Cape Cod

SO-X+06D
SO-X+10N
SO-Y
SO-Y

SG+45D
SG+66N

42°

Buzzards Bay

Nantucket Sound

Nantucket Island
LORAN-C STATION SO-Y

41°

GS-40D

72°

A
NEW APPROACH TO
PRECISION
TIME MEASUREMENTS

19:45:20

also in this issue:

SOUND-POWER MEASUREMENTS
TRANSISTOR MOUNTS FOR THE TRANSFER-FUNCTION BRIDGE
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39°

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About the Cover

The use of Loran-C radio transmissions for precise time measurement is discussed in this month's lead article. Shown against the background of a Loran-C chart are the Coast Guard's slave transmitting station at Nantucket, signals from that station as received at our Concord plant, and the new Digital Syncronometer® time comparator.

Loran-C station photo courtesy of U S Coast Guard. Background: Air/Surface Loran-C Navigation Chart VLC 30-22 U.S. Naval Oceanographic Office.

Figure 1. Type 1123-A Digital Syncronometer® time comparator, front (less bezel) and rear views.

A NEW APPROACH TO
PRECISION TIME MEASUREMENTS

The accurate, precise measurement and keeping of time are more than exercises for astronomers and guardians of the national standard. They are also matters of great concern to navigators, telemetry and communications specialists, data-system technologists, and many others who must establish time intervals and record local time with microsecond precision.

The modern method of precise local timekeeping involves (1) the use of standard time signals (such as those broadcast on WWV), (2) a standard-frequency oscillator, (3) some means of converting the oscillator's frequency into a time indication, and (4) a means for precisely comparing it against the broadcast time signals. The last two functions have traditionally been performed by such time comparators as General Radio's TYPE 1103,[1] a synchronous-motor clock driven by the output of a frequency standard, with the time of day displayed on a standard clock face. Inevitably limiting the resolution of such comparators have been the uncertainties inherent in any mechanical device, which have become progressively more troublesome with the increasing need for accurate resolution of short time intervals. Not even the most advanced mechanical com-

[1] R. W. Frank, F. D. Lewis, H. P. Stratemeyer, "The New GR Frequency Standard," *General Radio Experimenter*, Vol 35 No 4, April 1961.

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parator gives results repeatable to better than a microsecond, and to this disadvantage must be added the problems of wear and maintenance intrinsic in mechanical devices.

General Radio's new TYPE 1123-A Digital Syncronometer (Figure 1), a digital time comparator, avoids the problems of moving parts simply by avoiding the moving parts. There is no mechanical resolver, with its inherent inaccuracies in translating electrical angles to mechanical, no synchronous motor with its inherent starting delays. Instead, solid-state logic circuits, used in a new type of time comparator, are designed specifically to meet the stringent demands of modern time-standardizing and data-handling applications. Accuracy is limited only by the accuracy of the driving frequency standard and not by resolution. Time information is, in fact, given with a precision that challenges one's ability to extract it.

The TYPE 1123-A Digital Syncronometer ® time comparator is designed to be driven by the 100-kc output of the TYPE 1115-B Standard-Frequency Oscillator.[2] The time comparator's input circuits translate the oscillator's 100-kc sine-wave zero crossings into a 100-kc pulse train, which is applied to a series of five decade dividers to produce a one-pulse-per-second master tick. These pulses are accumulated in six digital counting circuits, and the to-

tals are displayed by in-line incandescent-lamp indicators as hours, minutes, and seconds. In addition, all 11 decades (five dividing and six counting and displaying) supply BCD electrical outputs at a rear-panel connector.

The one-second master tick can be easily compared with any other one-second signal on an oscilloscope. A set of seven thumb wheels on the front panel controls a precisely known delay between the master tick and a delayed pulse. To measure the time interval between master tick and a broadcast time signal, one simply brings the delayed pulse into coincidence with the broadcast signal and reads the time interval on the calibrated thumb wheels. Synchronizing the master tick with the time signals is then simply a matter of pushing a button on the comparator. Standard time can just as easily be transferred from one digital SYNCRONOMETER time comparator to another or to several others.

The new comparator can reproduce its time measurements with a precision approaching a nanosecond, and its master tick can be compared with suitable time signals with an accuracy of better than 100 nanoseconds. With appropriate terminal equipment for interrogation, it can provide time data in increments as small as 10 microseconds.

[2] H. P. Stratemeyer, "The Stability of Standard-Frequency Oscillators," *General Radio Experimenter*, Vol 38 No 6, June 1964.
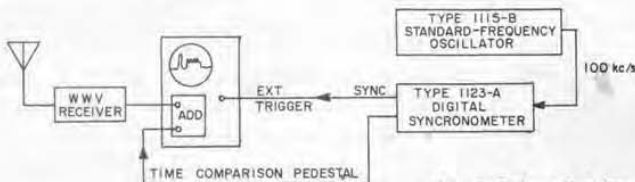

Figure 2. A typical time-comparison setup.

The low power consumption of the all-solid-state circuits makes it practical to operate the comparator from a small, self-contained, nickel-cadmium battery, which takes over automatically if the ac line fails and supplies power for at least 24 hours. Although the primary purpose of the built-in power pack is emergency operation, the fact that this instrument and the TYPE 1115-B Standard-Frequency Oscillator have built-in power supplies in effect makes both instruments and local time portable.

PHYSICAL CHARACTERISTICS

The digital SYNCRONOMETER time comparator is housed in a standard relay-rack-width cabinet, $5\frac{1}{4}$ inches high. Prominent on the front panel is the hours-minutes-seconds register, an in-line series of six digital indicators. At the right-hand side of the panel are the seven delay thumb-wheel controls used in time-comparison measurements and in the synchronization procedure. The only other normally exposed control is the dimmer adjustment for the time register. Controls that can affect clock time are normally kept out of harm's way by a protective bezel plate. These are the VISUAL REGISTER and PROGRAM controls and the INITIATE button. The latter ultimately controls all comparator operations (as well as the operations of any slave units), and, as a further precaution against accidental loss of accumulated time, both the VISUAL REGISTER and PROGRAM switches have OPERATE positions that lock out the INITIATE button; it takes very deliberate action by the operator to upset the time kept by the clock.

Standard frequency outputs in the form of pulse trains at 100 kc/s, 10
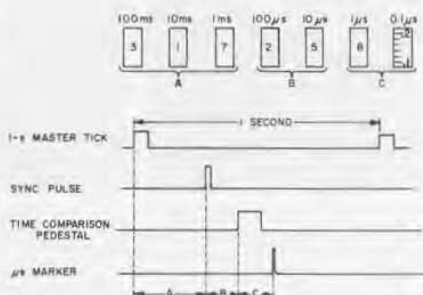
Figure 3. Timing diagram showing relations between panel thumb-wheel controls and the various timing pulses.

kc/s, 1 kc/s .... 0.1 c/s are available at rear-panel BNC connectors, as are various other pulse outputs to be described.

