the GENERAL RADIO Experimenter

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Measuring Impact Noise

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COVER

Measuring typewriter noise with the General Radio Impact Noise Analyzer. See article on page 10.

NEW STANDARD FREQUENCY MULTIPLIERS

The TYPE 1112 Standard Frequency Multipliers provide sine-wave signals of 1, 10, 100, and 1000 megacycles when driven from a 100-kilocycle source. Thus they greatly extend the useful range of conventional crystal-controlled frequency standards, such as the General Radio TYPE 1100-A, and facilitate accurate measurement of microwave frequencies. These multipliers are characterized by low noise and by almost complete freedom from submultiple-frequency spurious signals. In addition, the phase stability of the output signal at each desired carrier frequency is maintained at a high value instead of being rapidly degraded as it may be in some conventional multiplier circuits.

The multiplier chain consists of two units, the first providing 20 milliwatts at 1, 10, and 100 megacycles from three phase-locked quartz-crystal oscillators; the second, 50 milliwatts at 1000 megacycles from a phase-locked klystron oscillator. The input to the first unit, TYPE 1112-A, is normally 100 kilocycles, but alternatively, 1, 2.5, or 5 megacycles[1] can be used. The second unit, TYPE 1112-B, is driven from the 100-megacycle output of the first unit. The input frequency can vary a few parts in 10^6 from the nominal value without loss of control. The multiplier stages can be manually detuned on either side of the nominal standard frequency by an additional few parts per million if desired, provided that the operation of the multiplier is carefully monitored to prevent improper operation. Figures 1 and 2 are panel views of the two units.

Principle of Operation

The underlying principle on which the phase-stability and noise-reduction properties of these multipliers are based is the use of a narrow-band filter to select only the desired output harmonic at each output frequency. The filters used at the three lowest frequencies are quartz crystals since they afford the highest possible Q, and hence narrowest bandwidth, in this frequency range. In order to maintain these crystal filters at the correct resonant frequency to pass the desired harmonic, each crystal is incorporated in an oscillator circuit whose frequency is phase locked to the desired harmonic frequency by an automatic-phase-control loop.

[1] When 2.5 Mc or 5-Mc input is used, the 1-Mc output cannot be used.

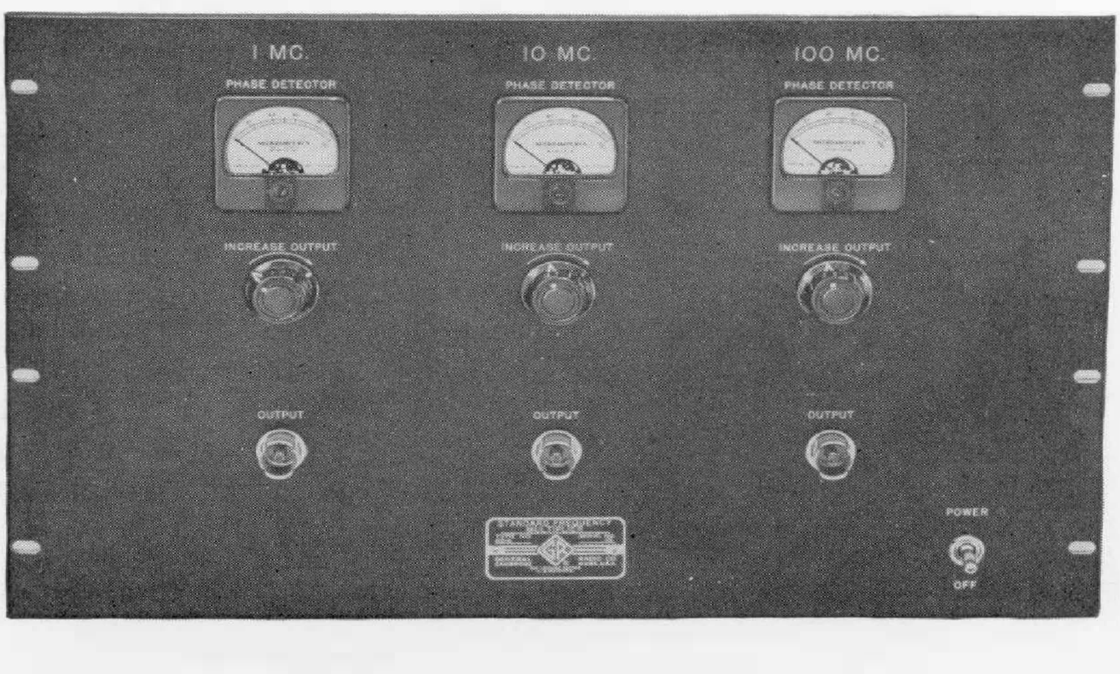


Figure 1. Panel view of Type 1112-A Standard Frequency Multiplier.

