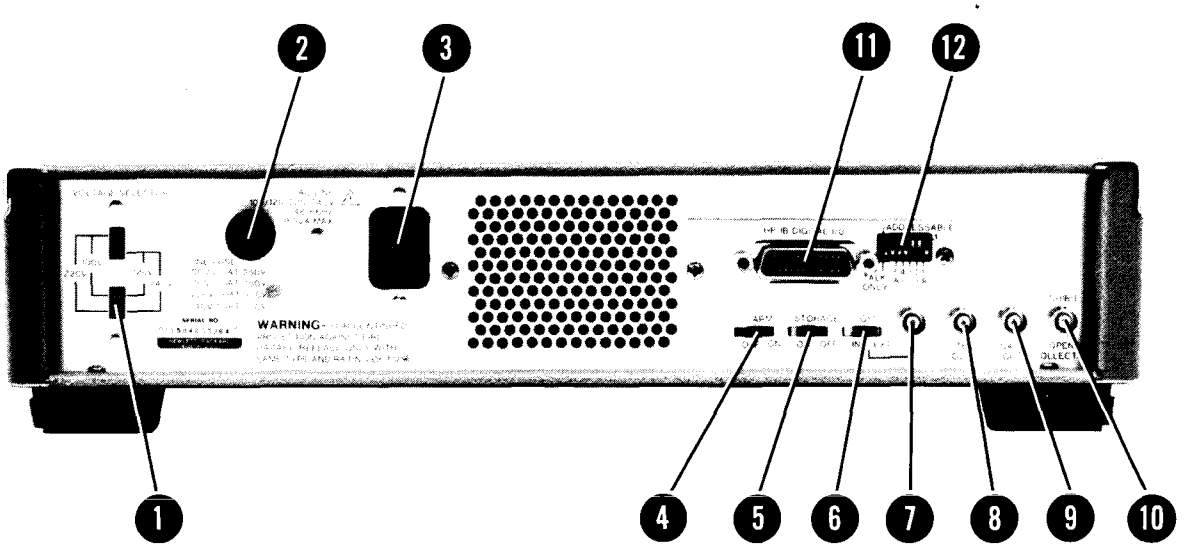
19. See 16.

20. See 15.

Figure 3-8. Standard 5328A Front Panel Operation Summary (Continued)



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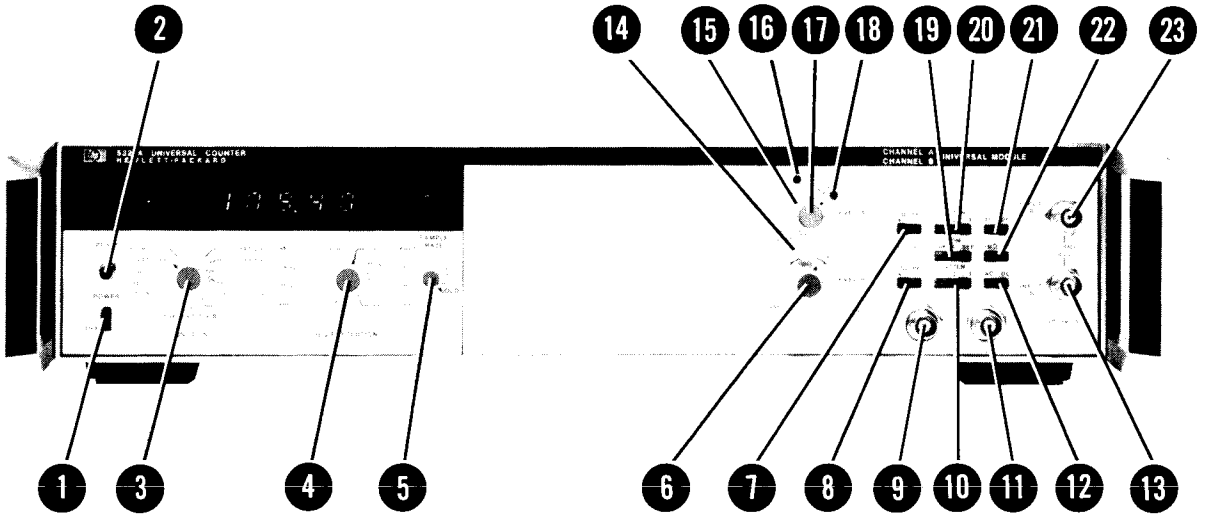



1. VOLTAGE SELECTOR switches. Selects 100/120/220/240 volt operation.
2. LINE FUSE. Requires a 2.0 amp fuse for 100–120 volt operation or a 1.0 amp fuse for 220–240 volt operation.
3. AC Line connector. IEC type with offset pin connected to chassis.
4. ARM switch. With switch in OFF, counter is armed by the same signal which is involved in the measurement (e.g., FREQ A measurements are armed by the signal at channel A). With arming ON, the measurement is armed by an input other than the input involved in the measurement. The following are armed by an event at B: FREQ A, PERIOD A, PERIOD AVG A, FREQ C, DVM, C/A; the following are armed by an event at C: T.I. A→B, T.I. AVG A→B, EVENTS C A→B, B/A (see Table 3-1).
5. STORAGE switch. Holds reading between samples when ON. When OFF, allows continuous display of count.
6. OSC switch. In INT, selects normal operation of counter using internal time base. In EXT, permits use of external time base applied to input connector ❼.
7. External Oscillator Input/Internal Oscillator Output connector. When OSC switch ❻ is in INT, a buffered TTL signal derived from the internal time base is available at the connector. When OSC switch is in EXT, the external time base is applied to the connector.
8. TB OUT connector. In START CLOCK position of the FUNCTION switch, provides TTL level at the frequency of the internal oscillator (10 MHz) divided by N (RESOLUTION switch). In START A the frequency at INPUT A divided by N, is available.
9. GATE OUT connector. High when the main gate is open.
10. INHIBIT connector. A TTL low or ground, when applied to this input (TTL standard load impedance), inhibits the counter from making a measurement.
11. Option 011 HP-IB Interface connector (24-pin). Used to convey data and programming instructions.
12. Option 011 HP-IB Interface address switch. See paragraph 5-4.

*Figure 3-9. Model 5328A Rear Panel Controls and Connectors*



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**WARNING**
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1. POWER switch ❶. In off (up) position, supplies standby power to oven of the Option 010 high stability time base to maintain a constant temperature for the crystal. In ON position, supplies normal operating power to the instrument.

2. RESET button ❷. Resets display and internal count to zero and arms counter for a new measurement. When continuously depressed, lights all segments of the LED display and all annunciator LED's for LED test. Returns 5328A to LOCAL control when Option 011, HP-IB Interface is in use.

3. FUNCTION selector ❸. Selects mode of operation.

   a. RATIO C/A. Sets counter to measure the ratio of the frequency at channel C (Option 030 channel C installed) to the frequency at channel A.

   b. CHECK. Applies 10 MHz to decade counting assemblies. Verifies operation of SAMPLE RATE control, RESOLUTION switch, and RESET.

   c. FREQ C. Sets counter to measure the frequency at the channel C input.

   d. DVM. Sets counter to measure the voltage applied to the terminals of the Option 020 or 021 digital voltmeter.

   e. START A, STOP. Sets the counter to totalize the number of events at the A input until STOP is selected, for N=1 on the RESOLUTION switch. For N>1, the number of counts divided by N is totalized. The scaled output (i.e., frequency of A÷N) is available at the time base out rear panel connector.

*Figure 3-10. Model 5328A Option 040, Front Panel Operation Summary*



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*f. START CLOCK. A "phantom" function located 1 switch position clockwise from STOP. Totalizes the internal 10 MHz clock ÷N where N is selected by the RESOLUTION switch (N ≤ 10). The scaled output (i.e., 10 MHz ÷N) is available at the time base out rear panel connector.

*g. DVM/A. A "phantom" function located 2 switch positions clockwise from STOP. Used for scaling DVM measurements. Counter displays DVM/freq A where freq A ≤10 MHz. N selects the number of events at A over which the measurement is made.

*h. DVM, A→B. A "phantom" function located 3 switch positions to the right of STOP. The voltage at the DVM terminals is integrated over the synchronized time interval defined by events at channels A and B. Units of the displayed reading are volt•seconds.

i. FREQ A. Sets counter to measure frequency at channel A.

j. PER A. Sets counter to measure period at channel A.

k. PER AVG A. Sets counter to make a period average measurment of the signal at channel A. The number of periods over which the average measurement is made is determined by N, selected by the RESOLUTION switch.

l. RATIO B/A. Sets counter to measure the ratio of the frequency at channel B to the frequency at channel A.

m. T.I. A→B. Sets counter to make a time interval measurement. Start signal is applied to channel A and the stop signal is applied to channel B.

n. T.I. AVG A→B. Sets counter to make a time interval average measurement of the time interval from A TO B. The number of time intervals over which the average measurement is made is determined by N, selected by the RESOLUTION switch.

o. EVENTS C, A→B. Sets the counter to totalize the number of events at the channel C input during the synchronized time interval determined by inputs to channels A and B.

*"phantom" functions which, due to relatively limited use, are not labeled on the 5328A front panel.

4. RESOLUTION, N selection ❹. Selects resolution in frequency measurements and N for totalizing and averaging measurements. Determines how long the main gate is open for frequency measurements:

| N | GATE TIME | RESOLUTION |
|---|---|---|
| 1 | 1 μs | 1 MHz |
| 10 | 10 μs | 100 kHz |
| 100 | 100 μs | 10 kHz |
| $10^3$ | 1 ms | 1 kHz |
| $10^4$ | .01 s | 100 Hz |
| $10^5$ | .1 s | 10 Hz |
| $10^6$ | 1 s | 1 Hz |
| $10^7$ | 10 s | .1 Hz |

5. SAMPLE RATE control ❺. Varies time between measurements continuously from less than 2 ms to HOLD which holds display indefinitely.

Figure 3-10. Model 5328A Option 040, Front Panel Operation Summary (Continued)



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6. LEVEL control ❻, ⓯. Used in conjunction with ATTEN switch to select voltage at which triggering occurs. With X1 attenuator, level is variable over ±2.5 volts. In X2, ±5 volts; in X20, ±50 volts.

7. SLOPE switch ❼, ❽. Selects triggering on either positive or negative slope of input signal.

8. See 7.

9. OUTPUT MARKER A ❾. Inverted channel A schmitt trigger output indicates when channel A has triggered; 0 to -100 mV level into 50Ω with less than 20 ns delay.

10. ATTEN switch ❿, ⓴. Selects attenuation of input signal. Signal amplitude is reduced by 2 in X2 and by 20 in X20. When input amplifier control switch ⓳ is in COM A, channel B attenuation is still determined by channel B attenuation switch.

11. OUTPUT MARKER T.I. A→B ⓫. Output is high during the time interval measured by the counter. 0 to -50 mV level into 50Ω with less than 20 ns delay.

12. Coupling switch ⓬, ㉑. Selects ac or dc coupling for input signal. When input amplifier control switch ⓳ is in COM A, channel B coupling is determined by the setting of the channel A coupling switch.

13. Channel inputs ⓭, ㉓. Input channels A and B.

14. Trigger lights ⓮, ⓰. Lights blinks when its channel is triggering. Light is OFF when input signal is below the trigger level. Light is ON when input signal is above trigger level.

15. See 6.

16. See 14.

17. Delay switch ⓱. Delay mode is activated by inner concentric knob on channel A LEVEL control. Red LED ⓲ indicates, when lighted, that delay is active. To activate, turn knob clockwise out of detent position. The delay disables the input from triggering for periods of time from 20 μs to 20 ms. The amount of delay is measured by placing the FUNCTION switch ❸ to T.I. A→B and the input amplifier control switch ⓳ to CHK.

18. Delay mode LED ⓲. LED is ON when delay is active.

19. Input amplifier control switch ⓳.

    a. CHK. With FUNCTION switch in FREQ A, counter should display 100 MHz ±1 count. Checks operation of phase-locked 100 MHz oscillator, SAMPLE RATE ❺, RESOLUTION, N ❹, and RESET .

    b. COM A. The signal at A is also applied to channel B for single source time interval measurement. The B input is disconnected from the input circuitry. Channel B coupling (but not attenuation) is determined by the channel A setting.

    c. SEP. Allows independent operation of channels A and B.

20. See 10.

21. See 12.

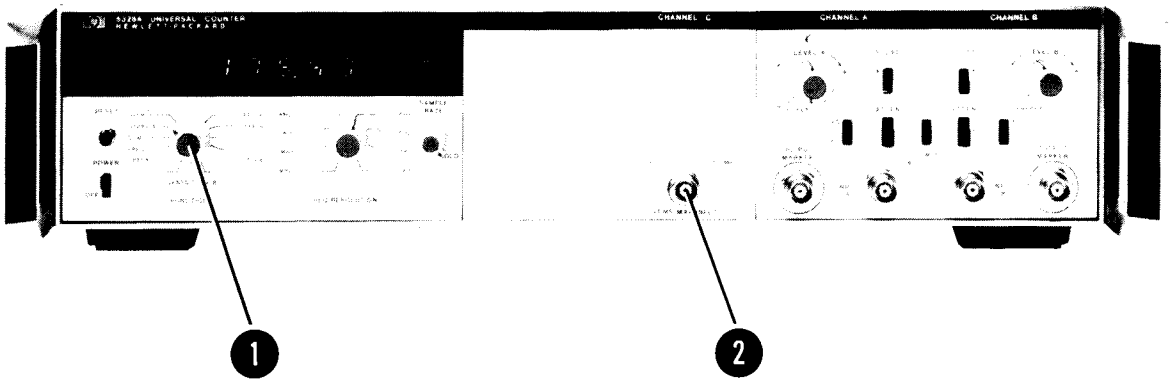
22. Input Impedance switch ㉒. Selects input impedance of 50Ω for both channels A and B. For input amplifier control switch ⓳ in COM A, impedance is 50Ω or 500 kΩ.