TIME COMPARISON

Once the comparator has been started and set in rough synchronism with a standard time signal, it is possible to determine the time interval between the comparator's master tick and the standard time signal. This interval is measured in terms of the time difference between the master tick and a pulse of 8-millisecond duration, whose occurrence the operator adjusts to coincide with the external reference. The comparator also supplies an oscilloscope-synchronizing pulse, slightly in advance of the 8-millisecond pulse, so that the latter can be moved away from the start of the oscilloscope sweep. Lagging the 8-millisecond pulse is another, very brief (0.2 microsecond), time-comparison marker pulse for super-precise measurements.

Figure 2 shows a typical time-comparison setup; the relations between the seven front-panel thumb-wheel controls and the various timing pulses are shown in Figure 3. When the leading

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edge of the 8-millisecond pedestal is aligned with the standard time signal, the exact interval between the comparator's master tick and the standard time signal is displayed on the five thumb-wheel controls designated A and B in Figure 3. The two controls designated C are calibrated to adjust and indicate the interval between the leading edge of the 8-millisecond pedestal and the 0.2-microsecond pulse. One of these controls is a step switch with 1-microsecond increments; the other is a continuous control covering the range from 0 to 1 microsecond and marked in 20-nanosecond increments.

Use of the 0.2-microsecond marker for a precise measurement of local time against a Loran C transmission is shown in Figure 4. Note the precision with which the 0.2-microsecond marker pulse of the comparator can be centered on the received Loran signal as displayed with a 1-μs/cm sweep rate. Time comparison to 0.1 microsecond is entirely practical, and a local precision oscillator can thus be rated within 1 part in 10^{10} in a measuring interval of only 17 minutes (1000 seconds)!

An important feature of this comparator is that, since all time comparisons are made by adjustment of delay pulses and independently of the clock's own master tick, several standard time sources can be intercompared without interference with the comparator's local time. For example, the theoretical interval between a WWV time tick and a Loran C burst can be calculated from the relative locations of the two transmitters and the receiver. This calculated interval can then be added to the WWV tick by means of the delay controls, and a specific Loran C burst can thus be identified and subsequently used to establish local time much more accurately than the WWV signal alone would permit.

SYNCHRONIZATION

Once a time comparison has been made, the instrument can easily be synchronized so that its master tick is time-coincident, within 10 microseconds, with the standard time signal. The operator simply backs off the delay dials 50 microseconds to compensate for the program time, sets the PROGRAM switch to SELF SYNC, and pushes the INITIATE button. Within the next second, the instrument falls into synchronism.

Figure 4. Time comparison of marker pulse and Loran-C 100-kc pulses. (Loran-C signals are those from Nantucket slave station, as received in Concord, Massachusetts.)

a. Sweep rate 1 ms/cm.
b. Sweep rate 100 μs/cm.
c. Sweep rate 20 μs/cm. (Note marker pulse on third cycle.)
d. Sweep rate 1 μs/cm, pulse centered.
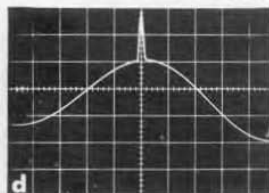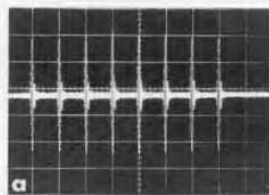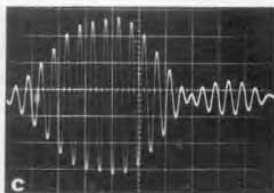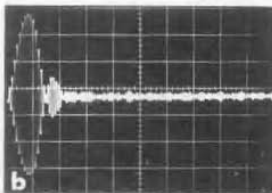
Figure 5. Time comparison of 8-ms pedestal and WWV time tick
(5 cycles at 1 kc/s).

a. Sweep rate 10 ms/cm.
b. Sweep rate 2 ms/cm.
c. Sweep rate 0.2 ms/cm.
d. Sweep rate 100 μs/cm.

Similarly, one or more slave comparators can be synchronized with a master unit, through wire lines. The PROGRAM switch on the slaves is set to ST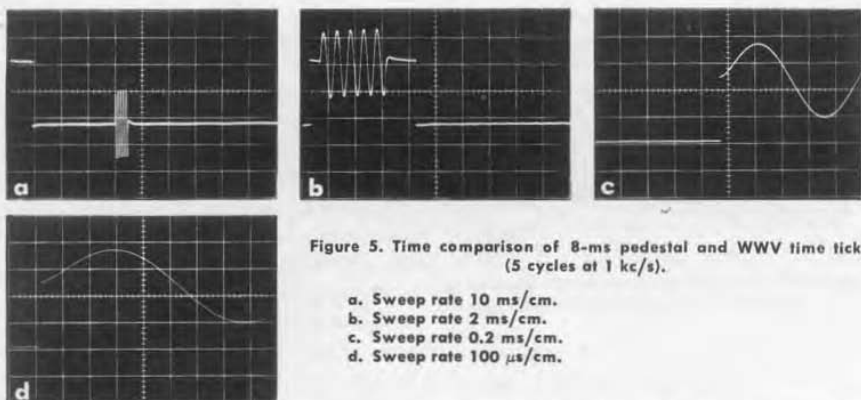OP, the master comparator is set to START SLAVE, and the INITIATE button on the master is pushed. The slaves then start at the precise fraction of a second set on the master's delay controls (subject to the propagation delay of the starting signal and the relative phase of the 100-kc standard-frequency inputs). If the master's delay controls are set to 00000, the slave's master ticks will coincide with those of the master; if the master's delay setting is 50000, the slaves will lag the master by 0.5 second.

CIRCUIT DESCRIPTION

It is most convenient to examine the circuits of the comparator in terms of its various programs, or modes of op-

eration, as indicated by the positions of the front-panel PROGRAM switch: START, STOP, SET, SELF SYNC, and START SLAVE.

Start Program

The purpose of the start program is to initiate the series of master ticks derived from the 100-kc standard-frequency input and to ensure that the instrument stops if the standard-frequency input changes frequency or misses even one cycle. Such fail-safe operation is, of course, necessary to prevent the comparator from making an error by ignoring even a momentary interruption or aberration of input.

