OPERATING AND SERVICING MANUAL

FOR

MODEL 202A

LOW FREQUENCY
FUNCTION GENERATOR

Serial 5612 and Above



SPECIFICATIONS

FREQUENCY RANGE: O. 008 to 1200 cps in five decade ranges with wide overlap at each dial extreme.

DIAL ACCURACY: Within ±2% from "1. 2" to "12" on dial; ±3% from ".8" to "1. 2".

FREQUENCY STABILITY: Within ±l% including warm-up drift and line voltage variations of ±1O%.

OUTPUT WAVEFORMS: Sinusoidal, square, and triangular. Selected by panel switch.

MAXIMUM OUTPUT VOLTAGE: At least 30 volts peak-te-peak across rated load (4000 ohms) for all three waveforms. (10. 6 volts RMS for sine wave.)

FREQUENCY RESPONSE: Constant within ±O. 2 db over entire frequency range at rated output and loado

INTERNAL IMPEDANCE: Approximately 40 ohms over the entire range.

DISTORTION: Less than 1% on all ranges except XlOO. Less than 2% rms on XlOO.

OUTPUT SYSTEM: Can be operated either balanced or single-ended. Output system is direct-coupled; de level of output voUage remains stable over long periods of time. DC adjustment available on front panel.

HUM LEVEL: Less than 0.05% at rated output.

SYNC PULSE: 10 volts peak negative, less than 5 microseconds duration. Sync pulse occurs at crest of sine wave and with corresponding positions on other waveforms.

POWER: Operates from 115/230V ±10%, 50/1000 cycles source. Requires 175 watts.

DIMENSIONS: Cabinet Mount: 20-3/4" wide, 12-1/2" high, 14-1/2" deep. Rack Mount: 19" wide, 1O-1/2"high, 14-1/4" deep.

WEIGHT: Cabinet Mount: 48 lbs; shipping weight, approximately 84 lbs. Rack Mount: 36 lbs; shipping weight, approximate1y 74 lbs.

ACCESSORIES AVAILABLE: For rack mount style: End Frames with handles for bench use. Specify~No. 17 End Frames.

SECTION I
GENERAL DESCRIPTION

1-1 GENERAL

The Model 202A Low Frequency Functíon Generator is a compact, convenient, and versatile source of transient-free test voltages between 1200 and .008 cycles per second. It ,s useful for any general purpose low frequency testing application and is particularly valuable in the testing of servo systems, geophysical equipment, vibration and stability character istícs of mechanical systems, electro-medical equipment, and for the electrical símulatíon of mechanical phenomena. Three types of output waveform are available; sine, square andtriangular.

Also, a sync output pulse is available for external use.

The Model 202A Low Frequency Function Generator contains a type of relaxation oscillator that is particularly advantageous for the generation of very low frequencies. Both a triangular and a square wave voltage function of time are inherent in the oscillating system. Also, a sine wave function is produced by synthesis from the triangular wave.

Output amplitude and distortion are virtually independent of the frequency of operation. This type of oscillating system in inherently a constant amplitude device so that no A. V. C. system, with associated delay in stabilization after frequency changes, is required.

The frequency range from . 008 to 1200 cycles per second is covered in 5 bands. The frequency dial is linear.

The output system is a direct-coupled amplifier system designed for either single ended or balanced output. It has good stability wíth respect to direct current in the output and very low hum level. Both the FUNCTION selectro switch and the AMPLITUDE control are so arranged that the characteristics of the amplifier are independent of their position. The internal impedance of the output amplifier is approximately 40 ohms, and the unit ís rated to deliver at least 30 volts peak-to-peak to a 4000 ohm loado A negative peak sync pulse of 10 volts into a 2500 ohm load is also provided. It has a duration of less than 5 microseconds and occurs at the crest of the sine wave and at corresponding positions with the other functions

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SECTION II
OPERATING INSTRUCTIONS

2-1 INSPECTION

After the instrument is unpacked, the instrument should be carefully inspected for damage received in transito H any shipping damage is found, follow the procedure outlined in the "Claím for Damage in Shipment" page at the back of the instruction book.

2-2 CONTROLS AND TERMINALS

RANGE

This switch is used to select the desired frequency range to be covered by the frequency díal,

FUNCTION

This switch is used to select any one of the three types of output waveform.

