



OPERATING AND SERVICE MANUAL

MODEL 3312A FUNCTION GENERATOR

Serial Number: 1432A01246

IMPORTANT NOTICE

If the Serial Number of your instrument is lower than the one on this title page, the manual contains revisions that do not apply to your instrument. Backdating information given in the manual adapts it to earlier instruments.

Where practical, backdating information is integrated into the text, parts list and schematic diagrams. Backdating changes are denoted by a delta sign. An open delta (Δ) or lettered delta (Δ_A) on a given page, refers to the corresponding backdating note on that page. Backdating changes not integrated into the manual are denoted by a numbered delta (Δ_1) which refers to the corresponding change in the Backdating Section (Section VIII).

WARNING

To help minimize the possibility of electrical fire or shock hazards, do not expose this instrument to rain or excess moisture.

Manual Part No. 03312-90003

Microfiche Part No. 03312-90053

Copyright Hewlett-Packard Company 1974
P.O. Box 301, Loveland, Colorado 80537 U.S.A.

Printed: April 1977

CERTIFICATION

Hewlett-Packard Company certifies that this instrument met its published specifications at the time of shipment from the factory. Hewlett-Packard Company further certifies that its calibration measurements are traceable to the United States National Bureau of Standards, to the extent allowed by the Bureau's calibration facility, and to the calibration facilities of other International Standards Organization members.

WARRANTY AND ASSISTANCE

This Hewlett-Packard product is warranted against defects in materials and workmanship for a period of one year from the date of shipment, except that in the case of certain components, if any, listed in Section I of this operating manual, the warranty shall be for the specified period. Hewlett-Packard will, at its option, repair or replace products which prove to be defective during the warranty period provided they are returned to Hewlett-Packard, and provided the proper preventive maintenance procedures as listed in this manual are followed. Repairs necessitated by misuse of the product are not covered by this warranty. **NO OTHER WARRANTIES ARE EXPRESSED OR IMPLIED, INCLUDING BUT NOT LIMITED TO THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE. HEWLETT-PACKARD IS NOT LIABLE FOR CONSEQUENTIAL DAMAGES.**

If this product is sold as part of a Hewlett-Packard integrated instrument system, the above warranty shall not be applicable, and this product shall be covered only by the system warranty.

Service contracts or customer assistance agreements are available for Hewlett-Packard products.

For any assistance, contact your nearest Hewlett-Packard Sales and Service Office. Addresses are provided at the back of this manual.

SECTION I

GENERAL INFORMATION

1-1. INTRODUCTION.

1-2. This manual contains installation procedures, operating instructions and maintenance information for the Model 3312A Function Generator. Instrument specifications and procedures for adjusting the instrument to those specifications, schematic diagrams, theory of operation, and troubleshooting information are provided for use in maintaining the instrument.

1-3. This section of the manual contains a description of the Model 3312A, the performance specifications and characteristics, and instrument identification information.

1-4. DESCRIPTION.

1-5. The Hewlett-Packard Model 3312A Function Generator is a compact, wide range, dual function generator consisting of a main generator and a modulation generator. The main generator provides sine, square, or triangle wave outputs over the frequency range of 0.1 Hz to 13 MHz. The modulation generator produces sine, square and triangle waveforms with a frequency range of 0.01 Hz to 10 kHz. The modulation generator can be used to Amplitude Modulate (AM) or Frequency Modulate (FM) the output signal of the main generator. The AM envelope can be adjusted from 0% to 100%; FM can change the carrier frequency up to $\pm 5\%$.

1-6. SWEEP OUTPUT.

1-7. For added versatility, the 3312A has a built-in sweep generator which can be used to sweep the frequency of the main generator. The frequency of the main generator can be swept as much as 100:1 on any range.

1-8. OUTPUT LEVEL.

1-9. The output voltage of the 3312A can be varied from 0 V to 10 V peak-to-peak into 50 ohms in four voltage ranges. A front panel control permits continuous adjustment within each voltage range. The dc level of the main generator output can be adjusted within the range of ± 10 volts using the front panel offset control. With the OFFSET in the CAL position the dc offset is eliminated.

1-10. BURST.

1-11. The burst is either a single pulse or a series of pulses which are rear panel selectable by a slide switch labeled SINGLE and MULTIPLE. The TRIGGER PHASE control adjusts the phase of the signal. FREE RUN disables the burst.

1-12. SYMMETRY.

1-13. The main and the modulation generators have separate front panel symmetry adjustments which will vary the symmetry of the output waveforms. The CAL position of each SYM knob will produce symmetrical waveforms. In the SWEEP mode, the SYM adjusts the sweep rate, and CAL selects a 90:10 ramp.

1-14. SPECIFICATIONS.

1-15. Table 1-1 is a complete list of the Model 3312A critical specifications. These specifications are the performance standards or limits against which the instrument can be tested. Table 1-2 lists some supplemental performance characteristics which are not specifications, but are typical characteristics included as additional information for the user.

1-16. Any changes in specifications due to manufacturing, design or traceability to the U.S. National Bureau of Standards are included in Table 1-1 of this manual. Specifications listed in this manual supersede all previous specifications for the Model 3312A.

1-17. INSTRUMENT AND MANUAL IDENTIFICATION.

1-18. The instrument serial number is located on the rear panel. Hewlett-Packard uses a two-section serial number consisting of a four-digit prefix and a five-digit suffix. A letter between the suffix and prefix identifies the country in which the instrument was manufactured (A = USA, G = West Germany, J = Japan, U = United Kingdom). All correspondence with Hewlett-Packard should include the complete serial number.

1-19. If the serial number of your instrument is lower than the one on the title page of this manual, refer to Section VIII for backdating information that will adapt this manual to your instrument.

Table 1-1. Specifications.