23. See 13.

Figure 3-10. Model 5328A Option 040, Front Panel Operation Summary (Continued)



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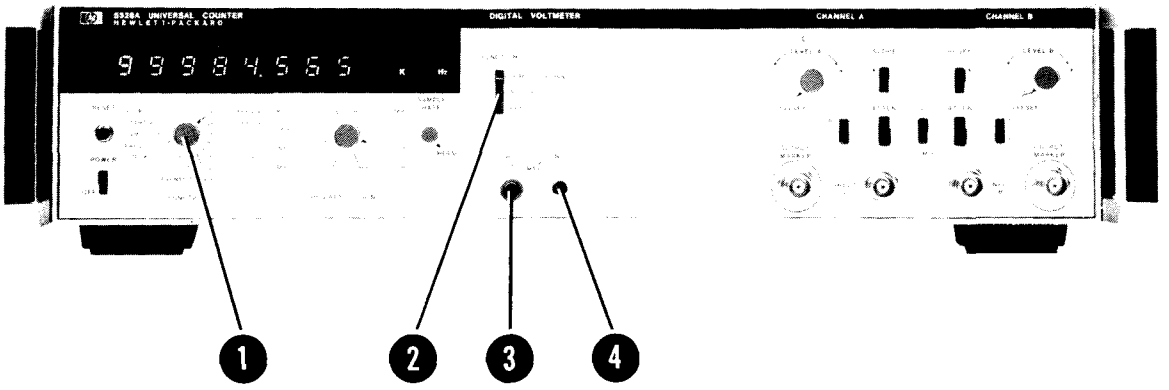



1. FUNCTION switch ❶. Functions which use channel C are:
   a. FREQ C. Measures frequency at C input.
   b. RATIO C/A. Measures the ratio of the frequency at channel C to the frequency at channel A.
   c. EVENTS C, A→B. Totalizes the number of events at channel C during the synchronized time interval determined by inputs to channel A and channel B.
2. ❷. Input for channel C. Frequency range of 5–512 MHz.

*Figure 3-11. Model 5328A Option 030, Channel C Front Panel Operation Summary*



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1. FUNCTION switch ❶. Functions which use the DVM are:

   a. DVM. Measures the voltage at the DVM terminals for a period of time determined by the setting of the RESOLUTION, N switch:

| N | MEASUREMENT TIME |
|---|---|
| $10^7$ | 10 s |
| $10^6$ | 1 s |
| $10^5$ | 0.1 s |
| $10^4$ | 10 ms |
| $10^3$ | 1 ms |

   *b. DVM/A. Scales voltage at the DVM terminals by the factor $\frac{1}{\text{freq A}}$ where freq A ≤ 10 MHz. N selects the number of events at A over which the measurement is made.

   **c. DVM, A→B. Integrates voltage at the DVM terminals over the synchronized time interval defined by events at channel A and B. Units of the displayed reading are volt•seconds.

   *"phantom" Function. 2 switch positions clockwise from STOP.
   **"phantom" Function. 3 switch positions clockwise from STOP.

2. DVM FUNCTION switch ❷.

   a. DVM 100 VDC RANGE. With FUNCTION switch ❶ in DVM, measures the voltage at the DVM terminals in the range of 0 to ±125V dc.

   b. READ A. Regardless of setting of FUNCTION switch ❶, measures channel A trigger level.

   c. READ B. Regardless of setting of FUNCTION switch ❶, measures channel B trigger level.

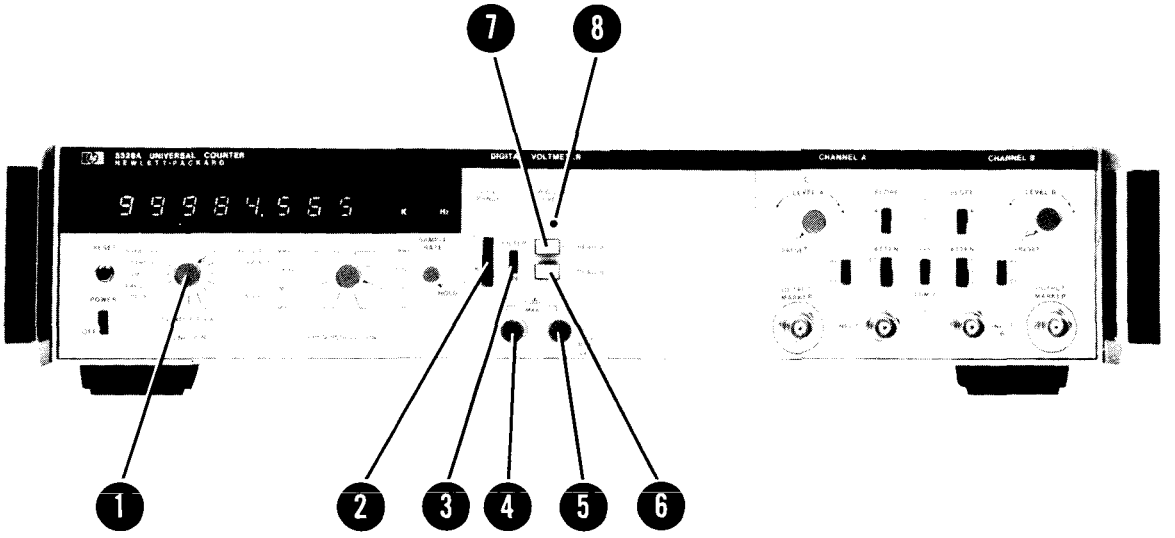
3. HI input terminal. Input terminal for high potential of external voltage.

4. GND input terminal. Input terminal for ground potential of external voltage.

*Figure 3-12. Model 5328A Option 020, DVM Front Panel Operation Summary*



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1. FUNCTION switch ❶. Functions which use the DVM are:

   a. DVM. Measures the voltage at the DVM terminals for a period of time determined by the setting of the RESOLUTION, N switch:

| N | MEASUREMENT TIME |
|---|---|
| $10^7$ | 10 s |
| $10^6$ | 1 s |
| $10^5$ | 0.1 s |
| $10^4$ | 10 ms |
| $10^3$ | 1 ms |

   *b. N•DVM/A. Scales voltage at the DVM terminals by the factor $\frac{1}{\text{freq A}}$ where freq A ≤ 10 MHz. N selects the number of events at A over which the measurement is made.

   **c. DVM, A→B. Integrates voltage at the DVM terminals over the synchronized time interval defined by events at channels A and B. Units of the displayed reading are volt•seconds.

   *"phantom" function. 2 switch positions clockwise from STOP.
   **"phantom" function. 3 switch positions clockwise from STOP.

2. DCV RANGE switch ❷. Permits selection of ±10V, ±100V, ±1000V range or AUTORANGE.

3. FILTER switch ❸. When on, allows measuring small signals in the presence of high common mode noise. Response time when on is 1 second, when OFF, 10 ms.

4. HI input terminal. Input terminal for high potential of external voltage. Must be less than 1100 volts above LO input terminal.

5. LO input terminal. Input terminal for low potential of external voltage. Must be less than 500 volts above chassis ground.

*Figure 3-13. Model 5328A Option 021, High Performance DVM Front Panel Operation Summary*



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6. READ B. When depressed, measures channel B trigger level regardless of setting of FUNCTION switch ❶.

7. READ A. When depressed, measures channel A trigger level regardless of setting of FUNCTION switch ❶.

**NOTE**

The 'V' annunciator on the display indicates that READ A or READ B is depressed

8. Access hole ❽. Access to DVM zero adjustment. (The label TRIGGER LEVEL pertains to the READ A and READ B switches.)

Figure 3-13. Model 5328A Option 021, High Performance DVM Front Panel Operation Summary (Continued)



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## 3-48. FUNCTION OF CONTROLS, INDICATORS, INPUTS AND OUTPUTS

3-49. The following paragraphs provide a detailed description of the function of controls, indicators, and connectors.

### 3-50. Display

3-51. The 5328A display consists of an 8 (or 9 with the Option 030 channel C) digit numeric, seven-segment LED display and annunciators for indicating the measurement units of Hz, SEC, and VOLTS as well as M ($10^{+6}$ or $10^{-3}$), k ($10^{+3}$), $\mu$ ($10^{-6}$) and n ($10^{-9}$ or $10^{+9}$). These display units and multipliers are automatically displayed along with the correct decimal point location. Overflow (OF) indicates that left most significant digits have overflowed the display. Remote (RMT) indicates that the counter (with Option 011 HP-IB interface) is under remote program control. A GATE lamp (G is displayed) indicates that the counter has been armed and that a measurment is in process.

### 3-52. Power

**WARNING**

**SAFETY PRECAUTIONS MUST ALWAYS BE OBSERVED WHEN THE COVERS ARE REMOVED FROM THE INSTRUMENT.**

3-53. The POWER switch turns the counter ON or OFF (standby). The off position turns off some but not all of the power supply voltages. This circuit arrangement allows the Option 010 high stability oscillator to operate continuously. Therefore, the input to main power transformer (T1) plus the unregulated dc voltage to the oscillator oven is always energized whenever power is connected even with the POWER switch off.

### 3-54. Reset

3-55. The RESET pushbutton resets the display and internal count to zero and also initiates single measurements when the SAMPLE RATE control is in the HOLD mode. On counters with Option 011 HP-IB Interface, providing remote control capability, pushing the RESET button restores the counter to local control (when not remotely locked out by the HP-IB Local Lockout universal command).

### 3-56. Sample Rate Control

3-57. The SAMPLE RATE control sets the minimum time between samples. This time is continuously variable from less than 2 ms between measurements to HOLD, which holds the display indefinitely. The counter will internally (self) arm (via the SAMPLE RATE control) only when ARMING is OFF and the FUNCTION selected is other than FREQ A, FREQ C, and RATIO C/A.

### 3-58. Arming

3-59. The counter may be armed internally (i.e., made ready to start a measurement) by the SAMPLE RATE control, or externally by the input signal itself, (arming off) or by a signal not directly involved in the measurement (arming on). Table 3-1 is an arming status table. A rear panel switch turns ARMING either ON or OFF. The counter is armed within 1 $\mu$sec after the event at the arming input.



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*Table 3-1. Arming Status*

| FUNCTION | ARMING OFF | ARMING ON |
|---|---|---|
| FREQ A | Armed by A input | Armed by B input |
| PERIOD A | Armed by SAMPLE RATE | Armed by B input |
| PERIOD AVG A | Armed by SAMPLE RATE | Armed by B input |
| T.I. A to B | Armed by SAMPLE RATE | Armed by C input |
| T.I. AVG A to B | Armed by SAMPLE RATE | Armed by C input |
| FREQ C | Armed by C input | Armed by B input |
| DVM | Armed by SAMPLE RATE | Armed by B input |
| EVENTS C, A to B | Armed by SAMPLE RATE | Armed by C input |
| RATIO B/A | Armed by SAMPLE RATE | Armed by C input |
| RATIO C/A | Armed by C input | Armed by B input |
| DVM/A† | Armed by SAMPLE RATE | Armed by B input |
| DVM A to B† | Armed by SAMPLE RATE | Armed by C input |
| START | Measurement controlled by FUNCTION switch | |
| START CLOCK† | Measurement controlled by FUNCTION switch | |

†"Phantom" functions

### 3-60. Resolution, N Switch

3-61. The RESOLUTION, N switch determines the amount of time that the counter's main gate is open for a particular measurement when the Main Gate FF (see Figure 3-1) determines the gate time. Depending on the measurement, this time results in a certain measurement resolution (e.g., frequency measurements), a number of intervals averaged (e.g., T.I. AVG measurements), a scaling factor by which the time base is divided (e.g., period measurements), or an integration time (e.g., DVM measurements). Table 3-2 shows the setting of the RESOLUTION switch and the corresponding time the main gate is open.

*Table 3-2. Resolution Switch Settings and Gate Times*

| RESOLUTION | N | GATE TIME |
|---|---|---|
| .1 Hz | $10^7$ | 10 s |
| 1 Hz | $10^6$ | 1 s |
| 10 Hz | $10^5$ | .1 s |
| 100 Hz | $10^4$ | 10 ms |
| 1 kHz | $10^3$ | 1 ms |
| 10 kHz | $10^2$ | 100 $\mu$s |
| 100 kHz | 10 | 10 $\mu$s |
| 1 MHz | 1 | 1 $\mu$s |

3-62. Table 3-3 summarizes the FUNCTIONS and the corresponding interpretation of the RESOLUTION, N switch setting.



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*Table 3-3. Functions and Resolution Switch Settings*

| FUNCTION | RESOLUTION, N Switch |
|---|---|
| FREQ A, FREQ C | Indicates frequency resolution in Hz. |
| PERIOD A, T.I. A to B | Indicates the factor (N) by which time base is scaled. Maximum resolution occurs with N=1. |
| PERIOD AVG A, T.I. AVG A to B | Indicates number of time intervals or periods over which the average measurement is made. |
| DVM | Indicates the integration time (per Table 3-2) for the measurment. |
| RATIO B/A, RATIO C/A, DVM/A† | Indicates the number of counts at the A input over which the ratio measurement is made. Resolution improves with increasing N. |
| START, START CLOCK | Indicates scale factor. In START, the frequency at A is scaled by N. In START CLOCK, internal oscillator is scaled by N. |
| EVENTS C, A to B; DVM A to B† | Independent of RESOLUTION setting. |
| DVM/A | Indicates the number of counts at the A input over which the ratio measurement is made. (The DVM circuits are of the V to F type with the factor 10 kHz/volt.) Resolution improves with increased N. Annunciator is not displayed in units (V) but prefix (m, μ, n, etc.) is displayed. |

†"Phantom" functions

### 3-63. Input Channel Selection

3-64. Two separate inputs are provided on the standard universal module. The A and B inputs are identical in specification and identical controls are provided for each input to allow maximum versatility and accuracy. The COM A-SEP switch, located between the two inputs, controls the selection of input.