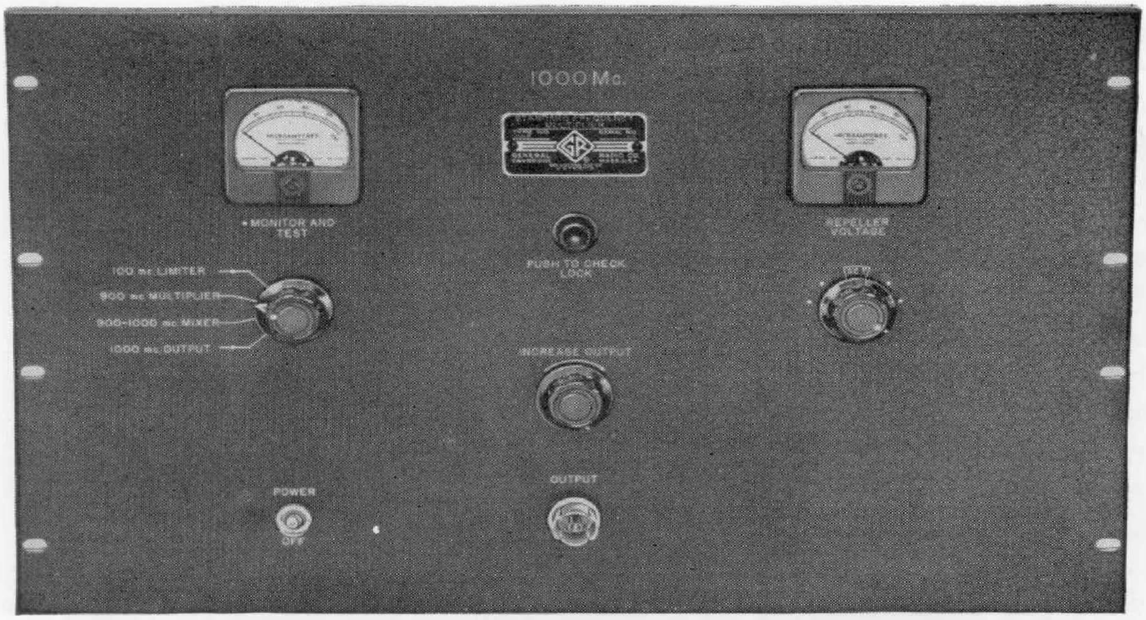


Figure 2. Panel view of Type 1112-B Standard Frequency Multiplier.

At the 1000-Mc output frequency, a phase-locked klystron oscillator is used as a selective filter to eliminate unwanted harmonics of the control frequency, thus operating in much the same manner as the locked crystal oscillators at lower frequencies. Since, however, the Q of the klystron resonator is not extraordinarily high, the phase modulation noise inherent in klystrons is reduced by means of negative feedback. The automatic-phase-control loop for the 1000-Mc klystron feeds back phase noise over a wide frequency band to reduce phase instability, the reference standard in this case being taken as the multiplied harmonic of the crystal-controlled 100-Mc driving signal.

Block Diagrams of Multiplier Units

The operation of the multiplier chain units can be understood easily with the aid of the block diagrams of Figure 3 (Type 1112-A) and Figure 4 (Type 1112-B).

The Type 1112-A Standard Frequency Multiplier receives a driving signal from the 100-kc frequency standard and multiplies it to 1000 kc. The signal from the 1000-kc crystal oscillator is then compared with the 1000-kc multiplied signal in a tuned, balanced, phase detector. The output signal from the phase detector is a d-c control voltage, which is applied to the grid of a reactance tube connected to the crystal-oscillator circuit. When the crystal-oscillator frequency is adjusted close to the frequency of the 1-Mc harmonic of the standard frequency, the phase-detector signal drives the reactance tube to the proper value of reactance to synchronize the crystal frequency exactly to that of the standard-frequency harmonic.

A small residual phase error remains, but, as long as the crystal-oscillator frequency is within the lock-in range of the system, the crystal oscillator stays locked directly at the harmonic frequency of the standard. The phase error provides the controlling voltage which holds the crystal oscillator in lock, or, putting it in different terms, the servo loop is closed with a small static error. If the crystal tends to drift, the phase error changes, and the change in the controlling voltage readjusts the reactance tube to hold the phase error to a minimum. Since the crystal has a high Q, the instantaneous phase stability of the crystal oscillator is high, and the locked oscillator then has good short-term stability, while its long-term stability is identical with that of the frequency standard used as the driving source.

If the servo circuit, including the reactance tube, phase detector, and reference harmonic generator, introduces noise into the reactance-tube grid circuit, frequency- or phase-modulation noise can be generated in the crystal-oscillator signal. The bandwidth of the feedback signal is kept narrow to minimize this noise. Thus a clean, crystal-controlled signal is available at the exact harmonic frequency desired.

In Figure 3, the functional diagram of the 10-Mc and 100-Mc stages is essentially identical with that of the 1-Mc stage. There are only minor differences in the circuits to take care of the different operating conditions at the different frequencies. A balanced phase detector is used at 10 Mc, but an unbalanced phase detector is used at 100 Mc to simplify the circuit. The 100-Mc crystal-oscillator circuit uses a fifth-overtone-mode crystal, and requires circuit refinements to insure stable operation at the fifth overtone.