In Figure 6, the 100-kc input is seen driving a Schmitt trigger circuit, which applies a series of pulses, 10 microseconds apart, to coincidence gate G1. By pushing the INITIATE button, the user applies an 11-microsecond start pulse
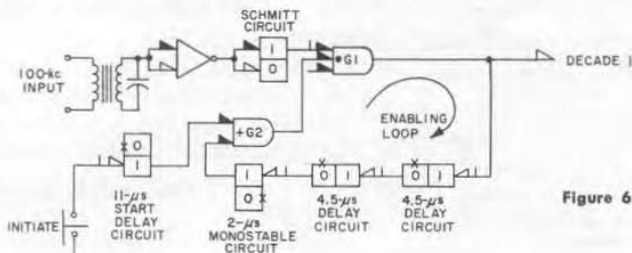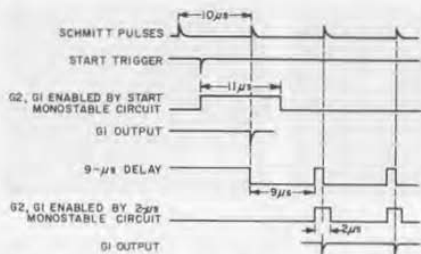

Figure 6. Start program.

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Figure 7. Timing diagram showing operation of the enabling loop and locking gate.

through OR gate G2 to coincidence gate G1. G1, thus enabled for 11 microseconds, passes at least one output pulse from the Schmitt circuit, and the comparator has been placed in operation. Each pulse is fed back through two 4.5-microsecond delay circuits to a 2-microsecond monostable multivibrator, which enables G1 for the passing of the next input pulse. If no pulse reaches G1 during the 2-microsecond period when it is enabled (9 to 11 microseconds after the passage of the last pulse), the enabling loop remains inactive, G1 is disabled, and the instrument is stopped to indicate failure of the 100-kc input. The sequence of operations for the enabling loop is shown in the timing diagram, Figure 7.

Stop Program

When the PROGRAM switch is set to STOP, and the INITIATE button is pushed, a 45-microsecond monostable multivibrator disables coincidence gate

G1, stopping the instrument, and sets the first five (dividing) decades to zero. The time displayed on the visual register is not affected. (See Figure 8.)

Set Program

The set program allows the visual register to be set to any time of day without affecting the normal operation of the five dividing decades. When one of the counting units (SECOND, 10 SEC, MIN, 10 MIN, HOUR, 10 HOUR) is selected by the VISUAL REGISTER switch, each push of the INITIATE button advances the corresponding register one digit. The first command pulse from the INITIATE switch also triggers a carry-inhibit circuit, which opens diode gates between the six counting units. Thus one register can be set independently of the next.

Addition or omission of 1-cycle counts is also possible while the instrument is running. With the VISUAL REGISTER switch at OPERATE and the PROGRAM switch at SET, the INITIATE button can be used to add counts to the seconds register. One-second counts are prevented from accumulating when the VISUAL REGISTER switch is set to its fully clockwise position.

Self-Sync Program

This program (see Figure 9) allows automatic synchronism of the comparator's master tick within 10 microseconds of an external reference (e.g., a
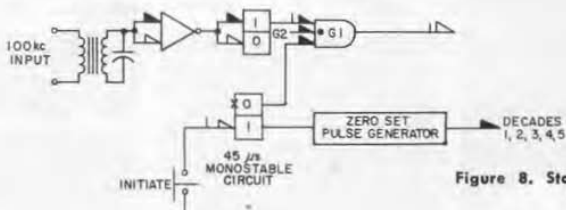
Figure 8. Stop program.
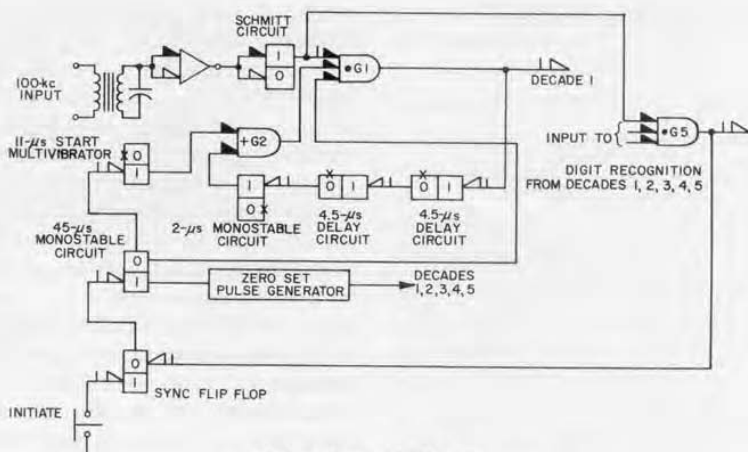
Figure 9. Self-sync program.

WWV time tick or a local, independent clock). The first step, as mentioned earlier, is to set the front-panel delay controls so that the internally generated 8-millisecond pedestal is brought into coincidence with the received time signals, as seen on an oscilloscope. Since the synchronizing operation will consume 50 microseconds, the delay-control setting is decreased by that amount. When the INITIATE button is pushed, the synchronizing flip-flop is set to the "1" state. The instrument keeps counting until the programmed delay setting is recognized by gate G5. G5 then sets the synchronizing flip-flop to "0" and triggers the 45-microsecond zero-set pulse generator. G1 is disabled, stopping the instrument, and the first five decades are set to zero. At the end of the 45 microseconds, a start pulse is automatically generated to restart the instrument on the next input pulse from the Schmitt circuit. As shown in the timing diagram (Figure 10), a total of 50 microseconds is lost during the entire synchronizing operation. Since the de-

lay-control settings were originally reduced by 50 microseconds, this time is accounted for. The internal master tick is now synchronized within 10 microseconds of the external standard. The time coincidence between the comparison pedestal and the external standard can then be observed with the delay controls set at zero.

Start-Slave Program

The start-slave program allows a second comparator to be started with a given time relationship to the master comparator. The start pulse is programmed by the time-delay setting of the master comparator. The slave can be set to lag the master by any amount

Figure 10. Timing diagram for the self-sync program.

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Figure 11. Start-slave program.

from 0 to 999.99 milliseconds. Once the desired delay is set on the master's delay controls, the master's INITIATE button is pushed once, setting the synchronizing f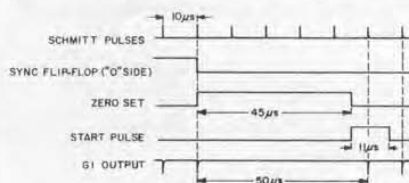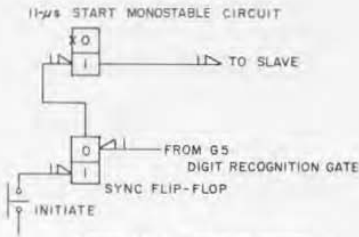lip-flop to "1" (see Figure 11). When the programmed delay setting is recognized by gate G5, the synchronizing flip-flop is reset to "0," generating a start pulse to the slave. The exact time relationship of the slave to the master is determined by the phase of the 100-kc input signals to the two instruments and by the length of the interconnecting cable.