3-65. In the SEP position, the A and B inputs and controls operate independently of each other for applications in time interval, ratio, or other operations where the signals applied to the A and B inputs are from different sources.

3-66. In the COM A position, the input circuits are connected as described in the following paragraphs. The difference beteen the standard and Option 040 universal modules is shown.

3-67. STANDARD UNIVERSAL MODULE. In the COM A position, the INPUT B connector is disconnected and the A and B input amplifiers are connected together to the INPUT A connector as shown in Figure 3-14. As can be seen from the figure, the channel B AC-DC switch and attenuator control are disabled when the COM A. The channel A AC-DC and attenuation controls condition the input signal to both channel A and channel B input amplifiers. The impedance remains 1 MΩ (although input capacitance increases from 40 pF to approximately 65 pF) and the channel sensitivity, dynamic range, and damage levels remain unchanged.



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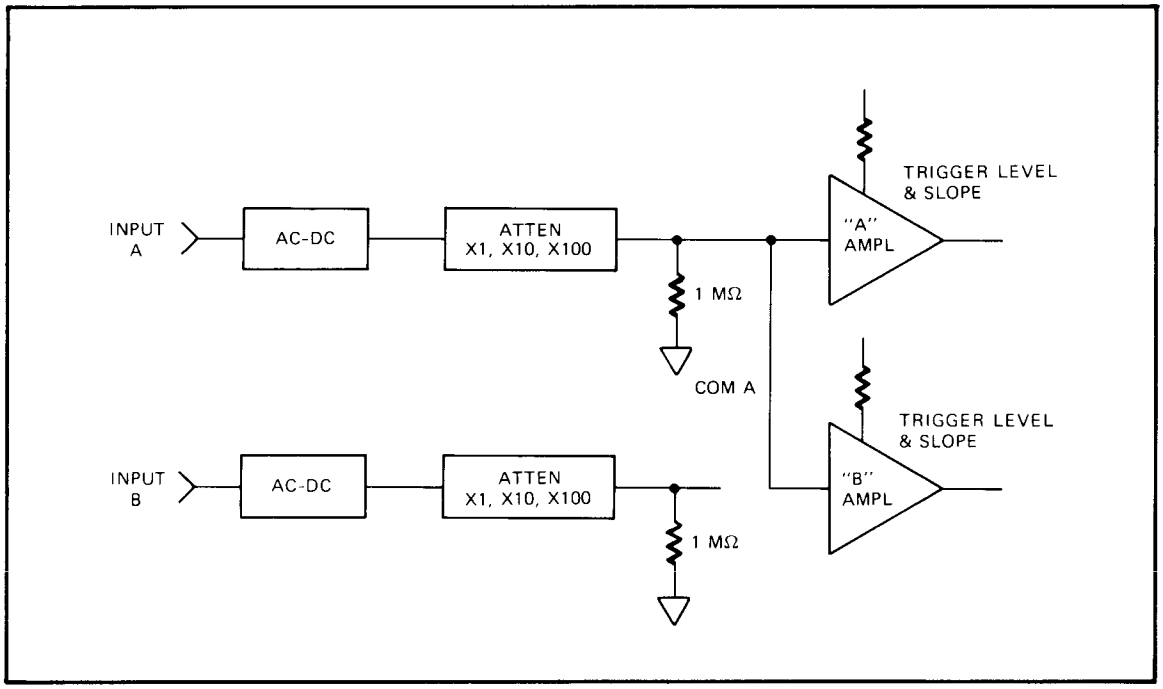



*Figure 3-14. Standard Universal Module Input Switch Configuration for COM A*

3-68. The A and B input amplifiers have independent LEVEL and SLOPE controls regardless of the mode of operation (SEP or COM A).

3-69. OPTION 040 UNIVERSAL MODULE. In COM A position, the INPUT B connector is disconnected and the A and B input amplifiers are connected together at the INPUT A connector as shown in Figure 3-15. As can be seen in the figure, the channel B AC-DC switch is disabled when in COM A. The channel A AC-DC switch also determines the coupling for the channel B amplifier. The impedance becomes 500 kΩ when in COM A and in the high impedance position (and the input capacitance increases to approximately 65 pF). In 50Ω position, the impedance remains 50Ω for COM A. The sensitivity, dynamic range and damage levels remain unchanged.

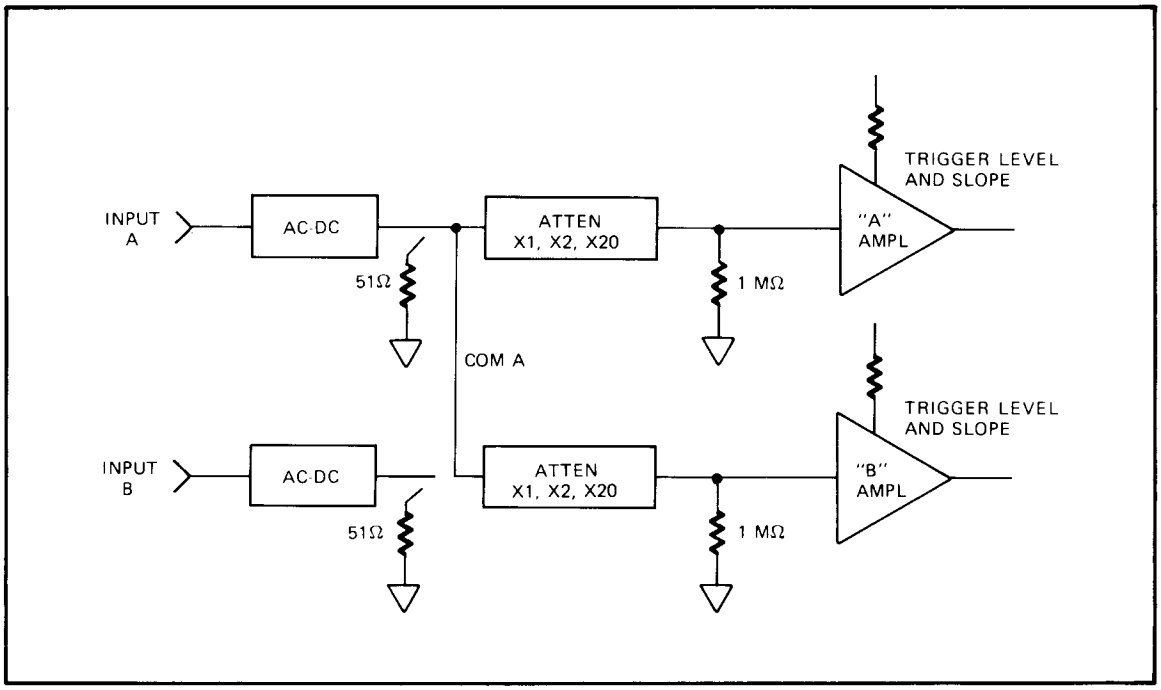



*Figure 3-15. Option 040 Universal Module Input Switch Configuration for COM A*



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3-70. The A and B input amplifiers have independent LEVEL, SLOPE, and ATTEN controls regardless of the mode of operation (SEP or COM A).

### 3-71. Signal Conditioning (Standard and Option 040)

3-72. AC-DC SWITCH. The AC-DC switch controls the coupling of the external signal to the attenuator-amplifier by switching a capacitor in series in the AC position or by direct coupling in the DC position. The obvious advantage of AC coupling is to provide a DC block for signals containing a DC component. AC has the disadvantage of being unable to pass low frequency signals (below 20 Hz for the 5328A). A distinct advantage of having DC coupling cover the full bandwidth (DC-100 MHz) is that extremely accurate time interval or pulse measurements can be achieved even though pulse widths or repetition rates vary since the trigger point is independent of the duty cycle of the input signal.

3-73. ATTENUATOR. The attenuator (ATTEN) connects the input signal directly to the amplifier (in X1) or through a 10:1 attenuator (X10) or a 100:1 attenuator (X100) to increase the voltage range by 10 or 100 times to allow measurement of high level signals that would otherwise be impossible without external attenuation. The Option 040 ATTEN is X1, X2, or X20.

3-74. SLOPE SWITCH. The ±SLOPE switch (provided for each channel) determines which slope of the input signal will trigger the counter. As a simple example, (Figure 3-16) if the pulse width of a positive pulse is to be measured, the A channel slope switch would be set to "+" and the B channel would be set to "-" (for time interval measurements the A channel always begins the measurement and the B channel ends the measurement).

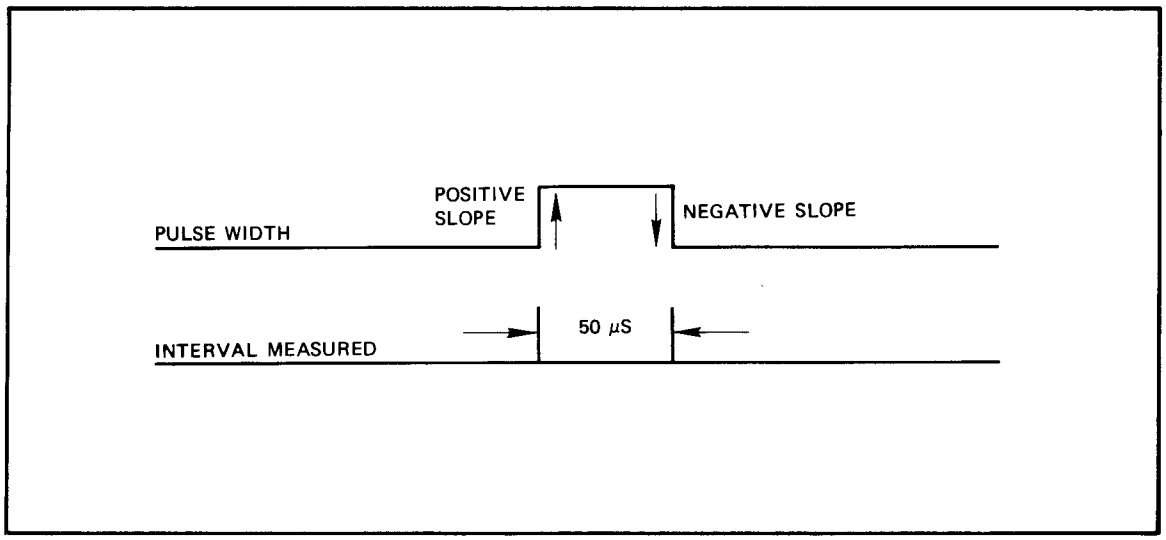



*Figure 3-16. Slope Switch Settings*

**NOTE**

*A simple pulse width measurement is achieved with the use of the +SLOPE setting for channel A and the -SLOPE setting for channel B.*

3-75. The LEVEL control for each channel is adjustable over the range of ±2.5V dc with the attenuator for that channel in the X1 position. A typical use of the LEVEL controls is shown in Figure 3-17. The trigger level may be read by the Option 020 or 021 digital voltmeter. Trigger level measurements are discussed under DVM measurements in Paragraph 4-24.



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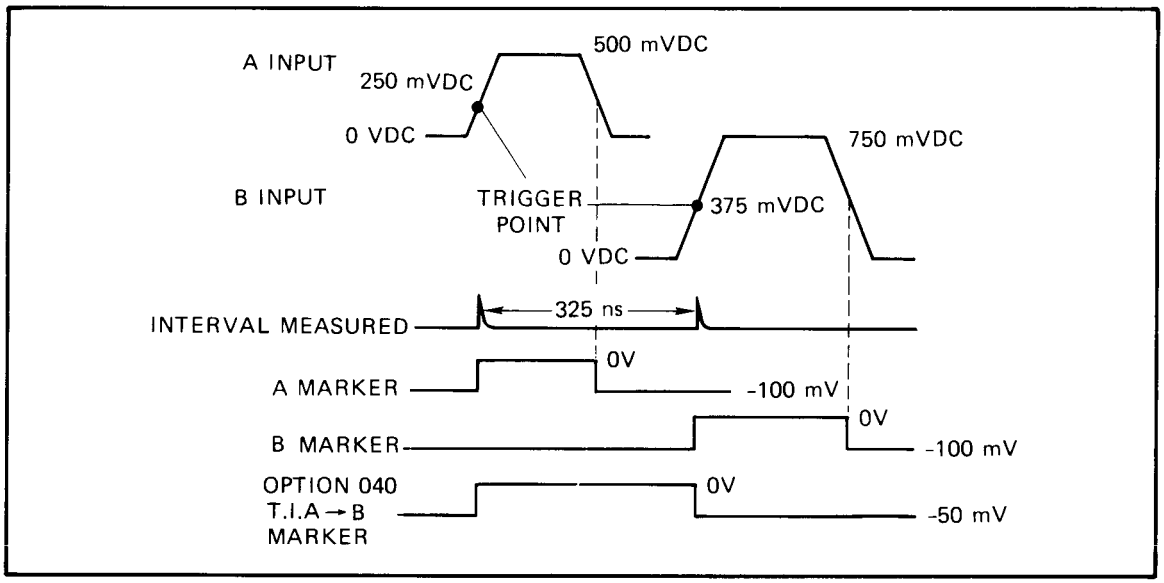



*Figure 3-17. Level Control Settings*

**NOTE**

*Simple measurement of a time interval, the +LEVEL control of the A and B input channels were used to set the trigger LEVEL of A and B.*

### 3-76. Hysteresis

3-77. The width of the hysteresis band, shown in Figure 3-18 is determined by the sensitivity of the counter. For frequencies below 40 MHz, it is less than 50 mV peak-to-peak. At frequencies from 40 MHz to 100 MHz, it is less than 70 mV peak-to-peak. The signal must pass through the entire hysteresis band before a trigger pulse is generated. If the SLOPE switch is set to "+", the trigger pulse occurs at the top of the hysteresis band. If the SLOPE switch is set to "-", the trigger pulse occurs at the bottom of the hysteresis band.