The Type 1112-B Standard Frequency Multiplier provides output at 1000 Mc from a locked klystron oscillator. In

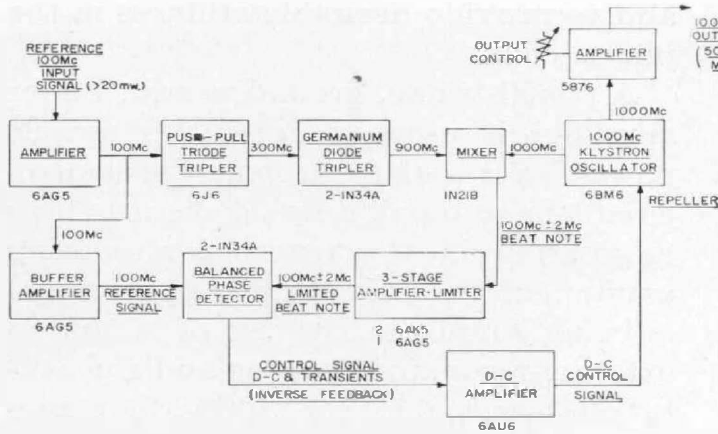


Figure 4. Block diagram of Type 1112-B Standard Frequency Multiplier, 100 to 1000 Mc.

order to prevent unnecessary conversion of amplitude-modulation noise to frequency modulation, several departures from the straightforward arrangement of the lower frequency stages are incorporated.

The frequency multiplication is obtained by multiplying 3 x 3 and adding 1 in order to obtain 10 times the input frequency. This circuit arrangement permits the use of small receiving-type vacuum tubes up to the 1000-Mc stages and makes possible the introduction of a limiter to insure a constant drive level for the phase detector.

The reflex klystron has a built-in "reactance tube" in its repeller, which allows the operating frequency and phase to be adjusted by variation of the repeller voltage. A d-c amplifier is incorporated in the repeller circuit to isolate the phase detector from the repeller

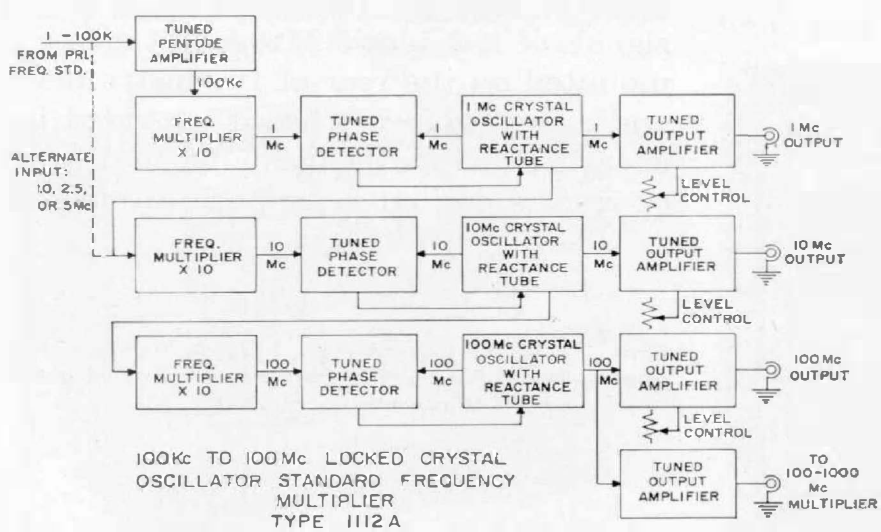


Figure 3. Block diagram of Type 1112-A Standard Frequency Multiplier, 100 kc to 100 Mc.

and to provide desirable stiffness in the phase lock.

A pencil-triode, grounded-grid, buffer amplifier is used to raise the output power level and to protect the control circuit from outside signal disturbances originating in the external measuring equipment to which the output signal is being supplied. The use of a plug-in external-resonator klystron and a pencil-tube amplifier in the 1000-Mc stages keeps tube replacement cost down. D-C heater power is supplied by a rectifier to the klystron to reduce hum modulation, and regulated plate supplies are used throughout.

Performance

Output power from each of the amplifiers at 1, 10, and 100 Mc is a maximum of 20 mw into a 50-ohm load. At 1000 Mc a maximum of 50 mw is available into 50 ohms.

The spurious signals at harmonics of the lower-frequency control signals are all at least 100 db below the desired output signal, except for higher harmonics of the desired signal. This means that a signal at 1000 Mc, for example, is not accompanied by a family of 100-kc or 1-Mc sidebands, unless they are specifically added by external mixing. For many measurements, such as marker generation applications, this feature alone is a great time saver and sometimes makes the difference between a practical measurement setup and an impractical one. The power levels directly available are adequate for a large percentage of measurement applications. The phase jitter, or phase-modulation noise, is low, being equivalent to that of a free-running crystal oscillator at 1, 10, and 100 Mc. The output signal at 1000 Mc appears to have the same stability as the crystal-controlled harmonic of the 100-Mc control signal supplied at the input connection. The amplitude modulation of the output signals is likewise low, as a result of the electronically regulated power supplies and the use of high-Q tuned circuits for the oscillator stages.