Power Supply

The main power supply is a conventional transistor series-regulator circuit (see Figure 12). A built-in, explosion-proof, 16-volt nickel-cadmium battery of 4.5-ampere-hour capacity is connected through rectifier CR1 to the counting circuits at all times. A temperature-compensated charging circuit supplies a trickle current to the battery

so that it stays fully charged. Supply voltages are so set that the battery normally supplies no current to the counting circuits (CR1 is back-biased). If the ac line voltage fails or drops so that the regulator voltage goes below 17 volts, CR1 becomes forward-biased, and the battery supplies current to the counting circuits. The indicator lamps are disconnected from the battery supply by CR2 to eliminate their heavy current drain, but a front-panel spring-return switch allows momentary operation of the lamps.

An external 24- to 32-volt battery, connected to the comparator through a rear-panel connector, can be used to supply the regulator directly in the event of a prolonged line-voltage failure.

Hours Reset Circuit

The comparator's time indicators can be set to recycle to 0 at any integral number of hours from 1 to 99. The desired full-scale hours indication is set by means of two front-panel thumbwheel controls, which select a particular matrix line from the hours and 10's-of-hours decades (see Figure 13). When the preset number is recognized by gate G8, the two counting units are set to 0. The setting 24, for example, recycles the clock from 23:59:59 to 00:00:00 on the next 1-second count.
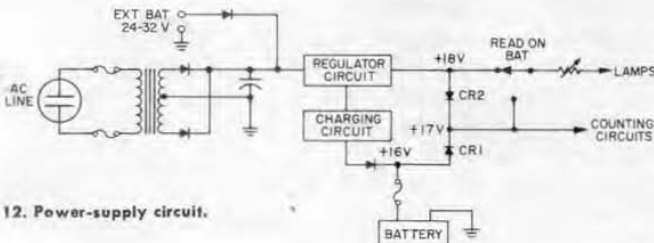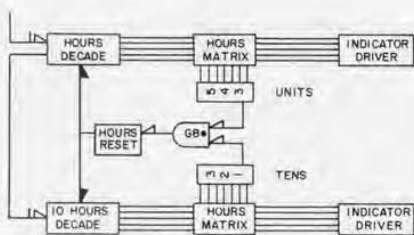

Figure 12. Power-supply circuit.

Figure 13. Hours-reset circuit.

0–10 Microsecond Delay Circuit

The 10-μs marker pulse is generated by an analog delay circuit. A negative-going ramp is initiated by the leading edge of the 8-millisecond comparison pedestal (see Figure 14). A Schmitt circuit, which generates the marker, triggers when the ramp decays to a preset voltage. The time delay between the start of the 8-millisecond pedestal and the transition of the Schmitt trigger depends on the slope of the ramp, which is in turn set by the front-panel 1-microsecond thumb wheel. This delay is quantized and set to the nearest exact multiple of 1 microsecond by combination with the 1-Mc input signal in gate G3. The output from G3 sets the flip-flop to 1 and initiates a second ramp, whose slope is continuously adjustable to produce an additional 0 to 1-microsecond delay. The 0.2-microsecond Schmitt trigger output is shaped with a monostable multivibrator and amplifier to produce a 10-volt, 0.2-microsecond pulse with rise and fall times of about 20 nanoseconds.

AUXILIARY TIME-STORAGE EQUIPMENT

No commercial equipment presently available can accept time readings as fast as the comparator can supply them. Required is a parallel-entry storage register with a capacity of 11 four-bit binary words. The register must accept and store the data from the clock in a time well under 5 microseconds. (The comparator contains full inhibit circuitry to prevent errors that could be caused by interrogation during time transfer.) We have developed such a storage register, capable of storing data in less than 1 microsecond, and can supply such equipment on special order.

APPLICATIONS

The Type 1123-A Digital Syncronometer time comparator is a general-purpose precision laboratory instrument for registering, measuring, and generating time. Driven by the Type 1115-B Standard-Frequency Oscillator, or other frequency standard with 100-kc output, it can be used:

(1) as a precise time-of-event source or accumulator of time in 10-microsecond increments up to 99 hours. (A modified comparator, supplied on special order, can accumulate decimal seconds up to a total of 999,999.) Thus decimal seconds from the start of an
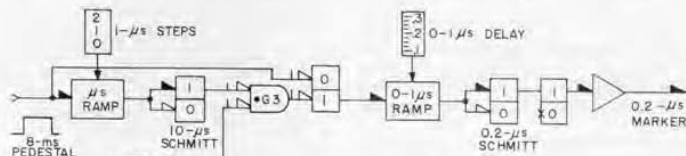

Figure 14. 0-10 μs delay circuit.

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event, in increments as small as 10 microseconds, can be logged in data-processing systems.

(2) as a source of precisely timed pulses to initiate experiments,

(3) as a precise, low-jitter source of timing pulses in decade sequence from 100 kc/s to 0.1 c/s,

(4) to transport precise time,

(5) to rate standard-frequency oscillators against transmitted time signals.

SUMMARY

The development of a solid-state time comparator is a significant step forward in the field of time-standard instrumentation. The TYPE 1123-A Digital Syncronometer time comparator is the most versatile instrument of its type, yet is the easiest to operate. Its low-power transistor circuits and built-in battery mean that one can literally carry reference time from one location to another. Its fail-safe regenerative circuits and absence of moving parts make it the most reliable comparator available. And its BCD-electrical, as well as visual, output ensures its usefulness with data-acquisition systems of today and tomorrow.

D. O. FISHER
R. W. FRANK

SPECIFICATIONS

Input: BNC connectors.
0.5 V at 100 kc/s (sinusoid or square wave).
0.5 V at 1 Mc/s (sinusoid or square wave).
Normally provided from TYPE 1115-B Standard-Frequency Oscillator (1 V into 50 Ω).