3-78. Since trigger level measurements made by the Option 020 or 021 DVM indicate the center of the hysteresis band (except for when hysteresis compensation is in effect, see Paragraph 4-32), a better value for the actual trigger level may be obtained by subtracting one half the hysteresis band ("-" slope) or adding one half the hysteresis band ("+" slope). A typical value for the width of the hysteresis band is 50 mV peak-to-peak.

3-79. The value to use for the hysteresis band depends on the frequency; or, for pulses, it depends on the rise time.

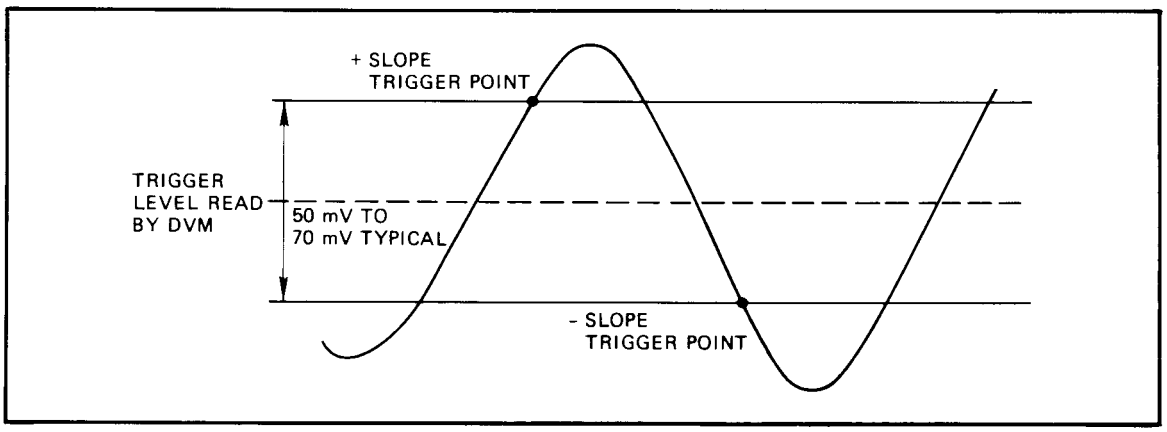



*Figure 3-18. Hysteresis Band*



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### 3-80. External Frequency Standard Input

3-81. The rear panel external frequency standard (OSC INT EXT) input is useful for locking the counter to a high stability external frequency standard. This external standard must be in the range of 30 kHz to 10 MHz with an amplitude of >1V rms into 1 kΩ (maximum input of 5V peak-to-peak). If the frequency input is not 10 MHz, the counter operates with frequency measurements multiplied by the factor 10 MHz/fext and time measurements multiplied by the factor fext/10 MHz. For example, in a frequency measurement, a 1 MHz external standard would give a 100 second measurement time for the RESOLUTION switch in the .1 Hz positon and would display a 100 kHz input as 1000 kHz whereas, in a period measurement (with RESOLUTION set for maximum) a 100 kHz input (10 μsec period) would be displayed as 1 μsec. The measurement time, however would be unaffected.

3-82. For the Option 040 only, the external frequency standard must be 10 MHz for PERIOD AVG, T.I. AVG A→B, PERIOD (N=1), and T.I. A→B (N=1). Otherwise, phase lock will not be achieved and the time base signal will bear no relationship to the frequency of the external frequency standard.

### 3-83. Marker Outputs

3-84. The marker outputs for the standard and for the Option 040 universal module are described in the following paragraphs.

3-85. MARKER OUTPUTS (STANDARD). Two marker output connectors are mounted on the front panel of the universal module. These outputs represent the inverted channel A and channel B Schmitt triggers. The outputs provide 0 to -100 mV levels into 50Ω delayed by less than 20 ns. These outputs are very useful for oscilloscope monitoring. Time interval measurement set-ups are simplified if the time interval of interest and the marker outputs can be simultaneously displayed on oscilloscope traces. Frequency measurements on noisy signals can be made with more confidence since the markers can indicate the presence of noise triggering. These outputs are protected from inadvertently applied voltage to ±5V dc.

3-86. MARKER OUTPUTS (OPTION 040). The Option 040 universal module has a channel A marker output like the standard universal modules. The other marker output is a T.I. A→B marker which is high during the time interval measured by the counter, delayed by less than 20 ns. The levels are 0 to -100 mV into 50Ω for the A marker; 0 to -50 mV for the T1, A→B marker. These markers are extremely helpful in time interval measurement set ups. The marker outputs do not show the effect of the Option 040's delay control.

### 3-87. Gate Out

3-88. This rear panel output supplies a TTL level which is high when the counter's main gate is open and low when it is closed. Monitoring the GATE OUT on an oscilloscope can provide this information for applications where the markers do not give the desired information. For example, when using the delay of the Option 040 and on armed measurements (even though the channel is triggering, the main gate may not be open if the counter hasn't been armed).

### 3-89. Time Base Out

3-90. The TB OUT connector on the rear panel supplies a TTL level output when the FUNCTION switch is in START CLOCK or START A position (see Figure 3-8). In START CLOCK, the internal oscillator 10 MHz is divided by N where N is selected by the RESOLUTION switch. When in START A function, the input at channel A, divided by N (for N>1), is available at the time base out rear panel connector.

### 3-91. External Frequency Standard



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3-91. When the OSC INT EXT switch is in the INT position, the 10 MHz oscillator output is available at the INT/EXT rear panel connector, providing TTL levels. When terminated in 50 ohms, the OSC INT EXT output is a square wave of approximately 1-volt amplitude.

### 3-93. Trigger Lights

3-94. A trigger light is provided for each (A and B) input channels to enable the user to know not only if the channel is triggering, but also in which direction the trigger level must be adjusted to cause triggering. The light is ON when input is above the trigger level; OFF when input is below the trigger level; BLINKING when channel is triggering. The trigger lights are operative over the full frequency range of dc to 100 MHz.

3-95. The trigger lights can be used with a 10:1 oscilloscope probe to provide a logic probe type function. By adjusting the trigger level to one tenth (since using 10:1 divider probes) of the threshold voltage for the logic family under investigation (e.g., .14 volts for TTL), the light indicates the logic state of circuit points which are contacted with the probe. When the trigger level light is ON, the circuit node is a high (i.e., above the threshold voltage). If the light is OFF, the node is a logical low. If the light blinks, then pulses (up to 100 MHz rep rate) are present at the node. The trigger lights can also detect the polarity of low rep rate pulses down to 5 nsec pulse width. Positive pulses cause the light to blink on while negative pulses cause the light to blink off.

### 3-96. Delay (Option 040)

3-97. The delay mode is activated by the inner concentric knob on the LEVEL A control of the Option 040 Universal Model (read LED indicates that delay is activated). In the delay mode, Channel A triggers and is then disabled from triggering again until the delay times out (disabled state occurs within 1 $\mu$s after triggering). Channel B is continously disabled until the delay times out. After the delay, both A and B are enabled. The delay time may be measured by placing the counter in T.I. A→B and the Universal Module in check (CHK). The delay mode of operation is illustrated in Figure 3-19. The range of delay time is continuously variable from 20 $\mu$s to 20 ms. For time interval average measurements using delay, the minimum dead time (time between the stop signal and the next start signal) is 1 $\mu$sec and is illustrated in Figure 3-20. Delay may be used in the following functions: FREQ A, PER A, PER AVG A, T.I. A→B, T.I. AVG A→B, RATIO C/A, START A, EVENTS C, A→B.

3-98. Delay mode is extremely useful for ignoring signals which would otherwise trigger the counter. Applications include relay timing measurements (use "delay" to ignore contact bounce), pulse timing between nonadjacent pulses, and frequency measurements on noisy signals.

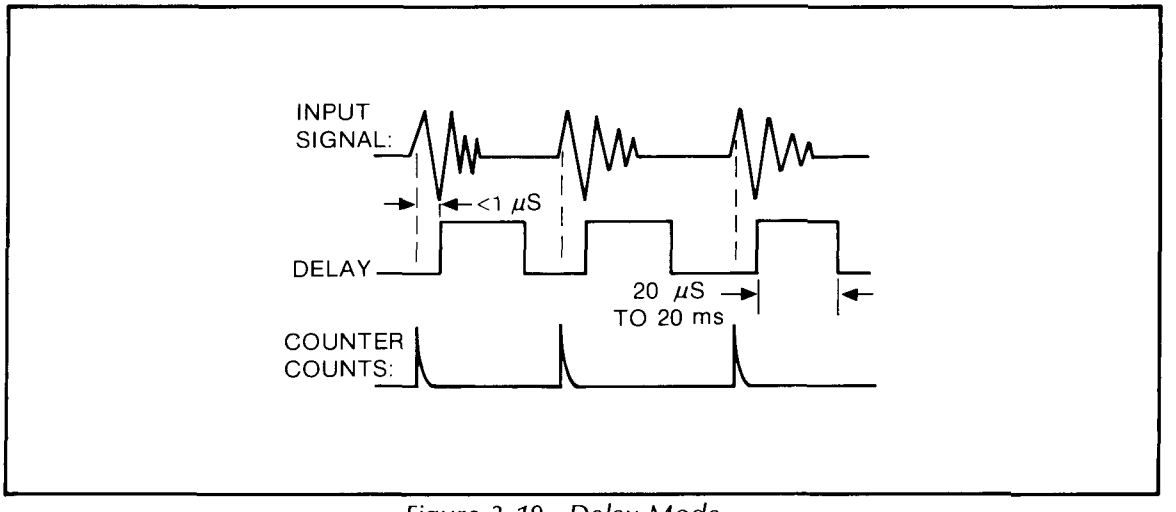



*Figure 3-19. Delay Mode*



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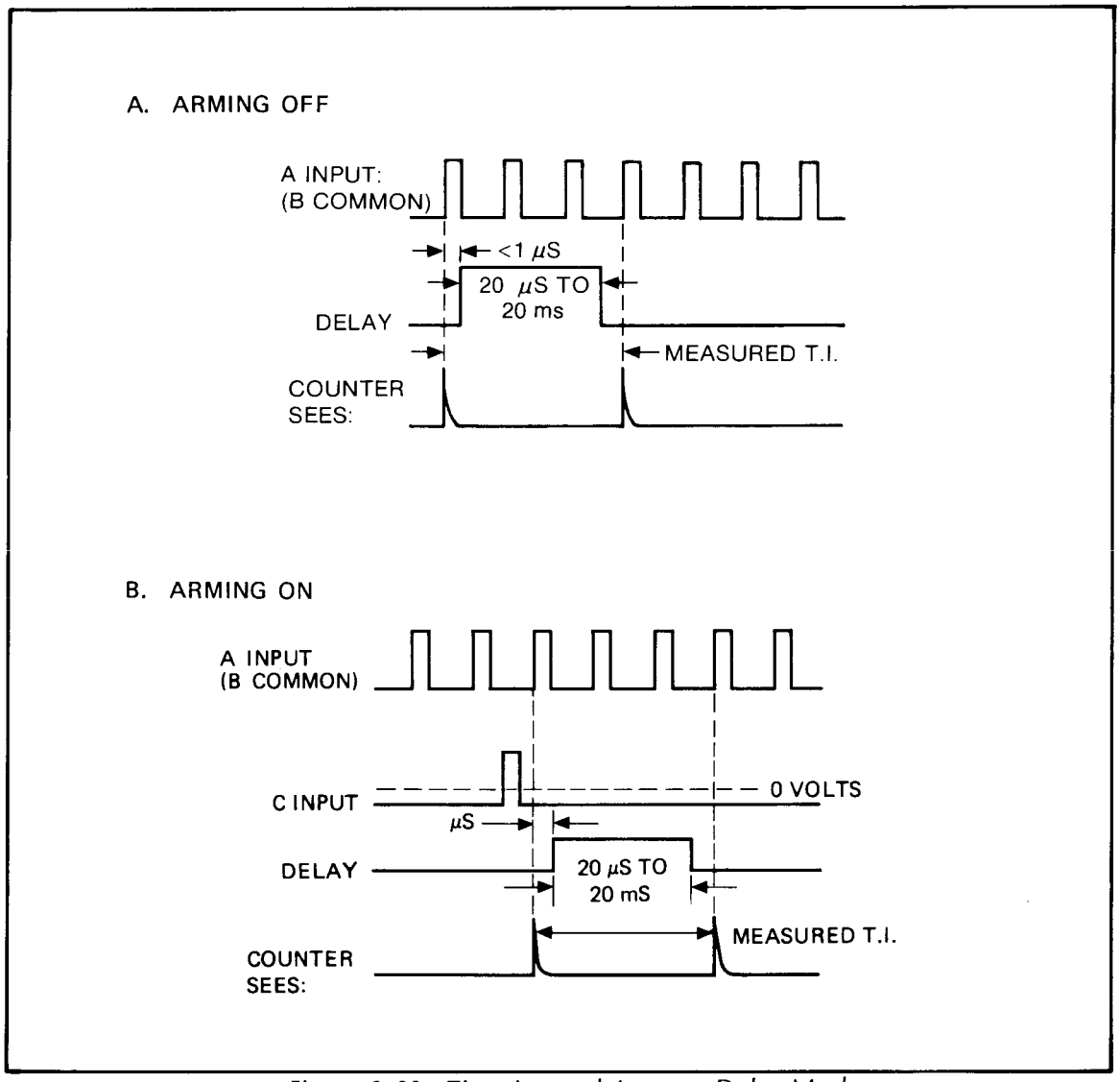



*Figure 3-20. Time Interval Average Delay Mode*



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# SECTION IV
# APPLICATIONS

## 4-1. INTRODUCTION

4-2. This section contains applications information necessary to obtain the most effective performance from the 5328A (and options). Specific details and examples are provided for making measurements of frequency, period, time interval and time interval average, totalizing, and ratio. Use of the optional DVM's in making measurements is included in addition to the use of the external frequency standard input. Programming information for use with the HP-IB Interface (Option 011) is provided in Section V.