Design Features

The Type 1112-A Standard Frequency Multiplier consists of three sections, each of which receives a driving frequency and emits an output signal at a harmonic of this input frequency. A rear view of this instrument, Figure 5, shows the manner in which the circuits are constructed. The three multiplier sections are arranged in three horizontal rows of shielded compartments. The top row receives the input signal at 100 kc and supplies an output signal at 1000 kc. The center row gives 10-Mc output, and the bottom row 100 Mc. The input connection is normally attached to the input amplifier in the top row, at the upper right-hand corner, but may be moved to the input amplifier of the second row at the left side for operation with input signals of 1, 2.5, or 5 Mc. A test meter is mounted on the rear of the instrument, and a series of switches is provided for energizing either the harmonic multiplier or crystal oscillator, or both at once, in

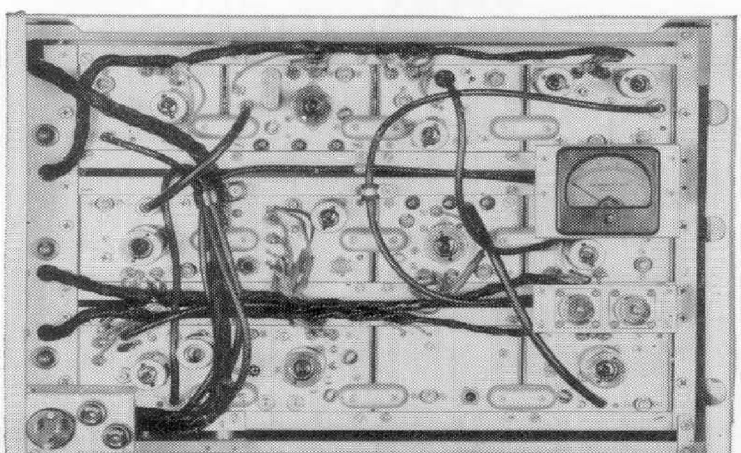


Figure 5. Rear view of Type 1112-A Standard Frequency Multiplier showing arrangement of stages in three horizontal rows.

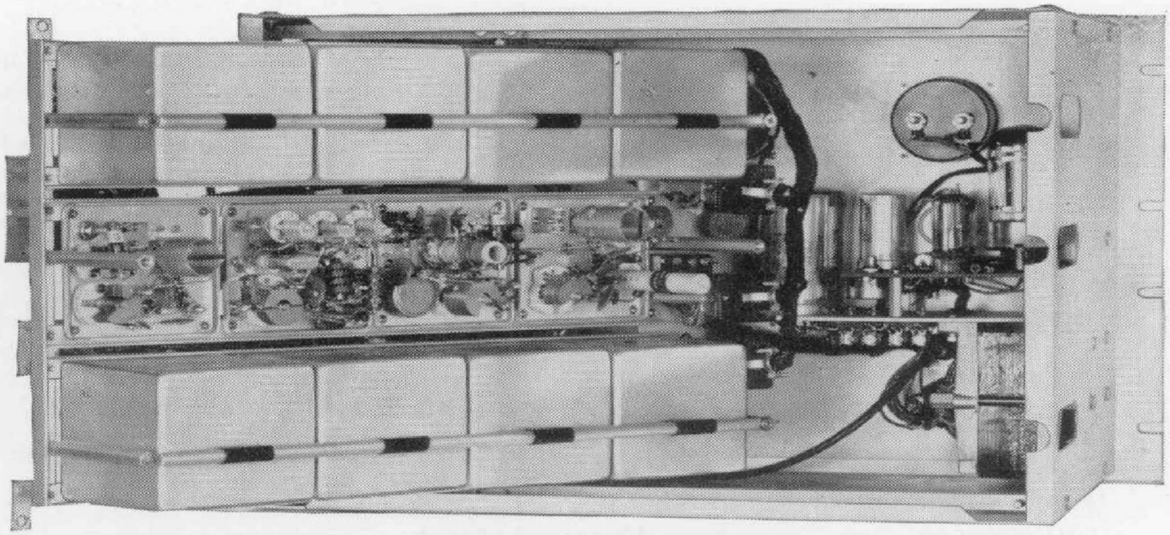
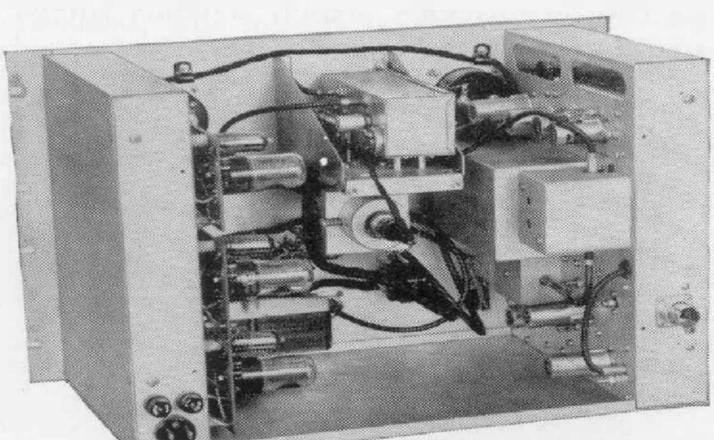


Figure 6. View of Type 1112-A Standard Frequency Multiplier with chassis assembly swung open for maintenance, covers removed from 1 to 10-Mc multiplier stages.

each row. These switches are visible at the left side of the rear view. The entire assembly swings out on hinges to allow access to the components in each compartment (Figure 6). The meters on the front panel are permanently connected in one side of the balanced phase-detector circuits for monitoring operating level and for indicating loss of lock.