Outputs:
Time of Day: From all decades, parallel 1-2-4-2 BCD. 1-2-4-8 BCD available on special order.
Logical 0: Approx 0.5 V.
Logical 1: Approx +15 V (open circuit).
Logical Line Source Impedance: 100 kΩ.
Timing Pulses: 10 kc/s, 100, 10, 1, and 0.1 c/s are available at output fittings on rear. These are +15-V pulses with approx 100-Ω source impedance and a duty ratio of 0.2. In addition, a 100-kc pulse signal is available.
Oscilloscope Sync Pulse: Settable in 1-ms steps 0.000 to 0.999 s.
Positive pulse, 13 V, Z_a = 2.2 kΩ.
Duration, ≈7.5 μs.
Time-Comparison Pedestal: Follows oscilloscope sync by 000 to 990 μs (100- and 10-μs steps).
Positive pulse, 10 V from emitter follower.
Duration, ≈8 ms.
T_r = 0.5 μs, T_f = 0.5 μs.
0.2-μs Mark: 10-V positive pulse, 0.2-μs duration, with approximately 20-ns rise and fall times, and 100-Ω source impedance. This marker is variable in 1-μs steps and a continuous 0- to 1-μs range from 0 to 10 μs after the 8-ms pedestal.
1-s Master-Tick Output: Positive pulse from emitter follower.
Amplitude, 10 V. Duration, ≈7.5 ms. T_r = 2 μs, T_f = 2 μs.

Input Start Pulse: Logical 0 (0 V) to 1 (+15 V) holding for > 10 μs. May come from second clock or external system.
Output Start Pulse: 11 μs, 0 to +15 V, from emitter follower.
Inhibit Pulse Output: Logical 1 (+15 V) to 0 (0 V); lasting approx 9 to 11 time units at lower frequencies, established by setting internal links for desired inhibit rate (no print on carry).
Visual Indication: 6 dimmable digital indicators for h, m, s.
Delay Setting for Time Measurement: 6 digital thumbwheel switches and 1 continuous (0-1 μs) control calibrated in 20-ns increments.
Visual Register Setting: Direct access to all six visual decades, carries inhibited.
Clock Functions: All control and setting functions are operated by a single pushbutton and are normally locked out and covered.
1. Operate: All program controls locked out.
2. Start: Clock will be started by 11-μs start pulse from pushbutton or from external source (BNC connector on rear). Start pulse produced and fed from instrument.
3. Stop: Clock will be stopped and all counting decades from 100 kc/s to 1 c/s will be set to zero by pushbutton. Zero will hold until start command is received.
4. Set: Permits setting visual register. All-visual register carries interrupted; 100-kc to 1-cycle dividers not affected. Selected decade is advanced by 1 count for each push of the initiate pushbutton.
5. Self Sync: Permits synchronizing master tick to within 10 μs of a measured time in another time system, as WWV on UT-2.

6. Start-Slave: Permits setting a second clock from the first. After the actuate button is pushed, a start pulse will be produced when the count reaches the setting of the time-delay switches of the first clock.

Measurement Rate: Switch permits oscilloscope sync at 10-cycle rate rather than the standard one-cycle rate.

Power Required: 90 to 130 or 180 to 260 V, 50 to 60 c/s, 32 W approx. Self-contained, pressure-relief, nickel-cadmium battery for approx 24-hour off-line operation is supplied.

Accessories Supplied: Digital-output plug assembly, TYPE CAP-22 Power Cord, spare fuses.

Mounting: Rack-bench cabinet.

Dimensions: Bench model—width 19, height 6, depth 14½ inches (485 by 155 by 370 mm); rack model—panel 19 by 5¼ inches (485 by 135 mm), depth behind panel 12 inches (305 mm).

Net Weight: 30 lb (14 kg).

Shipping Weight: 40 lb (18.5 kg).

Type		Price
1123-AM	Digital Syncronometer, Bench Model	$2950.00
1123-AR	Digital Syncronometer, Rack Model	2950.00

A NEW
FREQUENCY STANDARD
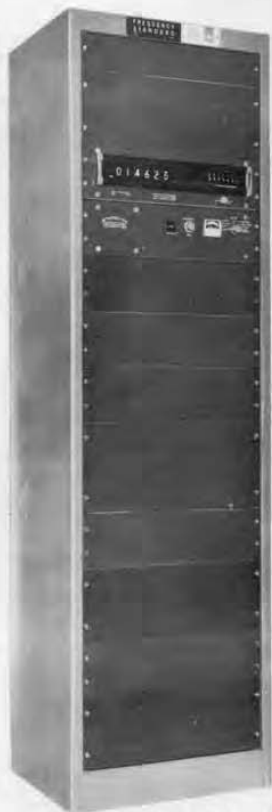
Type 1121-A

The new standard-frequency oscillator introduced several months ago [1] and the new digital SYNCRONOMETER® time comparator announced in this issue lead logically to a new General Radio frequency standard. It is called the TYPE 1121 Frequency and Time Standard, and it is available in any of four versions, depending on the output frequencies desired.

The TYPE 1121-A Frequency and Time Standard includes a TYPE 1115-B Standard-Frequency Oscillator and a TYPE 1123-A Digital Syncronometer time comparator, assembled in a relay rack and complete with all necessary interconnecting cables. The TYPE 1115-B Standard-Frequency Oscillator uses a 5-Mc fifth-overtone quartz crystal and supplies standard-frequency outputs at 5 Mc/s, 1 Mc/s, and 100 kc/s. The digital SYNCRONOMETER time comparator integrates the oscillator frequency to produce precise time-of-

[1] H. P. Stratemeyer, "The Stability of Standard-Frequency Oscillators," *General Radio Experimenter*, Vol 38 No 6, June 1964.

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day data, permits accurate comparison of the frequency standard with standard-time radio transmissions, and generates timing pulses at frequencies from 0.1 c/s to 100 kc/s in decade multiples.

In the Type 1121-AH model, Types 1112-A and 1112-B Standard-Frequency Multipliers are added to supply output frequencies of 10, 100, and 1000 Mc/s. The vhf and uhf signals are virtually free from submultiple output frequencies. The spectrum of the 5-Mc output of the crystal oscillator is un-

affected by the presence of the multipliers.

In the TYPE 1121-AL model, a TYPE 1114-A Frequency Divider is added to the TYPE 1121-A assembly to produce low-frequency sine waves of 10 and 1 kc/s, 400, 100, and 60 c/s, and 10-kc square waves.

The TYPE 1121-AHL 1000-Mc Frequency and Time Standard includes all the components of both the -AH and the -AL models, and its output frequencies extend from 60 c/s to 1 Gc/s.

SPECIFICATIONS

TYPE 1121-A
Components: TYPE 1115-B Standard-Frequency Oscillator, TYPE 1123-A Digital Syncronometer time comparator.
Output Frequencies: Sine waves at 5 and 1 Mc/s and 100 kc/s; timing pulses at 100, 10, 1 kc/s, 100, 10, 1, and 0.1 c/s.
Power Required: 40 W at 90 to 130 or 180 to 260 V, 40 to 2000 c/s, or 24 to 32 V dc. Internal nickel-cadmium batteries provide at least 24-hour emergency operation.
Net Weight: 170 lb (78 kg).
Shipping Weight: 350 lb (161 kg).