## 4-3. FREQUENCY MEASUREMENTS

4-4. To make a frequency measurement on a CW signal below 100 MHz, select FREQ A function, select the appropriate input signal conditioning (see Paragraph 3-71), and apply the signal to the A input of the standard or Option 040 universal module. The RESOLUTION switch determines the resolution of the measurement. Since the 5328A is a conventional counter, 1 Hz resolution is obtained in 1 second of measurement time (e.g., .1 Hz in 10 seconds). The .1 Hz best case frequency resolution limits the low frequency measurement accuracy. In practice, low frequencies are measured by making a period or period average measurement and inverting the result to obtain frequency.

4-5. To make a frequency measurement on a CW signal in the range of 5—512 MHz (Option 030), select FREQ C function and apply the signal to the Option 030 Channel C input. Make sure that the amplitude does not exceed 5V rms. The trigger level for the Channel C is fixed at 0V dc. If pulse waveforms are being measured, they must cross through 0 volts dc by least 25 mV. Pulse widths down to 1 ns can be counted.

4-6. The standard and Option 040 universal modules and the Option 030 Channel C module are direct count modules. Direct count allows greater resolution per second of measurement time than prescaling techniques and is important in making frequency measurements on pulse bursts since the allowable measurement time is fixed (must be less than the width of the burst).

4-7. When the 5328A is in FREQ A or FREQ C function and the rear panel ARM switch is OFF, a measurement cycle is initiated (i.e., arms the counter) upon the first trigger level crossing at the A (or C) input. This means that pulsed signals are measured as easily as CW if the measurement time (determined by the RESOLUTION switch) is less than the width of the pulse.

4-8. With the ARM switch ON, FREQ A and FREQ C are armed by a trigger event at the B input. This mode is useful whenever it is desired to have real time control over when a measurement is to begin. Useful applications include measuring frequency variations along a frequency burst and linearity testing of sweep generators. Figure 4-1 illustrates the set-up for measuring the linearity of a sweep generator. The Channel B Trigger level is adjusted to trigger (and thereby arm the counter) at various points along the sweep out waveform. By plotting the B trigger levels (use the Option 020 or 021 DVM) and the corresponding frequency measurements made at those levels, the linearity of the generator may be determined.

## 4-9. PERIOD MEASUREMENTS

4-10. The PERIOD and PERIOD AVG functions allow single period measurements or multiple period averages to be made on input signals into Channel A for frequencies up to 10 MHz. These modes are useful for making low frequency measurements where maximum resolution is desired.



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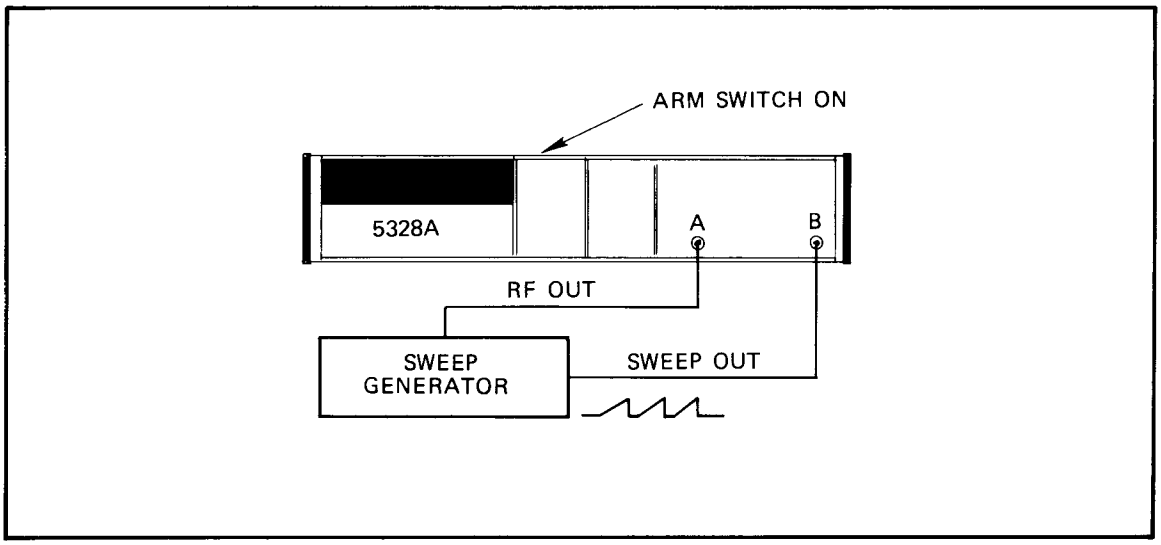



*Figure 4-1. Measuring Linearity*

4-11. To make a PERIOD or PERIOD AVG measurement, select the desired function, select appropriate input signal conditioning (see Paragraph 3-71), and apply the signal to the A input of the standard or Option 040 universal module. For single period measurements, the RESOLUTION switch scales the time base frequency which determines the resolution of the measurement. For optimum resolution, select N=1. Other N values may be desireable to prevent display overflow or to get rid of unstable digits. For PERIOD AVG measurements, the RESOLUTION switch selects the number of periods over which the period average measurement is made (the time base is 10 MHz for this case). The PERIOD AVG mode gives increased resolution and accuracy. Trigger error is decreased by N and the resolution is increased by N (resolution = $\frac{100\text{ ns}}{N}$ or $\frac{10\text{ ns}}{N}$ for Option 040). The measurement time is equal to the period times N.

4-12. In PERIOD and PERIOD AVG with the rear panel ARM switch OFF, the measurement cycle is initiated by the SAMPLE RATE control. With the ARM switch ON, PERIOD and PERIOD AVG are armed by a trigger event at the B input. To measure the frequency of a tone burst signal, use arming and the PERIOD AVG (for increased resolution over a low frequency measurement) as shown in Figure 4-2. Select N equal to or less than the number of periods in the tone burst and adjust channel B trigger level to trigger on the first cycle of the input signal.

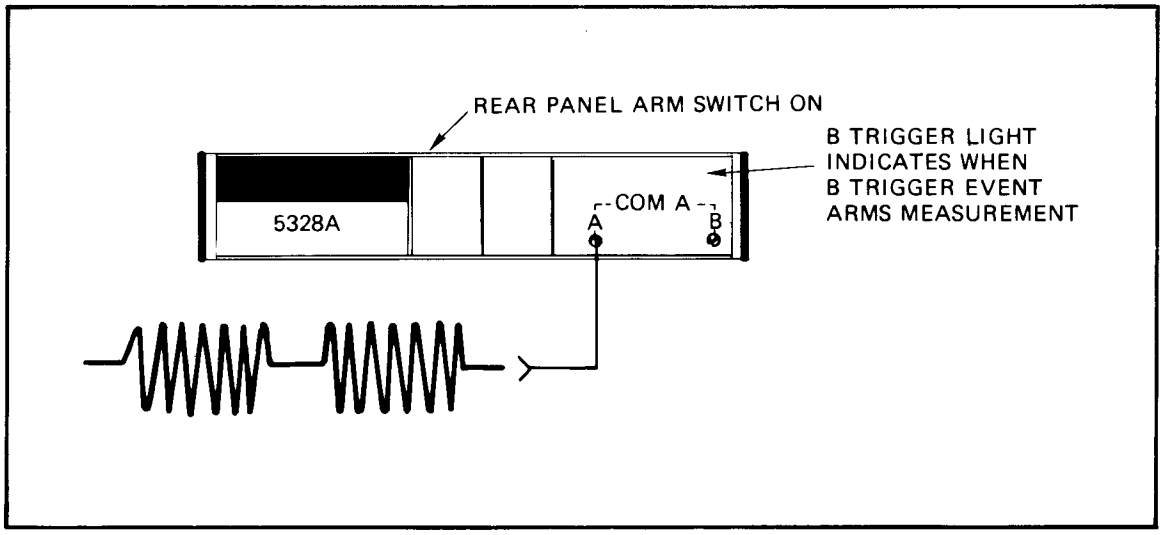



*Figure 4-2. Tone Burst Measurement*



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## 4-13. TIME INTERVAL MEASUREMENTS

4-14. One of two time interval functions can be selected, time interval or time interval average. These functions measure the time interval between a START signal at the channel A input and STOP signal at the channel B input. If both the START and the STOP signals are to be derived from the same signal, place the universal module in COM A position. Separate slope and level controls for each channel allow variable triggering on either positive or negative going slope.

4-15. In single shot time interval measurements, channel A opens the main gate and channel B closes the main gate. While the main gate is open, 10 MHz (100 MHz for Option 040) is divided by the setting of the RESOLUTION switch and totalized by the counter. For optimum resolution, select N=1. Other N values may be chosen to prevent display overflow (e.g., long time intervals) or to get rid of unstable digits. In time interval average measurements, the main gate is open for the number of time intervals selected by the RESOLUTION switch. The standard 5328A 10 MHz clock or the Option 040's 100 MHz clock is totalized only during the individual time intervals. The resolution of the measurement is improved by the $\sqrt{N}$.

4-16. In order to allow the synchronizers time to reset during time interval averaging, there must be at least 150 ns of dead time for the standard module (corresponds to a rep rate less than 6.5 MHz) and at least 20 ns dead time for the Option 040 (and the additional constraint that the rep rate be less than 10 MHz). Dead time is the time between the preceding time interval's stop event and the current time intervals start event as shown in Figure 4-3.

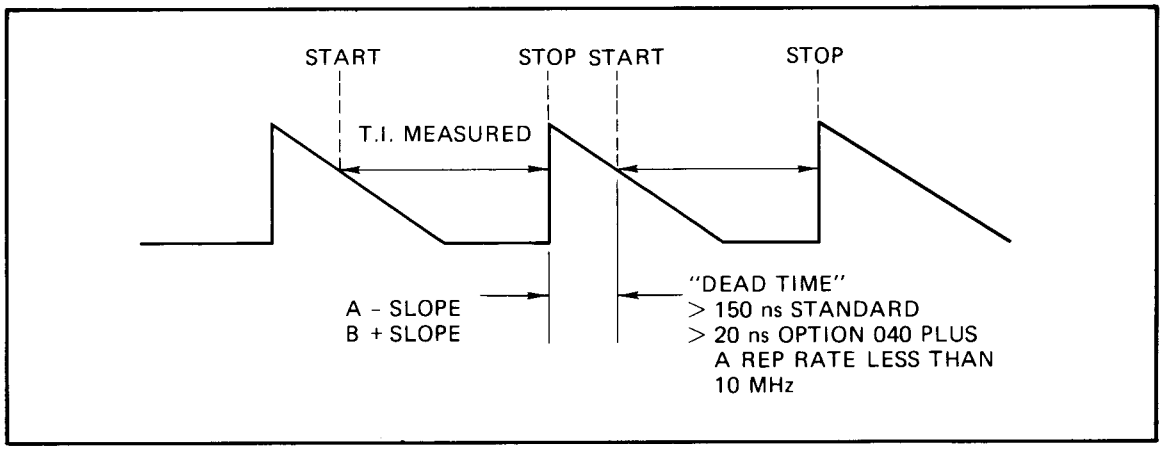



*Figure 4-3. Dead Time*

4-17. During a time interval average, there must be only one stop pulse for each start pulse. Extraneous stop pulses which occur before the next start pulse are accumulated and give erroneous readings. For example, the case illustrated in Figure 4-4 would result in a reading equal to one-half of the desired time interval. The delay feature of the Option 040 is useful for ignoring intervening stop pulses in time interval measurements with multiple stops (see Figure 3-14).

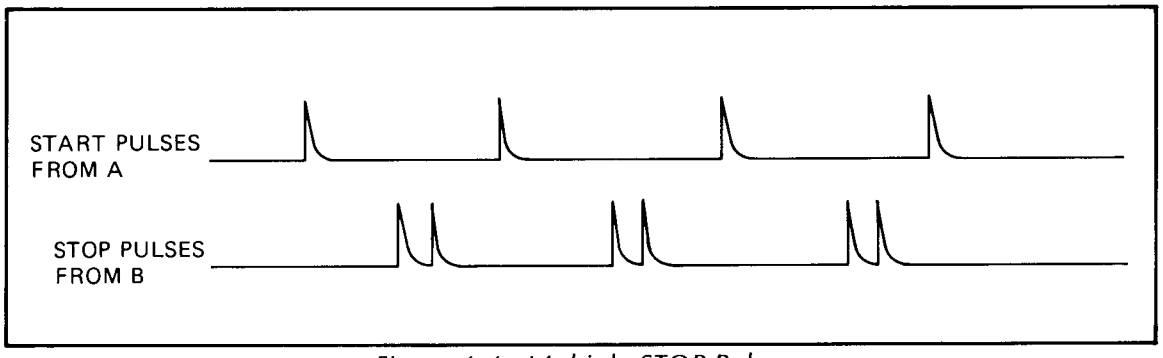



*Figure 4-4. Multiple STOP Pulses*



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4-18. To set up a time interval measurement, the marker outputs may be monitored on an oscilloscope (see Figure 4-5) to indicate where the channels are triggering with relation to the time interval of interest. The Option 040 T.I. A→B marker output is high during the time interval being measured. Voltage levels sent to the DVM (either Option 020 or 021) indicate trigger levels for ease in measurement set-up.