FREQUENCY

This dial is calibrated directly in cycles per second for the Xl frequency range of the oscillator. The knob just below the dial escutcheon is directly connected to the frequency varying elemento The lower lmob is a mechanical ve rnier for fine adjustment of the frequency.

AMPLITUDE

This control adjusts the amplitude of the oscillator voltage admitted 10 the amplifier and, therefore, the output of the instruments This control is calibrated from 0 to 100 in arbitrary units.

POWER

This toggle switch controls the power supplied to the instrument from the power line.

FUSE

The fuseholder, which is located on the panel, contains the power line fuse. Refer to the Table of Replaceable Parts for the correct fuse rating.

OUTPUT

This group consists of three terminals. The one marked "G" is connected directly to the ínstrument chassis. The other two terminals, vertically aligned, are the OUTPUT terminals. With respect to the ground terminal each of these outputs has equal magnitude of signal, but they are 180^0 out of phase with each other. The internal impedance between the two OUTPUT terminals is approximately 40 ohms.

SYNC OUT
The Sync Out terminals are single -ended and have an internal impedance of about 2,000 ohms.

Power Cable

The three-conductor power cable is supplied with a three -p rong plug. The third prong is a round off-set pin which provides a chassis ground. An adapter may be obtained to permit use of this plug with two-conductor receptacles.

2-3 230-VOLT OPERATION

This instrument is shipped from the factory with the power transformer primaries connected in parallel for 115 v operation, unless otherwise specüied on the order. H 230 v operation is desired, the primaries wi11 have to be connected in series as shown in "Transformer Detalls" on the schematic wiring diagram of the Power Supply Section.

2-4 OPERATION

The foUowing step-by-step procedure should be used as a guide when operating this instrumento
1) Turn the POWER switch to ON. Allow thirty seconds for oscillations to start. The instrument will operate nearly within specifications after a few minutes warm-up. It will be within specifications after 30 minutes.
2) Set the RANGE and FREQUENCY controls for the desired frequency. The frequency dial scale must be multiplied by the multiplying factor indicated by the RANGE switch setting to obtaín the oscillator frequency. Example: 4 (on dial scale) x .1 (multiplying factor indicated by RANGE switch setting) = .4 cycles/sec.
3} Set the FUNCTION switch for the desired output waveform.
4} Connect the equipment under test to the OUTPUT terminals
5} Adjust the AMPLITUDE Control for the desired output voltage. Because the frequency response is rated ±0. 2 db, the output amplitude may be measured at any convenient frequency and the output level will be correct (within these limits) for any other frequency

NOTES

When small output voltages are required it may be desirable to use an external attenuator. This is because the hum and noise in the output is nearly constant with output amplitude
To minimize distortion in the output waveform, always use the lowest RANGE when the overlap of the FREQUENCY dial permits a choice.

2-5 SINGLE-ENDED OUTPUT

The terminal marked *"G'* is isolated from the actual OUTPur terminals. For single-ended operatíon *"G'* must be connected to one of the OUTPUT terrnínals, and the strapped pair will then be the ground side oí the output.

2-6 BALANCED OUTPUT

Connect the two OUTPUT binding posts to the equipment being supplied. The "G" binding post may then be connected to the chassis of the equipment being driven. Under these conditions the internal impedance of the Model 202A from either OUTPUT terminal to ground is 7900 ohms in series with a 1 Ilf capacítor (C29). A maximum de voltage of 400 volts may be applied between either OUTPUT terminal and the "G" terminal without damaging the 1 Ilf capacitor (C29). The 40 ohms internal impedance (resistive) will shunt the impedance existing between the two signal inputs of the system being driven. Under circumstances where the connection place s the Model 202A in series with a path carrying current, dístortíon of the Model 202A output will occur if greater than 10 ma peak current is caused to flow through the Model 202A output system.

2-7 SYNC. OUT

The SYNC. OUT is a negative pulse of less than 5 microseconds duration and at least 10 volts peak into a 2,500 ohm loado It occurs on one of the sine and triangular crests and at the rise or fall of the, squarewave. It occurs at the positive crests with respect to one of the OUTPUT terminals and at the negative crest of the other. Therefore, ít can be changed by 180^0 with respect to the output system by reversing connections to the two OU'tPUT termínals, which are otherwise completely interchangeable. The SYNC. OUT terminal marked "G" is directly connected to the chassis.