TYPE 1121-AH
Components: TYPE 1115-B Standard-Frequency Oscillator, TYPE 1123-A Digital Syncronometer time comparator, TYPE 1112-A Standard-Frequency Multiplier, TYPE 1112-B Standard-Frequency Multiplier.
Output Frequencies: Sine waves at 1000, 100, 10, 5, 1 Mc/s, 100 kc/s; timing pulses at 100, 10, 1 kc/s, 100, 10, 1, and 0.1 c/s.
Power Required: Frequency multipliers, 235 W max at 105 to 125 or 210 to 250 V, 50 to 60 c/s. Oscillator and comparator, 40 W at 90 to 130 or 180 to 260 V, 40 to 2000 c/s, or 24 to 32 V dc. Internal nickel-cadmium batteries provide at least 24-hour emergency operation for standard-frequency oscillator and time comparator.
Net Weight: 220 lb (102 kg).
Shipping Weight: 400 lb (184 kg).

TYPE 1121-AL
Components: TYPE 1115-B Standard-Frequency Oscillator, TYPE 1123-A Digital Syncronometer time comparator, TYPE 1114-A Frequency

Divider (less Types 1114-P1 and -P2 plug-ins), Types 1114-P6 and -P7 Plug-In Units.
Output Frequencies: Sine waves at 5, 1 Mc/s, 100, 10, 1 kc/s, 400, 100, 60 c/s. Timing pulses at 100, 10, 1 kc/s, 100, 10, 1, and 0.1 c/s.
Power Required: Oscillator and comparator, 40 W at 90 to 130 or 180 to 260 V, 40 to 2000 c/s, or 24 to 32 V dc; frequency divider, 7 W max at 105 to 125 or 210 to 250 V, 50 to 400 c/s. Internal nickel-cadmium batteries provide at least 24-hour emergency operation for oscillator and comparator.
Net Weight: 190 lb (87 kg).
Shipping Weight: 360 lb (160 kg).

TYPE 1121-AHL
Components: Type 1115-B Standard-Frequency Oscillator, Type 1123-A Digital Syncronometer time comparator, Type 1112-A Standard-Frequency Multiplier, TYPE 1112-B Standard-Frequency Multiplier, TYPE 1114-A Frequency Divider (less Types 1114-P1 and -P2 plug-ins), Types 1114-P6 and -P7 Plug-In Units.
Output Frequencies: Sine waves at 1000, 100, 10, 1 Mc/s, 100, 10, 1 kc/s, 400, 100, 60 c/s, and 10-kc square waves. Timing pulses at 100, 10, 1 kc/s, 100, 10, 1 and 0.1 c/s.
Power Required: Oscillator and comparator, 40 W at 90 to 130 or 180 to 260 V, 40 to 2000 c/s, or 24 to 32 V dc; frequency multipliers, 235 W max at 105 to 125 or 210 to 250 V, 50 to 60 c/s; frequency divider, 7 W max at 105 to 125 or 210 to 250 V, 50 to 400 c/s. Internal nickel-cadmium batteries provide at least 24-hour emergency operation for oscillator and comparator.
Net Weight: 230 lb (106 kg).
Shipping Weight: 410 lb (189 kg).

Type		Price
1121-A	Frequency and Time Standard	$5295.00
1121-AH	1000-Mc Frequency and Time Standard	8110.00
1121-AL	Frequency and Time Standard	6300.00
1121-AHL	1000-Mc Frequency and Time Standard	9115.00

COAXIAL MICROWAVE NEWS

PRECISION COAXIAL CONNECTOR STANDARDIZATION AND THE GR900 CONNECTOR

> The GR900 Precision Coaxial Connector is the only commercial connector that meets the IEEE Recommended Practice for 14-mm General Precision Coaxial Connectors.

At its meeting on November 12, 1964, the IEEE Standards Committee approved sections of a standards document on Recommended Practices for Precision Coaxial Connectors, which is of special importance to all those concerned with coaxial systems and measurements. The document was prepared by the Subcommittee on Precision Coaxial Connectors,[1] after this subcommittee had studied the problems of designing, fabricating, and measuring the performance of precision connectors and had evaluated a number of designs. No particular connector is selected as a standard, but the document does set forth certain design and performance specifications for a standard connector. The mechanical requirements ensure that any connector meeting the specifications will mate with any other of the same line size but do not specify the actual coupling mechanism.

Two line diameters are specified by the document: a 14-mm diameter for precision applications up to 9 Gc/s and a 7-mm diameter for use up to 18 Gc/s. The larger-diameter line has about twice the accuracy of the smaller line. For each diameter, two types of connector are described: (1) a General Precision Connector (GPC), which includes a dielectric support for the center conductor, and (2) a Laboratory Precision Connector (LPC), which does not.

The IEEE Standards Committee's approval was given only to those parts of the Subcommittee document having to do with general requirements and definitions, parameters to be specified, and detailed specifications for 7- and 14-mm general precision connectors. The 7-mm section was approved for trial use and is not in final form, since the Subcommittee has yet to determine through evaluations of samples whether the specifications can be met in a practical connector and has still to specify the design of the critical mating surfaces or coupling arrangements. The 14-mm section, however, is complete, since these decisions and evaluations have already been made. The specifications, as proposed by the Subcommittee, appear in the December, 1964 *IEEE Transactions on Instrumentation and Measurements.*

In 1959, General Radio began investigating possible designs for a precision coaxial connector. Our own development program led to the GR900 Precision Coaxial Connector, several thousand of which have been produced over the past two years. This connector

[1] Of the IEEE Committee on Electronic and High-Frequency Measurements, G-IM.

has been thoroughly evaluated by several independent laboratories cooperating with the Subcommittee on Precision Coaxial Connectors and has been found to meet the specifications for the 14-mm general precision connector. Ever since the formation of the original committee in 1960, our engineers have cooperated with that group and have

freely exchanged technical information on connector design problems and on improved measurement methods. General Radio's cooperation with the Subcommittee has extended to the waiving of patent and other proprietary rights to the basic dimensioning and design of the GR900 Connector.

HIGH-FREQUENCY TRANSISTOR MEASUREMENT STANDARD

Another standards committee, that of the EIA, recently agreed on a proposed JEDEC standard on high-frequency transistor Y and H parameters and sent the standard out to industry

for review. All transistor measurements specified can be performed by GR's TYPE 1607-A Transfer-Function and Immittance Bridge and the new transistor mounts described below.