The Type 1112-B Standard Frequency Multiplier is constructed with vertical chassis mounting of the power supply components and control circuit elements, the klystron and associated buffer amplifier being mounted in a removable subassembly or "r-f head." A rear view of this instrument, with the shielding partially removed, is shown in Figure 7. The r-f head in the center of the unit is removable to facilitate replacement of the r-f amplifier tube and to allow easy replacement of other tubes in the side-mounted chassis assemblies. A view of the r-f head, with the cover plate of the amplifier removed, shows the grounded grid amplifier using a pencil triode (Figure 8). This view also shows the detuning "button" for introducing a small deviation in the frequency of the klystron resonator to check for locking of the oscillator. It is also possible to mount this r-f head assembly on an external "storage" resonator to improve the effective Q of the klystron resonator, if such an application is ever considered necessary.

Figure 7. Rear view of Type 1112-B Standard Frequency Multiplier showing vertical chassis construction and r-f head (center).



Applications

Two separate and distinct applications have been kept in mind during the development of this equipment. The first, and most obvious, is the generation of stable, low-noise, microwave, standard frequencies free from unwanted sideband frequencies, which are often present in multiplier chains of more conventional design. However, in order to generate the desired marker frequencies or microwave standard frequencies for various measurement purposes, it is sometimes necessary to mix or add signals of different frequencies.

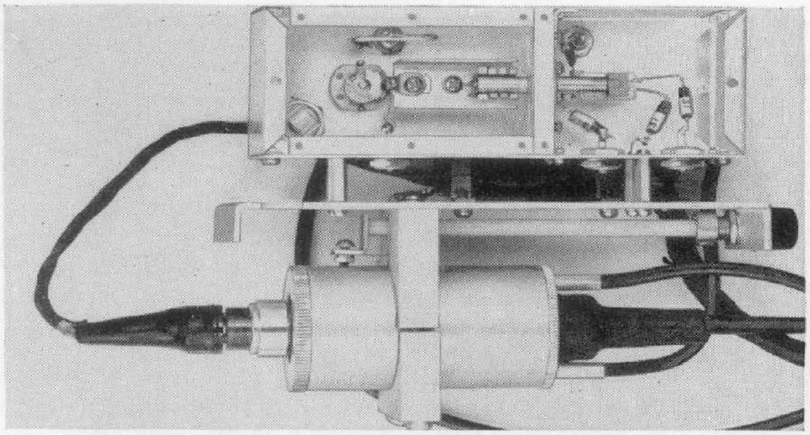


Figure 8. R-F head of Type 1112-B Standard Frequency Multiplier showing klystron installed in resonator (below) and grounded-grid 1000-Mc amplifier with cover removed.

The output circuits of the 1-, 10-, and 100-Mc stages of the TYPE 1112-A Standard Frequency Multiplier contain coupling networks that allow all three of these circuits to be connected in parallel without short circuiting each other. This arrangement is indicated in Figure 9, which also indicates a possible method of adding the 1000-Mc signal from the TYPE 1112-B Standard Frequency Multiplier. Another, and perhaps better, method of adding the 1000-Mc signal is indicated in Figure 10. In this arrangement, the signal from the low-frequency unit is added to that from the high-frequency unit in a tee, the branches being isolated by mismatching. A line stretcher in each branch allows adjustment of the mismatch for maximum isolation. By use of these paralleling schemes, it is possible to generate a marker frequency or harmonic series of marker frequencies at will in the microwave system. For some applications, additional power will be desirable, but for many uses the output of the multipliers will be adequate directly.

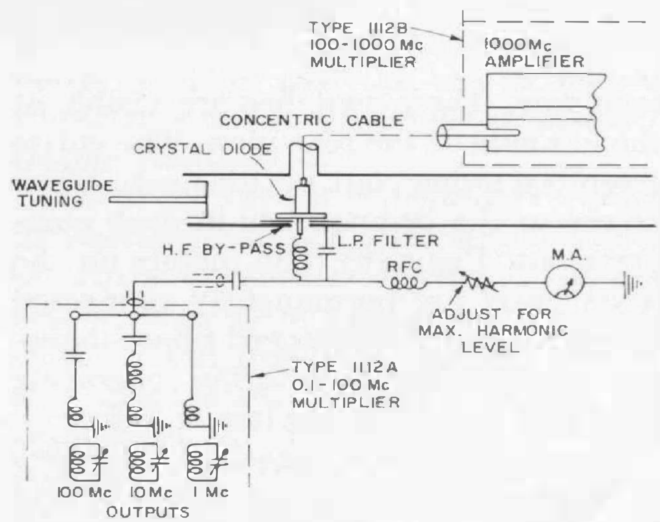


Figure 9. Schematic diagram showing parallel connection of 1, 10, and 100-Mc output circuits for application to generation of microwave harmonics. The 100-Mc signal is fed in separately.

The second application is in the intercomparison of standard-frequency oscillators for stability measurements. For example, a pair of 100-kc oscillators may be compared at 100 Mc, the frequency variations between them being then multiplied by 1000. A frequency difference of one part in 10^8, for instance, would appear as a one-cycle difference at 100 megacycles, which is easily measurable.