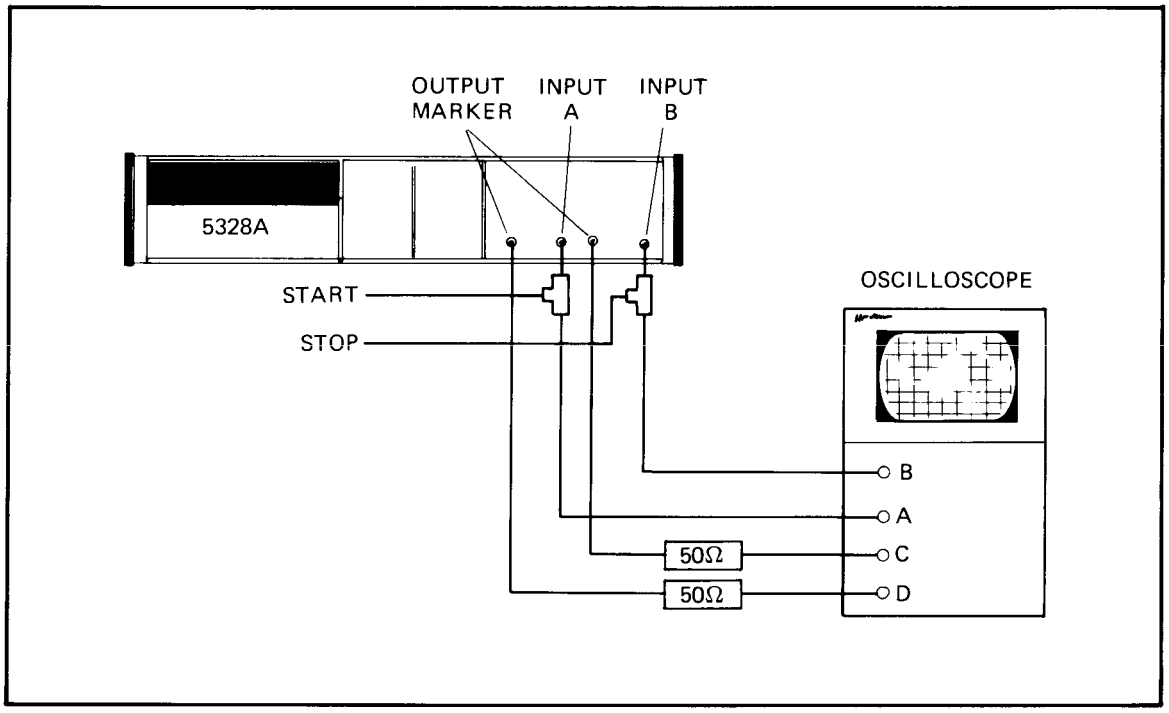



*Figure 4-5. Monitoring Marker Outputs*

4-19. In T.I. A→B and T.I. AVG A→B, both input amplifiers of the Option 040 universal module have an automatic compensation network that offsets the hysteresis band to keep the trigger level at the same potential when switching between positive and negative slope. This saves set-up time since trigger levels need only be set once for both positive and negative going triggering. There is the possibility, however, that if both levels are +slope and near the top of the waveform, that switching one of them to -slope will pace the hysteresis band beyond the signal and triggering would cease. This is illustrated in Figure 4-6.

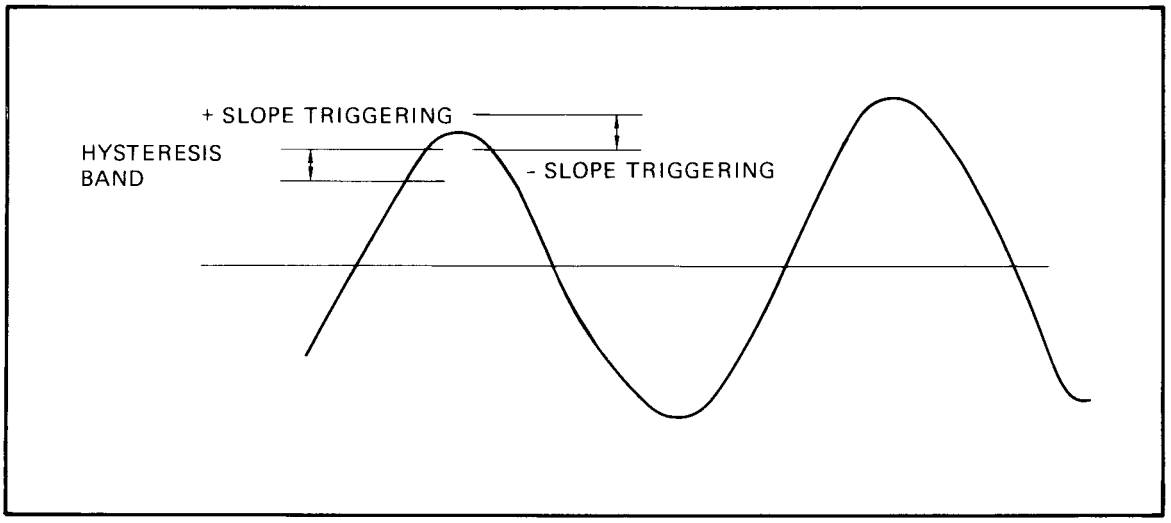



*Figure 4-6. Slope Switch Effect on Hysteresis Band*



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4-20. In T.I. A→B and T.I. AVG A→B with the rear panel ARM switch OFF, the counter is armed by the run down of the SAMPLE RATE control. With the rear panel ARM switch ON, T.I. A→B and T.I. AVG A→B are armed by an event at the C input (if Option 030 channel C is installed). For T.I. AVG A→B, only one arming signal is required per average measurement (i.e., the counter doesn't need to be armed prior to each individual time interval in the time interval measurement).

## 4-21. TOTALIZING MEASUREMENTS

4-22. Two totalizing functions are available: START A and Events at C during the time interval from A to B (Events C, A→B). In START A, the number of counts at the A input are totalized if N=1. If N is greater than 1, A/N is totalized and the scaled output is available at the (TB OUT) rear panel connector.

4-23. With Option 030 channel C, the events C, A→B function allows the number of events at the C input to be totalized during a synchronized time interval defined by inputs to channels A and B. A synchronized time interval means that the actual time interval during which events are totalized is a multiple of 100 ns (or 10 ns with Option 040) and is synchronized to the counter's clock.

## 4-24. DVM MEASUREMENTS

### 4-25. Option 020

4-26. Three modes of Option 020 voltmeter operation may be selected: DVM, READ A, or READ B. In the READ A and READ B modes, the digital voltmeter measures the trigger level of channel A or B, regardless of the setting of the FUNCTION switch. To return control to the FUNCTION control switch, the DVM control must be switched back to DVM 100V RANGE. When the digital voltmeter is in DVM 100V RANGE and the FUNCTION control is in DVM, the digital voltmeter measures the external voltage applied to its input connector.

4-27. The trigger level read by the voltmeter in READ A or READ B modes must be multiplied by the setting of the universal module's attenuator switch if using the standard universal module. The trigger level represents the center of the hysteresis band. If using the Option 040 universal module, the trigger level read by the DVM must be multiplied by 10 if the universal module attenuator position is in the X20 position (the X2 position is automatically accounted for) if the FUNCTION control is in T.I. A→B or T.I. AVG A→B. The trigger level represents the top of the hysteresis band for +slope and the bottom of the hysteresis band for -slope. In any other function, the trigger level represents the middle of the hysteresis band.

4-28. The DVM has a 0 to 125V range and allowable measurement times for 1 ms to 10 s. These times are determined by the setting of the RESOLUTION switch according to the following table.

| Max. Sensitivity | RESOLUTION, N | Measurement Time |
|---|---|---|
| 100 mV | 1 kHz $10^3$ | 1 ms |
| 10 mV | .1 kHz $10^4$ | 10 ms |
| 1 mV | 10 Hz $10^5$ | 100 ms |
| 1 mV | 1 Hz $10^6$ | 1 s |
| 1 mV | .1 Hz $10^7$ | 10 s |

The Option 020 DVM is single ended. One of the input terminals is grounded. Levels over 125V dc are read as 125V dc. Maximum input is ±500V dc.

### 4-29. Option 021

4-30. Three modes of Option 021 voltmeter operation may be selected: DVM, READ A or READ B. When a mode is selected (by depressing the appropriate pushbutton), the digital voltmeter measures the trigger level of channel A or B, regardless of the setting of the FUNCTION switch. A



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"V" annunciators is displayed to indicate that a voltage measurement is being made. To return control to the FUNCTION selector, the trigger level pushbutton must be released (by pressing). When the FUNCTION selector switch is in DVM, external voltages applied to the Option 021's floating input may be measured in a 10V, 100V, or 1000V range (or select AUTO ranging).

4-31. A filter switch allows a filter to be switched into the input path to allow the measurement of very small dc levels in the presence of high common mode or normal mode noise.

4-32. The trigger level read by the voltmeter in READ A or READ B modes must be multiplied by the setting of the universal module's attenuator switch if using the standard universal module. The level represents the center of the hysteresis band. If the counter has the Option 040 universal module installed, the setting of the attenuator switch is automatically taken into account. If the FUNCTION control is in T.I. A→B or T.I. AVG A→B (meaning that hysteresis compensation is in effect), the trigger level read represents the top of the hysteresis band for -slope. In any other functions, the trigger level represents the middle of the hysteresis band.

4-33. The DVM has three ranges, ±10V (±12.5 overrange), ±100V (±125V overrange), and ±1000V dc. Allowable measurement times and corresponding sensitivity is shown in the following table.

| RESOLUTION, N | Measurement Time | Sensitivity |
|---|---|---|
| 1 kHz, $10^3$ | 1 ms | 100 mV |
| 100 Hz $10^4$ | 10 ms | 10 mV |
| 10 Hz $10^5$ | 100 ms | 1 mV |
| 1 Hz $10^6$ | 1 s | 100 $\mu$V |
| .1 Hz $10^7$ | 10 s | 10 $\mu$V |

4-34. The Option 021 DVM is floating, thus allowing differential measurements to be made. Internal isolators and a floating power supply allow the floating measurements and permit DVM measurement output over the HP-IB. (The HP-IB is described in Section V.) Maximum input from HI to LO is 1100V dc. Maximum potential at LO with respect to chassis ground is ±500V dc.

4-35. With the rear panel ARM switch ON, a DVM measurement is initiated by an event at the B input. This ability to "command" a DVM measurement can be particularly useful when measuring switched dc levels such as from dc supplies or D-to-A converters operating in computer operated test systems. By adjusting channel B to trigger on the transition from one voltage to the next, the DVM makes a measurement only during the time that the level is stable.

4-36. Figure 4-7 illustrates an example of an armed DVM measurement. Select a measurement time less than the width of the step to be measured and adjust the B trigger level to trigger on the leading edge of the step.

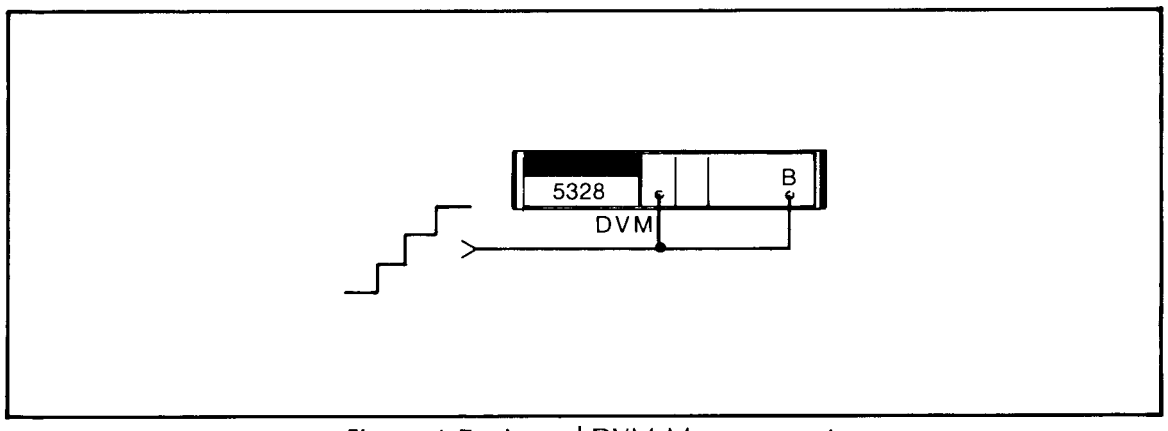



Figure 4-7. Armed DVM Measurement



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## 4-37. RATIO MEASUREMENTS

4-38. In contrast to many counters which relegate ratio measurements to limited capability rear panel inputs, the 5328A offers full bandwidth, sensitivity, and signal conditioning of the channel A, B, and C input amplifiers.