SECTION III
THEORY OF OPERATION

3-1 GENERAL

Figure 3-1 depicts the general scheme of the <ét>Model 202A and indicates the waveforms produced. The bistable círcuít consists of a flip-flop circuit capable of producing a square-wave output at point A, provided it is triggered at the proper time. This is done by including in the bi-stable circuit, a two-way comparator circuit which produces the proper tr íggers fo r the flip-flop whenever the switching s ignal becomes equal to either the "plus switching reference" or the "minus switching reference". The triangular switching signal returned to the bi-stable circuit is that seen between poínts B and D. The conversion of square wave to triangular wave takes place in the integrator unit which ís carefully designed to produce an accurate integral of the applied square wave. The bi-stable cí r cuít and linear integrator are loop coupled in such a manner that the resulting relaxation oscillator ís suitable fo r very Iow frequency operation. The sinewave output is taken from a point e between the triangular voltage at po ínt B and the average level at po int D. The resistance between B and e ís fixed, and the network between e and D is a

non-linear system which synthesizes a sinewave from the triangular wave. This network consists of a group of biased diodes arranged in such a manner that at certaín predetermined voltage levels they begin to conduct, therefore, providing shunt paths from C to D. Each additional shunt path reduces the slope of the triangle in the proper amount so that the wave is shaped to approximate a sinewave.

This approximation is as shown, and the degree to which a sinewave may be approached depends on the number of diodes. Thus there are available the sinewave C, triangular wave B, and square-wave A functions w ith respect to D to be selected and brought to the OUTPUT terminals through the output amplifier. The output amplifier has a differential input and push-pull output.

3-2 BI-STABLE CIRCUIT

Figure 3-2 shows the details of the bi-stable circuit and includes the integrator in block form in o rde r to indicate the bilateral connectíon from integrator output to comparator input.
The po rt íon of the diagram composed of VI, V2 and V3 is the "bi-stable circuit". Actually, this circuit is a combination of two circuits. If capacíto rs ClO and Cl3 are disconnected so that there is no possibility of inductive coupling from grids to cathode of VI and V2, the remaining circuit is the well-known "fl ip-flop" or Eccles-Jordan trigger circuito The other círcuít which appears in the bi-stable circuit is a voltage comparator known as the "Multíar ". The multiar is a circuit which employs a regenerative loop to produce a pulse when the two input voltages are equal. There are two of these in the bi-stable unit. One multiar is composed of VI, V3A and T2, and the other of V2, 3B and TI.

The cathode of V3A and the plate of V3B are connected to reference voltages derived from the voltage regulator tubes V5 and V6. The triangular wave ís applied to the plate of V3A and the cathode of V3B. As the voltage on the plate of V3A rises towards the plus swítchíng reference, VI is conduct íng, but when V3A conducts, a negative pulse is formed on the grid of VI whích flips the Bi-Stable Unit to íts other stable state and starts the voltage on the cathode of V3B towards the minus swítchíng reference. When V3B conducts the Bi-Stable Unit is flipped back to its original state, completing one cycle of ope ratíon.
Voltage regulator tubes V5 and V6 are connected by a voltage divider from which the switching reference voltages are taken. They also provide the limiting voltages applied to tubes V7 and V8 which are seen to be a push-pull clamping system. Inasmuch as the integrator output is directly related to the input, it is seen that the magnitude of square-wave applied must be carefully controlled. Although only the squarewave appearing at the plate of Vl is needed to drive the integrator, the clamp ís made push-pull to prevent excessive current variations in the regulator tubes. The actíon of V7B and V8B is such that if the applied waveform has peak excur stons in excess of the potentials on the remaining cathode and plate, these being determined by regulator tubes V5 and V6, a current will flow through *R20* which drops the voltage to *very* nearly the potential of the regulated element of the conducting se ctíon of the diode. The action of the other diodes is the same, but 180^0 out of phase, inasmuch as they are coupled to the plate of V2. In this way, waveforms appearing on the clamped sides of R21 and *R20* are assured to be of equal magnítude as well as 180^0 out of phase, and further the average of de level of the squarewave is accurately controlled.