— FRANK D. LEWIS

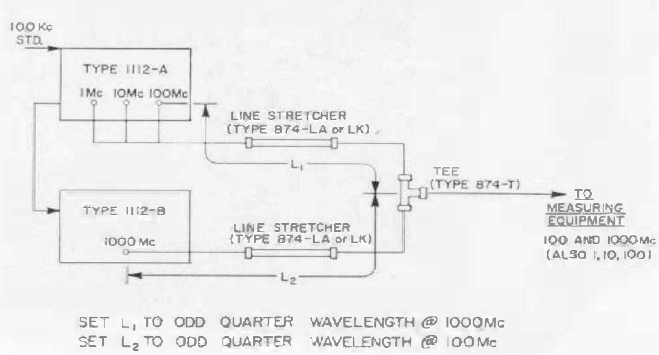


Figure 10. Arrangement for paralleling output signals of Type 1112-A and Type 1112-B Standard Frequency Multipliers using coaxial-line adding network.

SPECIFICATIONS

TYPE 1112-A STANDARD FREQUENCY MULTIPLIER

Input: 1 volt, 100-kc sine wave from standard-frequency oscillator. Can also be driven at input frequencies of 1, 2.5, and 5 Mc. Will run free with no input signal, but absolute frequency will be in error by several parts per million unless standardized.

Output: Four channels; one each of 1 Mc and 10 Mc, and two of 100 Mc; all sine wave; all 50 ohms; 20 milliwatts, max., into 50 ohms.

Terminals: TYPE 874 Coaxial Connectors; adaptors are available to fit all commonly used connector types. See *Experimenter* for March, 1958.

Power Supply: 105 to 125 (or 210 to 250) volts, 50 to 60 cycles, 100 watts. Power input receptacle will accept either 2-wire (Type CAP-35) or 3-wire (Type CAP-15) power cord. Type CAP-35 2-wire cord is furnished. Type CAP-15 3-wire cord can be purchased separately at $2.25.

Mounting and Dimensions: Relay-rack panel, 19 x 12¼ inches; over-all depth, 11½ inches.

Net Weight: 25 pounds.

TYPE 1112-B STANDARD FREQUENCY MULTIPLIER

Input: 20 milliwatts, 100 Mc, sine wave from TYPE 1112-A Standard-Frequency Multiplier; 50-ohm input impedance.

Output: 1000-Mc sine wave; 50 mw into 50-ohm load; 50-ohm output impedance.

Net Weight: 35 pounds.

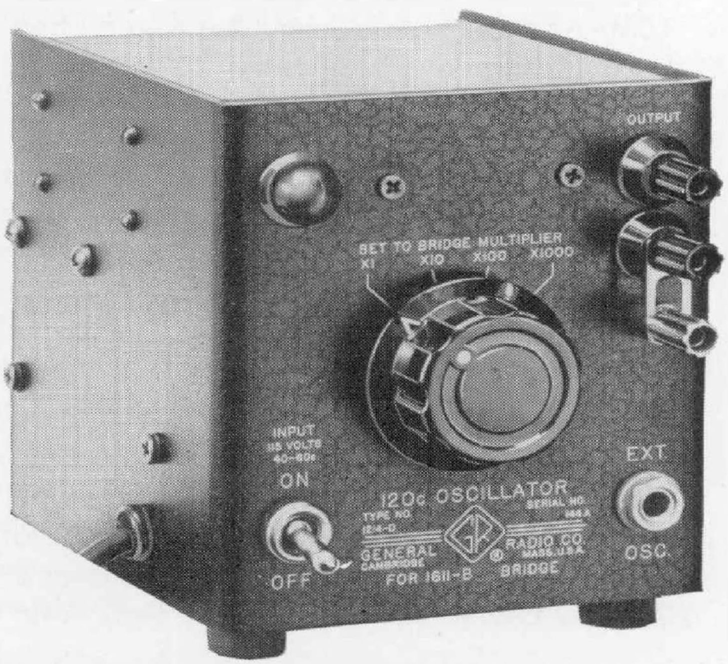
Other specifications are identical with those for TYPE 1112-A, above.

Type		*Code Word*	*Price*
1112-A	**Standard Frequency Multiplier**	EPOCH	**$1450.00**
1112-B	**Standard Frequency Multiplier**	EPODE	**1360.00**

TYPE 1214-D UNIT OSCILLATOR

The TYPE 1214-AS2 Unit Oscillator, which has been supplied for use with the TYPE 1611-B Capacitance Test Bridge[1] in the measurement of electrolytic capacitors at 120 cycles, has now been given the type number 1214-D. Specifications, which were originally published in the August, 1956, issue of the *Experimenter*, remain unchanged, and are reprinted below.

[1]"Capacitance Test Bridge," *General Radio Experimenter*, 32, 9, February, 1958, pp. 6-8.



SPECIFICATIONS

Frequency: 120 cycles ±2%.

Output Impedance: Four impedances to match the impedance of the TYPE 1611-B Capacitance Test Bridge at four multiplier positions.

Output: At least 2000 mw into matched load.

Distortion: Less than 3% into a matched load.

Terminals: The output terminals are jack-top binding posts with standard ¾-inch spacing; a ground terminal is provided, adjacent to one of the output terminals. Jack is provided for connecting external oscillator.

Power Supply: Unlike most instruments of the Unit line, the power supply is built into the instrument; 115 volts, 40–60 cycles; power consumption is about 16 watts.

Accessories Supplied: Spare fuses; the power cord is integral with the unit.

Tube: One 117N7-GT, which is supplied with the instrument.

Mounting: Aluminum panel and sides finished in black-crackle lacquer. Aluminum dust cover finished in clear lacquer. Relay-rack adaptor panel available.