MOUNTS FOR TRANSISTOR MEASUREMENTS WITH THE TRANSFER-FUNCTION BRIDGE

Accurate measurements of high-frequency transistors rapidly became commonplace after the introduction, in 1959,[1] of commercially available transistor mounts for use with the TYPE 1607-A Transfer-Function and Immittance Bridge. These mounts, designed primarily for development applications,

[1] W. R. Thurston, R. A. Soderman, "The TYPE 1607-A Transfer-Function and Immittance Bridge," *General Radio Experimenter*, Vol 33 No 5, May 1959.

Figure 1. One of the new transistor mounts, with transistor fully seated in socket.

left some problems for the production tester, who had either to clip the leads of his transistors or to leave most of the leads exposed and in circuit.

A new series of transistor mounts now permits the insertion and accurate measurement of transistors with leads up to two inches long. The leads are hidden from the field, the connection point is just below the transistor header, and parasitic lead inductance and capacitance are just about eliminated. In the new mounts, the transistor leads are inserted into hollow inner conductors of tiny coaxial lines. A short section of each inner conductor, near the top, is compressed to a narrow diameter to make a stable electrical contact with the transistor lead. An incidental feature, useful to the circuit designer, is that the transistor can be connected to the mount with just the right amount of lead left in circuit to simulate its

eventual connection. The transistor can thus be measured to include the parasitic lead effects that will be present in the circuit. Four such mounts are now available: two for transistors with a 0.2-inch-diameter pin circle (TO-5 packages) and two for the 0.1-inch pin circle (TO-18 packages). A grounded-base and a grounded-emitter mount are available for each size. (The grounded-emitter mounts can also be used for the grounded-collector configuration; the transistor is simply oriented differently upon insertion.) Four-hole sockets in all mounts include a connection for dc or metallic ground.

INTERNAL CONFIGURATION

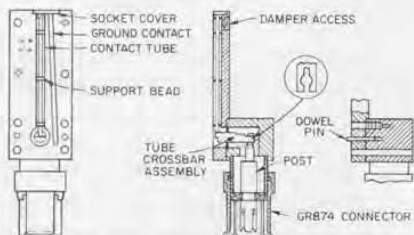The internal configuration of the new mounts is shown in Figure 2. Two jogs

Figure 2. Cross-section drawings showing internal configuration of new mounts.

in the internal coaxial line are used to make the substantial transition from GR874 Connector to the small transistor lead spacing. A more obvious design would have employed tilted conical tapers converging to the small socket size. The step transition was chosen because it allows the transistor leads to go straight into the socket, it is easier to control in manufacture, and it is not at all difficult to compensate locally for the discontinuities existing at the 90°
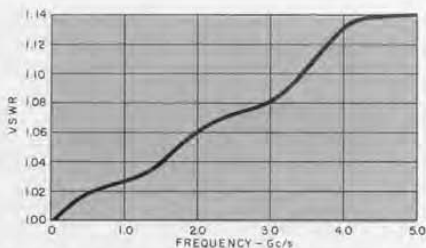
Figure 3. Typical VSWR characteristics of new transistor mounts.

jogs. How well this has been done is shown by the mounts' vswr characteristics (Figure 3).

The small coaxial lines inside the mounts consist of square outer conductors and round inner conductors (see Figure 4). This configuration was necessary to achieve the close spacing of the coaxial line pair, corresponding to the transistor lead spacing. In the 0.2-inch pin-circle mounts, the coaxial-line dimensions are 0.132 inch (square) and 0.062 inch (diameter of the round inner conductor). In the 0.1-inch pin-circle mounts, these dimensions are 0.068 and 0.032 inch, respectively.

The use of such small coaxial lines in the mounts offers several advantages. Discontinuities between coaxial lines and transistor leads are minimized; a colinear relation exists between lines and leads; and the damper (a 50-ohm dc-block resistor assembly used to suppress transistor oscillation) can be located closer to the reference plane (ac-
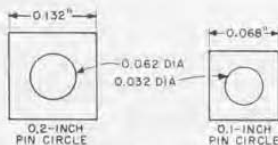
Figure 4. Cross section of internal coaxial leads.

tual distance is 3/32 inch) to reduce its effect on the measurement. All these factors add up to greatly increased accuracy of transistor measurements.

The reference plane of the new mounts (the point on the transistor lead to which the measured values apply) is 0.025 inch below the top of the mount socket, or 0.025 inch below the header when the transistor is firmly seated in the mount. The electrical length from the reference plane to the short-circuit plane of a TYPE 874-WN Short-Circuit Termination is 9.5 cm.

The elements used to set up the reference plane on the older mounts cannot be used for this purpose with the new mounts. A new set based on the 9.5-cm length is available as the TYPE 1607-P40 Termination Kit.

The new mounts will be useful to the circuit designer, the transistor developer, and the production-line tester. A procedure has been devised for the rapid production-line measurement of β, and some companies guarantee Y parameters measured with this equipment.

One especially important transistor-design application involves the use of Linvill charts.[2] Transistor parameters are measured, and the charts are then used to determine circuit parameters. Examples of this and other procedures are given in several papers.[3, 4, 5]

LEAD ACCOMMODATION

The mounts accept transistor leads as long as two inches. The TYPES 1607-

P41 and -P42 (0.2-inch pin circle) mounts can accommodate leads with diameters from 0.014 to 0.032 inch. The TYPES 1607-P43 and -P44 (0.1-inch pin circle) mounts accept leads with diameters from 0.014 to 0.021 inch.

The mounts will not accept very crooked leads, and leads should be straightened and made perpendicular to the header to ensure accurate measurement.

SOCKET ACCESSIBILITY AND FEATURES

On each mount, the socket is out in the open and readily accessible. A marker indicates the proper orientation of the transistor tab. Four tapped holes surround the socket to permit attachment of a heat sink. Socket contacts are heat-treated beryllium copper and are quite rugged.

The socket itself is made of polycarbonate, an extremely tough plastic with a dielectric constant of 2.73.

APPLICATIONS

The mounts can be used with the TYPE 1607-A Transfer-Function and Immittance Bridge to measure all immittance and hybrid transistor parameters directly, in the frequency range from 25 Mc/s to 1.5 Gc/s. They can also be used with a slotted line to measure driving-point parameters up to about 5 Gc/s.

NOTE: The older mounts (TYPES 1607-P101, -P102, -P111, -P401) will continue to be available and are recommended for those applications that do not require the long-lead capability or the four-lead socket.