4-39. Two ratio functions are available: B/A and C/A (for Option 030 channel C installed). The ratio of the frequency at B (or C) to the frequency at A is measured for N counts of A where N is selected by the RESOLUTION switch. The resolution of the measurement improves with increasing N and is given by 1 part in B/A x N (or C/A x N). Since the range of A is 0—10 MHz while B is 0—100 MHz, the lower frequency is normally applied to the A input although there is no restriction that this be the case (i.e., ratio's less than 1 may be measured). If B/A is greater than 1, the measurement resolution is better than switching the inputs for a ratio <1, provided the value of N remains the same.



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# SECTION V

# PROGRAMMING
# (Option 011 HP-IB Interface)

## 5-1. INTRODUCTION

5-2. Option 011 makes the 5328A Universal Counter fully compatible with the Hewlett-Packard Interface Bus (HP-IB). With this option installed, the counter can respond to remote control instructions and can output measurement results via the HP-IB. Thus the 5328A gives all the benefits of standardized systems operation with the HP-IB. At the simplest level the 5328A can output data to other devices such as the 5150A Thermal Printer or the 59303A Digital-to-Analog Converter. In more sophisticated systems, the calculator or other system controller can remotely program the 5328A, trigger measurements, and read the results. Of course, a calculator or computer adds other benefits to an HP-IB based measurement system. The calculator can manipulate data to compute the mean and standard deviation, check for linearity, compare results to limits, or perform many other functions.

5-3. This section describes how to use the HP 9820A, HP 9821A, and HP 9830A Calculators to program the 5328A Universal Counter. Before starting to operate a system it helps to be familiar with the selected calculator, the capabilities of the HP-IB, and the manual operation and capabilities of the 5328A. The following HP manuals provide very useful background information:

HP-IB User's Guide, 9820A/21A
HP-IB User's Guide, 9830A
5328A Service Manual

Each of these manuals is included with the appropriate hardware. The User's Guides are included with the I/O cards that interface the calculators to the HP-IB. The 5328A Service Manual is shipped with the 5328A Universal Counter.

## 5-4. SETTING ADDRESS SWITCHES

5-5. To use the 5328A in an HP-IB based system the first step is to set the rear panel address switches shown in Table 5-1. The left-most switch sets the counter to ADDRESSABLE or TALK ONLY mode. ADDRESSABLE mode is used whenever a calculator or other controller is used within the system. TALK ONLY mode is used when the counter will be controlled manually but will output results to another device on the bus such as a printer or D-A converter.

5-6. The five right-hand switches, A5 through A1, set the talk and listen addresses of the 5328A when it is used in the ADDRESSABLE mode. Table 5-1 shows the possible address settings and the corresponding ASCII codes for talk and listen addresses.

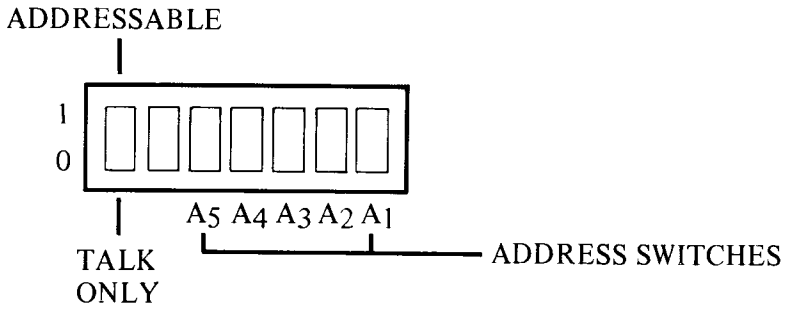
5-7. The examples listed in this section assume an address setting of 01010. This setting gives a talk address of "J" and a listen address of "*".

5-8. The setting 11111 should not be used as it is reserved for the Untalk and Unlisten commands.



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*Table 5-1. Addressing*




ASCII ADDRESS CODES

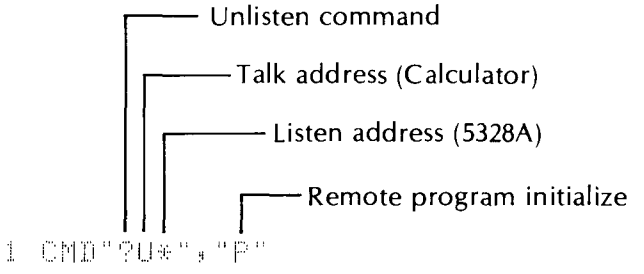
| $A_5$ | $A_4$ | $A_3$ | $A_2$ | $A_1$ | ASCII LISTEN ADDRESS | ASCII TALK ADDRESS |
|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | SP | @ |
| 0 | 0 | 0 | 0 | 1 | ! | A |
| 0 | 0 | 0 | 1 | 0 | " | B |
| 0 | 0 | 0 | 1 | 1 | # | C |
| 0 | 0 | 1 | 0 | 0 | $ | D |
| 0 | 0 | 1 | 0 | 1 | % | E |
| 0 | 0 | 1 | 1 | 0 | & | F |
| 0 | 0 | 1 | 1 | 1 | ' | G |
| 0 | 1 | 0 | 0 | 0 | ( | H |
| 0 | 1 | 0 | 0 | 1 | ) | I |
| 0 | 1 | 0 | 1 | 0 | * | J |
| 0 | 1 | 0 | 1 | 1 | + | K |
| 0 | 1 | 1 | 0 | 0 | , | L |
| 0 | 1 | 1 | 0 | 1 | - | M |
| 0 | 1 | 1 | 1 | 0 | . | N |
| 0 | 1 | 1 | 1 | 1 | / | O |
| 1 | 0 | 0 | 0 | 0 | ø | P |
| 1 | 0 | 0 | 0 | 1 | 1 | Q |
| 1 | 0 | 0 | 1 | 0 | 2 | R |
| 1 | 0 | 0 | 1 | 1 | 3 | S |
| 1 | 0 | 1 | 0 | 0 | 4 | T |
| 1 | 0 | 1 | 0 | 1 | 5 | U |
| 1 | 0 | 1 | 1 | 0 | 6 | V |
| 1 | 0 | 1 | 1 | 1 | 7 | W |
| 1 | 1 | 0 | 0 | 0 | 8 | X |
| 1 | 1 | 0 | 0 | 1 | 9 | Y |
| 1 | 1 | 0 | 1 | 0 | : | Z |
| 1 | 1 | 0 | 1 | 1 | ; | [ |
| 1 | 1 | 1 | 0 | 0 | < | \ |
| 1 | 1 | 1 | 0 | 1 | = | ] |
| 1 | 1 | 1 | 1 | 0 | > | ^ |

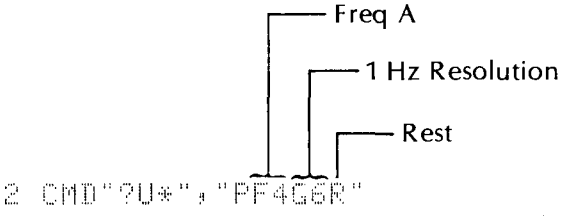


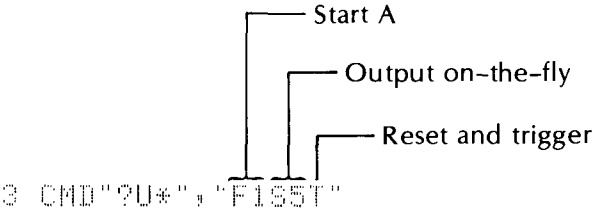
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## 5-9. PROGRAMMING THE 5328A

5-10. The HP 9820A/21A/30A Calculators use the CMD statement to program the 5328A. The calculator addresses itself to talk and the counter to listen, then transmits a series of program codes. The codes to control the operation of the 5328A are listed in the program code set (Table 5-2). Suppose you have set the counter to talk address "J" and listen address "*". Then typical statements to program the counter are:




The program codes are from the 12 groups of the program code set (shown in Table 5-2). No more than one code from a group should be used in a program code string; use the codes in the same order that the groups are listed.

5-11. The code "P" gives a simple way to initialize the state of the counter program. "P" substitutes for "F0G0S0246:<>UR". When codes other than "P" are used; either "R" or "T" should be included at the end of the string. Both of these codes update the counters program storage cells. The code "T" also initiates a measurement; "R" does not.



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*Table 5-2. Program Code Set*

**NOTE**

Codes shown in **bold face** are start-up conditons. These conditions are set by the code "P", Remote Program Initialize, or by the bus commands Device Clear or Selected Device Clear.

1. Initialization Code

   P Remote Program Initialize

2. Function Codes

   **FØ Stop**
   F1 Start A
   †F2 Start Clock
   †F3 DVM/A
   F4 Freq. A
   †F5 DVM/T.I. A→B
   F6 Period A
   F7 Period Avg A
   F8 T.I. A→B
   F9 N•B/A
   F: T.I. Avg A→B
   F; Events C, T.I. A→B
   F< Check
   F= N•C/A
   F> Freq. C
   F? DVM

   †Functions not labeled on instrument front panel (see Figure 3-8)

3. Time Base Codes

| Code | Freq Res | Multiplier | Time Res (Std) | Time Res (Opt. 040) |
|---|---|---|---|---|
| **GØ** | **1 MHz** | **1** | **100 ns** | **10 ns** |
| G1 | 100 kHz | 10 | 1 μs | 100 ns |
| G2 | 10 kHz | $10^2$ | 10 μs | 1 μs |
| G3 | 1 kHz | $10^3$ | 100 μs | 10 μs |
| G4 | 100 Hz | $10^4$ | 1 ms | 100 μs |
| G5 | 10 Hz | $10^5$ | 10 ms | 1 ms |
| G6 | 1 Hz | $10^6$ | 100 ms | 10 ms |
| G7 | 0.1 Hz | $10^7$ | 1 s | 100 ms |

4. Single-Multiple Measurement

   **SØ Single Measurement**
   S1 Multiple Measurement

5. Measurement Cycle

   **S2 Wait to output; Service Request at end of measurement**
   S3 Continue cycle; no Service Request

6. Output Mode

   **S4 Output at end of measurement**
   S5 Output when addressed (on-the-fly)



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Table 5-2. Program Code Set (Continued)

7. Sample Rate

**S6 Maximum**
S7 Manual control (from front panel)

8. Arming

**S: Off**
S; On

9. Display Storage

**S< On (normal)**
S= Off

10. Decade Reset

**S> Normal**
S? Disabled (for cumulative measurements)

11. Display Blanking

**U Normal display**
Q Blank display (digits and decimal point)

12. Reset; Trigger (Also see Bus Command GET, Paragraph 5-13)

**R Reset, no trigger**
T Reset and trigger



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## 5-12. Triggering a Measurement

5-13. The calculator must trigger each measurement when the 5328A is programmed for single measurement mode, "S0". Two trigger methods are available. The program code "T" offers the simplest way to trigger a measurement. However, the bus command Group Execute Trigger (GET) may also be used. The counter responds more quickly to GET; also, GET can trigger the counter simultaneously with other devices on the bus.

Using the progarm code "T":

```
CMD"?U*";"T"
```
(9820A/21A/30A)

Using Group Execute Trigger:

```
CMD "?*":⊢
```
(9820A)

```
CMD "?*@":⊢
```
(9821A)

*(This "strange" symbol is produced by the display key.)*

```
10 CMD"?U*"
20 FORMAT 3B
30 OUTPUT(13,20)256,8,512;
```
(9830A)

5-14. If the counter is programmed for multiple measurements, "S1", the counter will start each measurement without a trigger command (see Figure 5-1). When the counter is also programmed to wait to output, "S2", it will start a new measurement as soon as the calculator reads the previous one. In the continuous cycle mode, "S3", the counter does not wait to output, but starts a new measurement. This mode is useful for the user to visually monitor a series of readings.