Dimensions: (Height) 5¾ x (width) 5 x (depth) 6¼ inches, over-all, not including power-line connector cord. **Net Weight:** 4½ pounds.

Type		*Code Word*	*Price*
1214-D	**Unit Oscillator**	ABBOT	**$100.00**

SHORT DECAY-TIME IMPACT-NOISE MEASUREMENT

Perhaps the greatest causes of noise in offices (other than people) are typewriters, calculators, and other business machines. Aware of this, Underwood Corporation's General Research Laboratory in Hartford, Connecticut, has, for over twenty years, carried on a program of measurement and interpretation of business-machine noises.

Noise from a typewriter is made up of a series of short-duration bursts of sound. Continuous spectrum and band-spectrum analyzers are not suited to the measurement of these extremely short impact noises. The General Radio TYPE 1556-A Noise Analyzer, however, has been designed specifically to measure this type of noise.

The decay times of the impact noises from typewriters are very short, and, consequently, the Underwood Corporation found it convenient to modify the Impact-Noise Analyzer to have lower time constants for the time-averaging circuit.

The modification for short decay-time measurement is easily accomplished. The time constant of the analyzer is determined by an R-C circuit whose series resistance is set with the analyzer's TIME CONSTANT switch. Any one of seven different resistances can be selected to provide charging times from 2 milliseconds to 0.2 second. The recommended modification procedure is to change the capacitive element to a lower value. For example, if this capacitance is halved, all the time constants of the circuit are divided by 2, or if the value is reduced by a factor of 5, the time constants are then divided by 5.

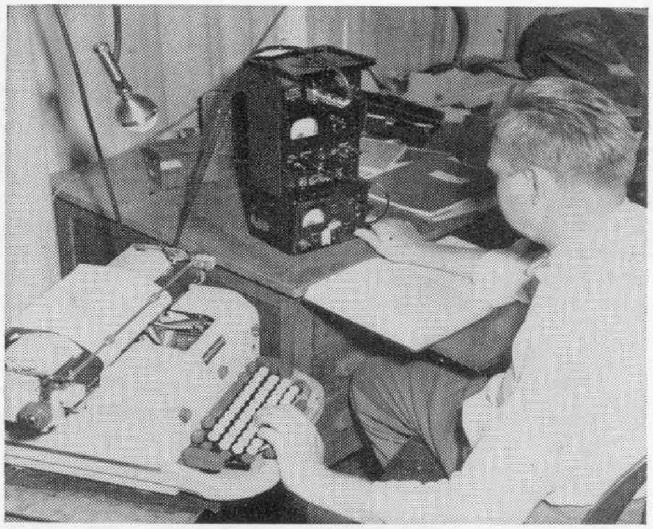


Figure 1. Setup used by Underwood for noise analyses of their "Golden Touch" typewriters. The transients are picked up by the suspended microphone, amplified by the Type 1551-A Sound-Level Meter, and then fed into the Type 1556-A Impact-Noise Analyzer.

Figure 1 shows an over-all view of the measuring setup used at the General Research Laboratories of the Underwood Corporation. The ease and rapidity of measurement possible with the TYPE 1556-A Impact-Noise Analyzer permitted extensive investigation into the nature of impact noises. Measure-

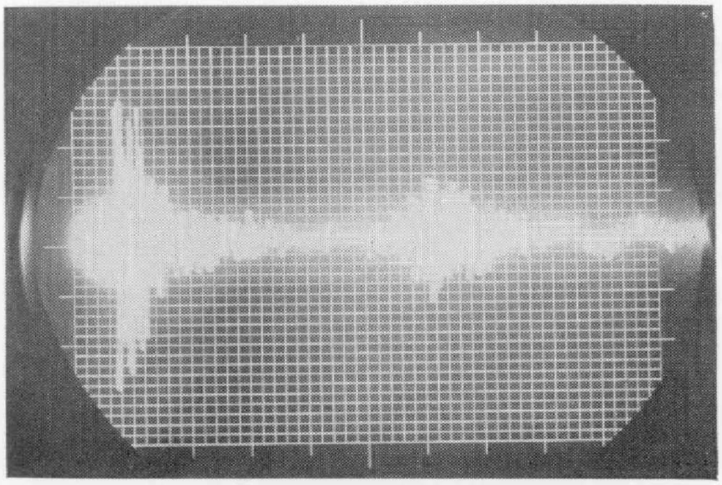


Figure 2. Oscillogram of typical typewriter noise. First impact occurs when bar strikes the platen — peak value is approximately 115 db and lasts about 3 milliseconds. A second peak occurs some 50 msec later when type bar returns to its rest position.

ments could be made quickly and conveniently to ascertain the effects of various typewriter modifications. No elaborate test equipment other than the Impact-Noise Analyzer and the Sound-Level Meter were required for preliminary measurements. Oscilloscopes, tape recorders, and other test equipment were necessary only when detailed investigations were required (Figure 2).

Underwood Corporation found the Impact-Noise Analyzer well suited to their measurement needs and, with its help, were able to make their "Golden Touch" typewriter the quietest that they have ever built.

VARIAC® USED IN THE JETCAL ANALYZER AND TESTER

In jet aircraft, exhaust-gas temperature and engine speed are vital to best engine life, efficiency, and safe operation. Engine temperature and engine speed must be maintained within close limits and be indicated accurately on the pilot's cockpit instruments during flight. To test and to calibrate the systems that measure and indicate these quantities, the B & H Instrument Company of Fort Worth have developed the Jetcal Analyzer and Tester.