—J. ZORZY

[2] Linvill and Gibson, *Transistors and Active Circuits* McGraw-Hill, 1961.
[3] V. Gelnovatch and G. E. Hambleton, "1 Gc Transistor Amplifier Stage Using Linvill Technique," *Proceedings of the IEEE*, Vol 52 No 10, p 1262.
[4] P. E. Kolk, "Design of Three UHF Transistor Circuits," *Micro Waves*, November 1964, p 32-37.
[5] G. E. Hambleton and V. Gelnovatch, "L-Band and Germanium Mesa Transistors," *Microwave Journal*, Vol. 8 No 1, January 1965, p 42-46, 67-68.

SPECIFICATIONS

	Types 1607-P41, -P42	Types 1607-P43, -P44
Transistor Packages Accepted:	TO-5, 9, 11, 12, 16, 26, 31, 33, 37, 38, 39, 43; MD-14; MM-4, 8; MT-13, 20, 28,37; RO-2, 3, 4, 5, 10, 24, 30, 33, 34, 46, 49, 50, 61, 62, 79, etc.	TO-18 28, 52, 54; MT-30, 38; RO-44; 48, 51, 64, 65, 66, 70, 73, 78; U-3; X-8, etc.
Characteristic Impedance (of coaxial lines):	50 Ω ± 0.8%	50 Ω ± 1.6%
Pin-Circle Diameter:	0.2 inch	0.1 inch
Range of Transistor Lead Diameters:	0.014 to 0.032 inch	0.014 to 0.021 inch
Maximum Transistor Lead Length:	2 inches	
Frequency Range:	dc to 5 Gc/s	
Accessory Supplied:	One Type 1607-P30 Damper (to prevent oscillation)	
Accessory Required:	Type 1607-P40 Termination Kit	
Net Weight:	Mount, approximately 12 oz (0.4 g); Termination Kit, approximately 14.5 oz (0.5 g)	

Type		Price
1607-P41	Transistor Mount (0.2-in pin circle, grounded base)	$115.00
1607-P42	Transistor Mount (0.2-in pin circle, grounded emitter/collector)	115.00
1607-P43	Transistor Mount (0.1-in pin circle, grounded base)	115.00
1607-P44	Transistor Mount (0.1-in pin circle, grounded emitter/collector)	115.00
1607-P40	Termination Kit	42.50

SOUND-POWER MEASUREMENTS
ABOVE A REFLECTING SURFACE

A preferred method of rating the noise output of a device is to determine the sound power radiated from it.[1] General procedures for measuring sound power are specified in an American standard (S1.2–1962, American Standard Method for the Physical Measurement of Sound), and some specialized test codes are based on that standard.

One basic test procedure requires suspending the noisy device in the middle of an anechoic chamber. Twenty microphones are placed at points uniformly distributed on a hypothetical measurement sphere surrounding the source. The sound-pressure level at each of these points is then measured, and the radiated sound power is calculated from the results of these measurements.

If the device being measured is large and heavy, suspending it in a chamber may be impractical. It is often easier and more sensible to place it on a large concrete foundation, as it might be mounted in actual use; any surrounding walls are made anechoic. Or the device may be placed on a large paved area in the open. The flat mounting surface then becomes a reflecting plane for the sound, and the measurement positions are distributed on a hypothetical hemisphere above the plane and surrounding the device. The 12 microphone positions usually chosen for these measurements have not been as satisfactory as those for the complete sphere, because four of the points are in the reflecting plane. (P. K. Baade, "Sound Radiation of Air-Conditioning Equipment; Measurement in the Free-Field Above a Reflecting Plane," *Technical papers on sound*

[1] For a general discussion of sound-power measurements and a list of references, see A. P. G. Peterson and E. E. Gross, Jr., *Handbook of Noise Measurement*, Chapter 7, General Radio Company, West Concord, Massachusetts, 1963.

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$(0.127, 0.934, 0.333)$

$(-0.333, 0.577, 0.745)$ $(0.745, 0.577, 0.333)$

$(-0.872, 0.357, 0.333)$

$(0, 0, 1)$ $(0.667, 0, 0.745)$

$(-0.872, -0.357, 0.333)$

$(-0.333, -0.577, 0.745)$ $(0.745, -0.577, 0.333)$
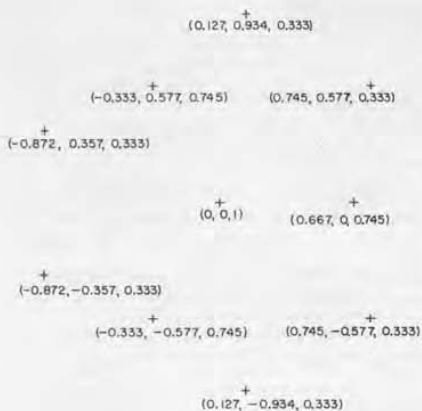
$(0.127, -0.934, 0.333)$

Figure 1. Plan view of 10 points distributed on a hemisphere of unit radius. Coordinates are given in terms of distances from center along three mutually perpendicular axes (X, Y, Z).

measurement, presented ASHRAE 71st annual meeting, Cleveland 1964.)

Another, related set of measurement points can be used to avoid making measurements in the reflecting plane. This new set, shown in Figure 1, is in effect the earlier set rotated 20.9° about an axis in the reflecting plane passing through the source. This set has 10 points, and, although the distribution is not strictly uniform, the deviations from uniformity are so small that equal weight can be given to all the points.

The sound power is then computed from the measured values of sound-pressure level by the equations given in the standard (ASA S1.2–1962). Thus:

$$L_W = \overline{L}_P + 20 \log_{10} r - 2.5$$

where L_W = sound-power level in decibels referred to 10^{-12} watt,

$\overline{L}_P$ = mean-square sound-pressure level over the test hemisphere in decibels referred to 0.0002 microbar,

r = radius of the test hemisphere in feet.

(If r is in meters, the formula is

$$L_W = \overline{L}_P + 20 \log_{10} r + 7.8.)$$

$\overline{L}_P$ can be calculated from the 10 sound-pressure-level measurements in the following way. Convert each decibel level to an equivalent power ratio by means of a decibel conversion table (such as that given in the General Radio *Handbook of Noise Measurement*). Add the 10 power ratios, divide by 10, and reconvert to a decibel value. The result is $\overline{L}_P$.

This new set of measurement points avoids the error that can occur with a nondirectional pattern for the 12-point system, but, if the source is highly directional, any such set of relatively few points can give serious errors. The first time any new device is measured, some exploration of the field is desirable in order to check its directivity pattern. If it is highly directional, more detailed exploration of the field will be necessary.

—A. P. G. PETERSON

General Radio Company

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