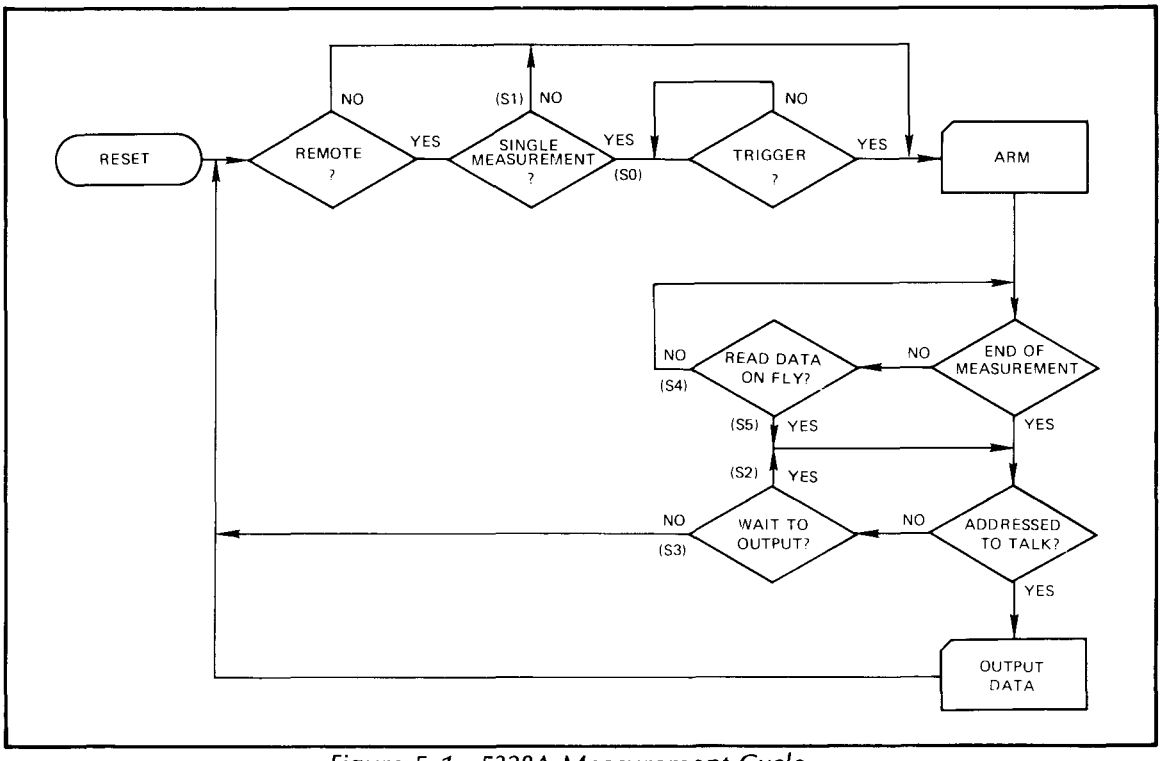


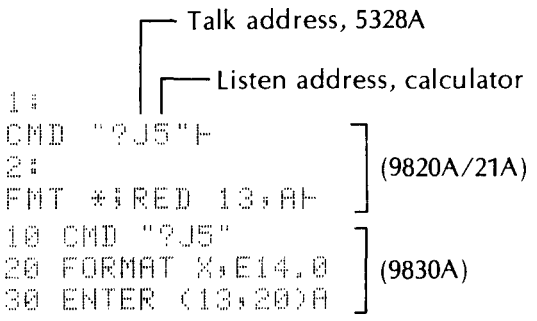

*Figure 5-1. 5328A Measurement Cycle*



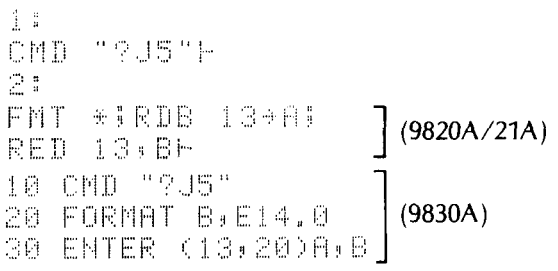
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## 5-15. Reading a Measurement

5-16. To read a measurement from the counter to a calculator, the counter must first be addressed to talk and the calculator to listen. The examples below indicate how a calculator may read a measurement from the counter.




5-17. Note that the data output string from the 5328A may include a leading "O" when a counter measurement overflows. The 9830A example above includes the format specification "X" so that calculator will skip over the first character and not be confused by the letter "O". The examples that follow show how a calculator may also read in the value of the leading character:




5-18. In these examples, A contains the decimal value of the leading character; B contains the value of the reading. If the leading character is "SP" then A=32; if the character is "O" then A=79.

## 5-19. PROGRAMMING EXAMPLE

5-20. The following program illustrate how the HP 9820A/21A and 9830A calculators can control the 5328A counter. Both programs cause the counter to make a series of frequency measurements. The calculator reads the measurements into memory and prints the results. The programs assume the counter talk address is "J" and listen address "*". Table 5-3 contains a program explanation.



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```
0:
FMT Y3,Z;WRT 13⊢
1:
CMD "?U*","PF4G6
R"⊢
2:
1→X⊢
3:
CMD "?*Σ("⊢
4:
CMD "?J5"⊢
5:
FMT *;RED 13,RX⊢
6:
PRT RX⊢
7:
X+1→X;IF X≤10;
GTO 3⊢
8:
END ⊢
R158
```

```
10 CMD "?U"
20 FORMAT B
30 OUTPUT (13,20)768;
40 CMD "?U*","PF4G6R"
50 FOR I=1 TO 10
60 CMD "?U*","T"
70 CMD "?J5"
80 FORMAT X,E14.0
90 ENTER (13,80)A[I]
100 PRINT A[I]
110 NEXT I
120 END
```

*Table 5-3. Program Explanation*

| Operation | 9820A/21A Line No. | 9830A Statement No. |
|---|---|---|
| Set HP-IB to Remote Enabled state | 1 | 10–30 |
| Program counter to frequency measurement, 1 Hz resolution | 2 | 40 |
| Trigger a measurement. (9820A/21A listing uses Group Execute Trigger; 9830A uses code "T".) | 4 | 60 |
| Read the measurement | 5–6 | 70–90 |
| Print result | 7 | 100 |



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## 5-21. MEASUREMENT OUTPUT FORMAT

5-22. The 5328A transmits the following string of characters to output a measurement:

| Position | 1 | 2 | 3 thru 12 | 13 | 14 | 15 | 16 | 17 |
|---|---|---|---|---|---|---|---|---|
| Character | O / SP | + / - | 9 digits and decimal point . | E | + / - | d | CR | LF |

*"O" in the first position indicates measurement overflow. Leading 0's in positions 3 to 12 are output as SP (space) if they occur to the left of the decimal point except for the 0 next to the decimal point. The decimal point may appear at positions 4 to 12. The output string is always 17 characters long. Typical character output strings are:*

| **1** | **2** | **3** | **4** | **5** | **6** | **7** | **7** | **9** | **10** | **11** | **12** | **13** | **14** | **15** | **16** | **17** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SP | + | 5 | 0 | 3 | . | 2 | 1 | 7 | 6 | 9 | 8 | E | + | 6 | CR | LF |
| SP | + | SP | SP | SP | 5 | 4 | 3 | 2 | 1 | Ø | . | E | - | 3 | CR | LF |
| 0 | + | Ø | 5 | 3 | 1 | . | 8 | 5 | 4 | 2 | Ø | E | + | 6 | CR | LF |

## 5-23. BUS COMMANDS

5-24. The 5328A Universal Counter obeys the following Bus Commands (ASCII codes shown in parenthesis and in Table 5-4):

a. Unaddress Commands:

UNL Unlisten (ASCII question mark "?")

Clears the counter from acting as a listener.

UNT Untalk (ASCII underscore "—")

Clears the counter from acting as a talker. The same result can be achieved by addressing any other device on the bus to talk.

b. Universal Commands:

LLO Local Lockout (ASCII DC1)

Disables all programmable controls including reset. Go to Local (GTL) may be used to return to manual control.

DCL Device Clear (ASCII DC4)

Resets the programmed state of the counter to the codes shown in bold face in the program code set. Has the same effect as the program code "P".

SPE Serial Poll Enable (ASCII CAN)

Sets the counter to the serial poll mode. When addressed to talk during the serial poll mode, the 5328A produces a status byte to indicate its condition. If the counter has completed a measurement and is requesting service, the status byte contains a "1" in bit 7 (decimal value 64). If the counter has not requested service, the status byte will be "0" in all bits. When addressed to talk in the serial poll mode, the counter will immediately stop requesting service.



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SPD Serial Poll Disable (ASCII EM)
Terminates the serial poll mode. The 5328A can resume its normal data output mode.

c. Addressed Commands:

GTL Go to Local (ASCII SOH)
Returns the 5328A to local (manual) control from remote control.

SDC Selected Device Clear (ASCII EOT)
Responds as with Device Clear or program code "P".

GET Group Execute Trigger (ASCII BS)
Starts a measurement. This command provides the quickest method to start a measurement cycle.

*Table 5-4. American Standard Code for Information Interchange (ASCII)*

**USA STANDARD CODE FOR INFORMATION INTERCHANGE**

| BITS | | | | $b_7$ $b_6$ $b_5$ | $0\,0\,0$ | $0\,0\,1$ | $0\,1\,0$ | $0\,1\,1$ | $1\,0\,0$ | $1\,0\,1$ | $1\,1\,0$ | $1\,1\,1$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $b_4$ | $b_3$ | $b_2$ | $b_1$ | COLUMN / ROW | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 0 | 0 | 0 | 0 | 0 | NUL | DLE | SP (blank) | 0 | @ | P | ` | p |
| 0 | 0 | 0 | 1 | 1 | SOH | DC1 | ! | 1 | A | Q | a | q |
| 0 | 0 | 1 | 0 | 2 | STX | DC2 | " | 2 | B | R | b | r |
| 0 | 0 | 1 | 1 | 3 | ETX | DC3 | # | 3 | C | S | c | s |
| 0 | 1 | 0 | 0 | 4 | EOT | DC4 | $ | 4 | D | T | d | t |
| 0 | 1 | 0 | 1 | 5 | ENQ | NAK | % | 5 | E | U | e | u |
| 0 | 1 | 1 | 0 | 6 | ACK | SYN | & | 6 | F | V | f | v |
| 0 | 1 | 1 | 1 | 7 | BEL | ETB | ' | 7 | G | W | g | w |
| 1 | 0 | 0 | 0 | 8 | BS | CAN | ( | 8 | H | X | h | x |
| 1 | 0 | 0 | 1 | 9 | HT | EM | ) | 9 | I | Y | i | y |
| 1 | 0 | 1 | 0 | 10 | LF | SUB | * | : | J | Z | j | z |
| 1 | 0 | 1 | 1 | 11 | VT | ESC | + | ; | K | [ | k | { |
| 1 | 1 | 0 | 0 | 12 | FF | FS | , | < | L | \ | l | ¦ |
| 1 | 1 | 0 | 1 | 13 | CR | GS | – | = | M | ] | m | } |
| 1 | 1 | 1 | 0 | 14 | SO | RS | . | > | N | ↑ | n | ~ |
| 1 | 1 | 1 | 1 | 15 | SI | US | / | ? | O | ← | o | DEL |

UNIVERSAL ADDRESS COMMANDS

LISTEN ADDRESSES

UNLISTEN COMMAND

TALK ADDRESSES

UNTALK COMMAND

DATA WHEN ATN IS HIGH.
ADDRESSES WHEN ATN IS LOW.



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HEWLETT hp PACKARD

# MANUAL CHANGES

**MANUAL DESCRIPTION**

INSTRUMENT: 5328A Universal Counter
Users Manual
SERIAL PREFIX: Applies to all serial prefixes

DATE PRINTED: APRIL 1975
HP PART NO: 05328-90002
MICROFICHE NO: 05328-90010

**CHANGE DATE** March 1, 1976

(This change supersedes all earlier dated changes)

- Make all changes listed as ERRATA.
- Check the following table for your instrument's serial prefix or serial number and make listed change(s) to manual.

| IF YOUR INSTRUMENT HAS SERIAL PREFIX OR SERIAL NUMBER | MAKE THE FOLLOWING CHANGES TO YOUR MANUAL | IF YOUR INSTRUMENT HAS SERIAL PREFIX OR SERIAL NUMBER | MAKE THE FOLLOWING CHANGES TO YOUR MANUAL |
|---|---|---|---|
| | | | |
| | | | |

► NEW OR REVISED ITEM

► ERRATA

*Page vi (front matter)* SAFETY CONSIDERATIONS:
Delete the entire paragraph entitled "HIGH VOLTAGE" and substitute the following:

HIGH VOLTAGE

Caution — to prevent electric shock, do not remove cover.
Refer servicing to qualified personnel.

Page 1-0, Figure 1-1, Model 5328A Universal Counter with Options:
Change the marking of the 5328A front panel power switch as follows:
Change "POWER" to "LINE" and "OFF" to "STBY". At top left side of switch insert the word "ON". Make this same change to all front view photos, Figures 3-8, 3-10, 3-11, 3-12, and 3-13. In Figures 3-8 and 3-10, Step 1, change the first part "In off (up) position, . . . " to read "In STBY position, . . . "

Page 1-1, Paragraph 1-7:
Delete all of this paragraph except the first two sentences. Add the following:
"The five-digit number is the serial number of each instrument. A manual change sheet is included when instrument changes have affected the contents of this manual."

Page 1-3, Paragraph 1-20:
Add the following:
"The test leads listed in Table 1-2 are used with the DVM options. The coax cable listed is used with input A, B or C. The rack flange kit is used to install the 5328A in a cabinet."

Page 1-3, Table 1-2, Accessories Available:
Change Table 1-2 as follows:
Delete all information entitled "Rack Mount Flange" and insert the following:

| DESCRIPTION | HP PART NO. |
|---|---|
| Front Handle Kit | 5061-0088 |
| Rack Flange Kit (for instruments without handles) | 5061-0076 |
| Rack and Handle Kit (Installation instructions included with above kits) | 5061-0082 |
| Test leads, dual banana plug to alligator clips, 60 inches long | 11002A |
| Test leads, dual banana plug to pencil probe and alligator clips, 60 in. long | 11003A |
| 50Ω Coaxial Cable, terminated on both ends with UG-88C/U BNC male connectors, 48 inches long | 10503A |



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►ERRATA (Cont'd)

Page 1-6, Table 1-3, Specifications:
Change heading (bold type) from "Opt. 010 over oscillator" to "Opt. 010 oven oscillator."
Delete all information under "Available Accessories" and insert "See Table 1-2".

Page 2-2, Paragraph 2-18:
Delete all of paragraph 2-18 except the first sentence and add the following:
"To mount the counter in a rack, it is necessary to order and install the rack flange kit listed in Table 1-2."

Page 3-8, Figure 3-8;

Page 3-12, Figure 3-10;

Page 3-19, Paragraph 3-52:

Delete all information under "WARNING" and substitute the following:

Refer to HIGH VOLTAGE warning on page vi, "SAFETY CONSIDERATIONS".

Page 3-24, Figure 3-17, Level Control Settings:
In the waveform shown for the A MARKER and the B MARKER, change the polarity of the pulses from positive-going to negative-going, 0V to -100 mV.

Page 4-3, Paragraph 4-16:
In paragraph 4-16 and Figure 4-3, change the dead time for Option 040 from "20 ns" to "40 ns".

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