3-3 LINEAR INTEGRATOR

Consider the block diagram of the linear of feedback integrator as shown in Figure 3-3. Starting with the output voltage E 0, it is seen that if the gain of the amplifier is hígh, then the signal appearing at the junction of R and C (the amplifier input) must be small. Fo r a fixed output E ₒ as the gain is increased the resultant signal at the input of the amplifier becomes arbitrarily small. Since the voltage at the junction at R and C ís arbitrarily small, a squarewave applied to the input will cause a constant current in R. Because the current chargíng and discharging C is constant, except for direction, the voltage across C will be triangular.

Since there is virtually no s ígnal at the junction of R and C the output voltage must also be triangular In thís case the frequency of the applied signal is so low that the amplifier used must be direct coupled. There is a net voltage rise between input level and output level in a de amplifier. **In** this particular application the average output level is determined as the average of the "plus reference" and "minus reference" levels, since the output excur s íon is limited to these levels. If this level does not coincide with the average level of the applied squarewave, then the positive and negative excursions of the squarewave will not be equal, resulting in unequal rise and fall rates of the output triangle. Because the squarewave input is generated from the triangular output by the bi-stable circuit, the net result ís that under such cond ítíons the squa:rewave is reallya rectangular wave. The resulting rectangular wave has an average value just equal to that demanded of the amplifier input by virtue of the pre-set output level. The average le veIs of the input and output are stabilized by the use of a differential amplifier that has high gain to the difference between the voltage applied to its inputs but little or no gain to any voltage change common to both inputs.

Figure 3-4 shows how this is done. The right hand grid of the differential amplifier V15, is the signal input and ís driven through R by the rectangular wave appearing on the FREQUENCY control. The average voltage of this rectangular w"C.ve is dependent on the clamping levels and the ratío of "on" to "off" time. When the system is adjusted for equal on-off times (squarewave) the average ís just the average of the clamping levels. The left hand grid has no signal because the voltage divider which includes the balance control is connected to the nos ígnal sides of the clamping tubes. However, any change in the clamping level changes the average level appearing on both input grids in the same amount. Due to the Iarge common cathode resistors of V15 and Vl6 a common mode change has very little effect.

The input to the left hand grid has another function. If the balance control *R60,* ís varied slightly, the output of the amplifier will show a considerable change in average level; and therefore

the average level oí the output can be adjusted to exactly the voltage midway between the "reíerence" levels. This control then serves adequately to adjust the triangular wave balance which in turn equalizes the on-off time oí the squarewave. The signals appearing at the plates oí the first tube V15, are 180^0 out oí phase and nearly equal in magnitude. These signals are also very nearly the difference between the inputs on the two grids. Since there is no signal on the left gr íd, the only signal into the amplifier is trat at the junction oí R and e, which is the condition originally required. The second stage is a push-pull amplifier employing the signals Irom the plates oí the previous stage. Again the cornmon cathode resistance is very hígh, but there is very little degeneration oí the push-pull input. The gain of the system to changes common to both grids is about one-half while the gain to voltages appearing between the input grids ís something over 250. Finally e is íed back to the signal grid írom the cathode of V17A which is 180^0 out of phase with the signal input.

The cathode follower is used as an isolation stage between the integrator and the bt-stable circuito This completes fue oscillating loop with íts inherent production of both square and triangular ñmctíons.

3-4 SINE SYNTHESIZER AND FUNCTION SELECTOR SWITCH

The triangular wave f rorn the linear integrator is connected to R94. In the SINE position oí the FUNeTION selector switch (S3) the other end oí R94 is connected to the sine synthesizing diodes and to R93B, one half of the dual AMPLITUDE potentío-meter. The synthesized sinewave signal appears as the difíerence signal between points e and D, but an error signal which appears at D with respect to B- also appears at e with respect to B-. This composite signal ís applied to a differential amplifier in the output circuito
The plus and minus switching references in the bi-stable unit are adjusted so that the ratio of the triangular wave amplitude to the conductíon voltages oí fue synthesizer diodes produces the least distortion oí the sinewave. This adjustment also fixes the average voltage at e and is equal to the average of the plus and m ínus switching reíerences.
The dc voltages at D, and the cathode of V4 are adjusted to be the average oí the plus and minus switching references. Since fuese voltages are equal there is no change in De level applied to the Output Amplifier as the AMPLITUDE control is varied.