The Jetcal is a rugged, portable instrument, which contains various check circuits, potentiometer, temperature regulator, meters, switches, and the necessary probes, cables, and adaptors for performing all tests. For convenient movement from one aircraft to another along a flight line, the Jetcal has wheels, adjustable handle, and support post.

Unique features of the Jetcal are: (1) It is a precision instrument of laboratory accuracy that is taken to the aircraft, performing its functions anywhere the aircraft is parked; (2) the Jetcal test system is isolated from the aircraft's system and thus provides means for checking and calibrating engines and cockpit instruments free of errors or limitations in the aircraft systems.

The Jetcal is used to determine the accuracy of the aircraft exhaust gas temperature system without the engine running and to read engine speed accurately during engine run-up. In checking the EGT system, the Jetcal heater probes apply precisely measured heat to thermocouples in the engine tail pipe.

The Type V-20 Variac® Autotransformer is an important component of every Jetcal Analyzer and Tester — the Variac is the Jetcal's temperature regulator. It controls the temperature of

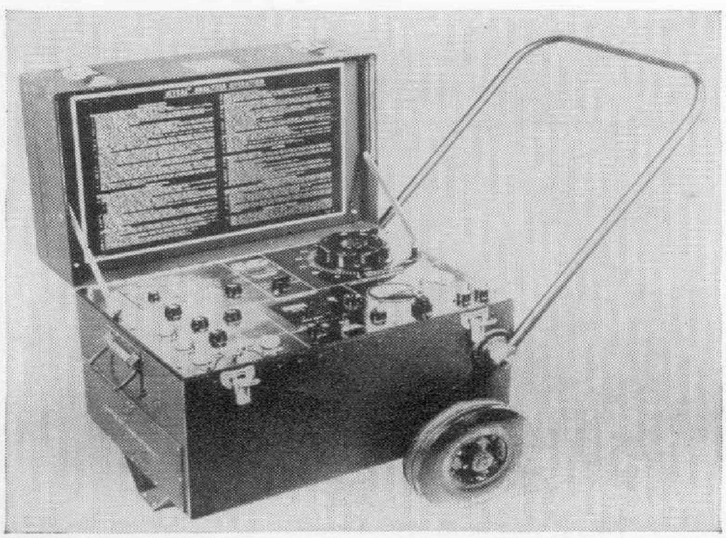


Figure 1. View of the Jetcal Analyzer and Tester. Wheels and handle permit the instrument to be moved conveniently to the aircraft to be tested.

resistance heaters in the heater probes, which apply accurately measured heat to jet engine thermocouples (or to other thermal systems).

Depending upon line voltage available, the Variac will vary the temperature of the Jetcal's wire-wound resistance heaters from 0 to approximately 900 degrees centigrade.

The Jetcal operates on any 95-to-135 volt, 50-400 cycle, AC power supply, in temperatures of –54° C. (–65° F.) to 71° C. (160° F.).

Since the aircraft exhaust gas temperature system is functionally checked without the engine running, the Jetcal achieves important savings — savings of fuel, savings of maintenance man-hours, savings of engine operating life. Here's just one example of savings: Prior to Jetcal, one major aircraft manufacturer had to make an average of three flights — at an average $752.57 per hour — to check a jet plane's cockpit indicator of tail pipe temperature. With the Jetcal, the EGT system is calibrated to within ± 4° C., without flight or engine running.

If test by Jetcal shows that an engine's EGT system is not functioning within allowed tolerance, the Jetcal will trouble-shoot and isolate errors in the system — still without the engine running.

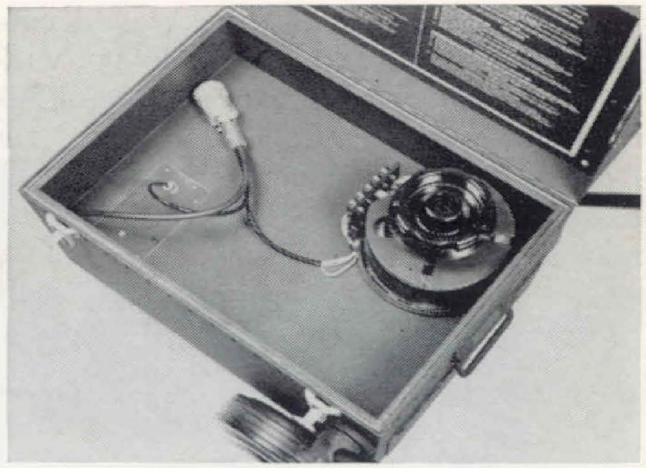


Figure 2. View of interior of Jetcal, showing the Type V-20 Variac® Autotransformer in position.

The Variac was selected for the Jetcal by B & H design engineers because it fully meets B & H standards to assure reliability and durability in sustained field use.

Jetcals, with Variacs and other highest quality components, have been proved in world-wide operational use. More than 3600 Jetcals are being used by the United States Air Force, Army and Navy, the NATO forces, jet engine and aircraft manufacturers, and airlines.

The August and September numbers of the *Experimenter* will be combined in a single issue, to be published about September 1.

General Radio Company

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