The sinewave is approximated by varying the shunt resistance across R93B is steps determined by the diode synthesizing network. The waveform slope, at first, is just that determined by R94, R93B and the input waveform. When the first díode conducts R93 is shunted by a predetermined amount, decreasing the slope. Each diode in turn decreases the slope until all the diode s are conducting and the triangular wave has reached its crest. The triangular wave starts down, the diodes stop conducting in turn until the triangular wave has reached its crest.

The triangular wave starts down, the diodes stop conduct ing in turn until the triangular wave reaches the average level. The other half-cycle is formed in the same manner, but by the diodes that are biased to shape the negative excursion.

It can be shown that using seven segments to approximate one half cycle of the sinewave results in approximately 1/6% rms distortion. However, variations in the diodes limit the practical result to about 1% rms distortion.

In the triangular wave pos ítíon of the FUNCTION selector switch the non-linear load consisting of the diode network is replaced by R95 so that the combínatíon R94 and R95 ís a simple linear divider for all voltage levels. It is adjusted to gíve equal

sine and triangular wave peak magnitude. The squarewave is connected to the FUNCTION selector switch through the divider R59 and R22 which adjusts the average voltage of the squarewave to the voltage at the cathode of V4. In the squarewave position of the selector switch, R63 parallels R93B to adjust the amplitude of the squarewave to be equal to the amplitude of the sinewave and the triangular wave.

3-5 OUTPUT SYSTEM

The output system consists of three stages as shown in Figure 3-7. The first stage V18 ís a dual triode acting as a pair of separate cathode followers. These cathode followers isolate the signal input from the output stage. Any de unbalance at the output terminals can be corrected by varying R65.

The second stage V19 ís a differential amplifier. The difference between the two signals at its grids appears at both plates in nearly equal magnitudes and 180^0 out of phase. This effect is due to the large common cathode resistance. In this stage amplification takes place and also the signal difference E minus F is converted to push-pull voltages. The third stage V20 is another pair of cathode followers.

The signals appearing at the plates of V19 are attenuated before being applied to the cathode follower grids. The small shunt capacítors on the upper sides of the dividers improve the high frequency response of the amplifier. The voltages appearing at the cathode follower output terminals are equal in magnitude and 180^0 out of phase. Negative feedback ís used to reduce distortion, lower the output impedance and improve stability. This improved stability applies not only to the signal output, but to the de level at the output terminals.

The symbol for chassis or ground is used for the first time in the output terminal network R98, R99 and *C29.* In all other description the reference level for ope ratíon has been B-, and in the Model 202A the B- line is completely isolated from the chassis. Thus, the chassis ground is available for whatever

connection is desired. It is possible to consider the two output terminals as a transformer output and further to balance this apparent transformer to chassis by making R98 equal to R99. The capacitar *C29* insulates the apparent transformer secondary from ground. *H* single-ended operation is desired the ground connection can be tied to either output terminal wíthout affecting the amplifier.

3-6 SYNC PULSE OUTPUT

The output sync pulse is obtained from the bi-stable circuit VI and V2. On the minus swítchíng reference at the plate of multiar diode V3, one positive pulse and one negative pulse appear for every cycle of ope ratron. These pulses are coupled to the grid

of the sync pulse amplifier, V17, through an RC coupling which Iowe r s the average voltage on the grid to B-. In the absence of pulses, Vl7 is biased to cut-off by the bleeder to B+. When a positive pulse appears at the grid, it momentarily turns Vl7 "on", thus, inducing a large voltage swíng in the pulse transformer primary. The resistor and diode in the secondary remove the positive excursion, resulting in a negative pulse at the SYNC OUT terminals.

3-7 POWER SUPPLY

The Power Supply is a full wave rectüier and regulator which supplies + 375 volts. The + 75 volt and + 225 volt regulated outputs are taken from a voltage divider ac ro s s the + 375 volt supply. The main requirement on the three regulated voltages is very low impedance at low frequencies. Reasonable vart-atíons in the actual voltages do not affect the output frequency or waveform .