FREQUENCY CHARACTERISTICS. Dial Accuracy: $\pm 5\%$ of full scale (After 1-hour warm-up.) Square Wave Rise or Fall Time (10% to 90%): < 18 nsec at full rated output. Aberrations: $< 10\%$. Triangle Linearity Error: $< 1\%$ of rated amplitude at 100 Hz. Variable Symmetry: 80:20 to 20:80 to 1 MHz. Spectral Purity: Sine Wave Distortion: $< 0.5\%$ THD from 10 Hz to 50 kHz. > 30 dB below fundamental from 50 kHz to 13 MHz. OUTPUT CHARACTERISTICS. Impedance: $50\ \Omega \pm 10\%$. Level: 20 V p-p into open circuit, 10 V p-p into $50\ \Omega$. Level Flatness (Sine Wave): $< \pm 3\%$ from 10 Hz to 100 kHz at full rated output (1 kHz reference). $< \pm 10\%$ from 100 kHz to 10 MHz at full rated output. Step Attenuator Accuracy: better than 5%. Sync Output: Impedance: $50\ \Omega \pm 10\%$, > 1 V p-p square wave into open circuit. Rise or Fall Time (10% to 90%): < 10 nsec. DC Offset: ± 10 volts maximum (subject to coarse amplitude attenuator setting). MODULATION CHARACTERISTICS. Internal Modulation Source Output Level: > 1.0 V p-p into $10\ k\Omega$.	Spectral Purity: Sine Wave Distortion: $< 2\%$ THD from 10 Hz to 10 kHz. Amplitude Modulation Carrier 3 dB Bandwidth: < 100 Hz to > 5 MHz. Carrier Envelope Distortion: $< 2\%$ at 70% sine wave modulation with $f_c = 1$ MHz, $f_m = 1$ kHz. External Sensitivity: < 10 V p-p for 100% modulation. Frequency Modulation: $\pm 5\%$. Deviation: 0 to 5% (internal). Modulation Frequency: Internal: 0.01 Hz to 10 kHz. External: DC to > 50 kHz. Distortion: < -35 dB at $f_c = 10$ MHz, $f_m = 1$ kHz, 10% modulation. Sweep Ramp Linearity Error: $< 1\%$ at 100 Hz. EXTERNAL FREQUENCY CONTROL. Input Requirement: With dial set to 10, application of 0 to -2 V dc $\pm 20\%$ to the VCO input will linearly decrease frequency by more than 1000:1. An ac voltage will FM the frequency about a dial setting within the limits of $(.1 < f < 10)$ x range setting. Linearity: The frequency vs voltage curve will be linear within 0.5% over a 100:1 frequency range.
--	--

Table 1-2. General Information.

MAIN GENERATOR CHARACTERISTICS. General: Sine, Square, triangle, ramp, and pulse. Variable Symmetry. Range is 80:20 to 20:80. Frequency Characteristics Range: 0.1 Hz to 13 MHz in 8 decade ranges. Output Characteristics Attenuator: 1:1, 10:1, 100:1, 1000:1 and > 10:1 continuous control. MODULATION CHARACTERISTICS. General: Types: Internal AM, FM, Sweep, Trigger, Gate or Burst. External AM, FM, Sweep, Trigger, Gate or Burst. Amplitude Modulation: Depth: 0 to 100%. Modulation Frequency: 0.01 Hz to 10 kHz (internal). DC to > 1 MHz (external).	Frequency Modulation: Modulation Frequency: 0.01 Hz to 10 kHz (internal). DC to > 50 kHz (external). Sweep Characteristics Sweep Width: $< \text{Range}$: 100:1 on any range. Sweep Rate: 90:10 ramp, (0 Hz provides manual setting of "Sweep Start" without Modulation Generator oscillating). Sweep Mode: Repetitive linear sweep between start and stop frequency settings. Retrace time can be increased with symmetry control. Gate Characteristics Frequency Range: 0.1 Hz to 1 MHz (useful to 10 MHz). Start/Stop Phase Range: $+90^\circ$ to -80°. Gating Signal Frequency Range (External): DC to 1 MHz. (TTL compatible input level.) External Frequency Control Range: 1000:1 on any range. General: Operating Temperature: 0°C to $+55^\circ\text{C}$; specifications apply from 0°C to 40°C. Storage Temperature: -40°C to $+75^\circ\text{C}$. Power: 100/120/220/240 V $\pm 5\%$, -10%, switchable; 48 Hz to 440 Hz; ≤ 25 VA.
---	---

SECTION II

INSTALLATION

2-1. INTRODUCTION.

2-2. This section explains how to prepare the Model 3312A Function Generator for use. Included are initial inspection procedures, power and grounding requirements, environmental information, mounting instructions and instructions for repackaging for shipment.

2-3. INITIAL INSPECTION.

2-4. This instrument was carefully inspected both mechanically and electrically before shipment. If the shipping container is damaged it should be kept until the contents of the shipment have been checked mechanically and electrically. If the instrument does not pass a mechanical inspection or the electrical performance tests given in Section V, notify the carrier and refer to the warranty on the front cover of this manual.

2-5. POWER REQUIREMENTS.

2-6. The Model 3312A can be operated from any source of 100, 120, 220 or 240 volts ac $\pm 5\%$ -10% , of 48 Hz to 440 Hz frequency. The instrument can be easily adapted to the available line voltage by changing the position of the slide switches on the rear panel.

2-7. Figure 2-1 illustrates the standard power plug configurations that are used throughout the United States and in other countries. The -hp- part number shown directly below each plug drawing is the part number for a 3312A power cord equipped with the proper plug. If the appropriate power cord is not included with the instrument, notify the nearest Hewlett-Packard office and a replacement cord will be provided.

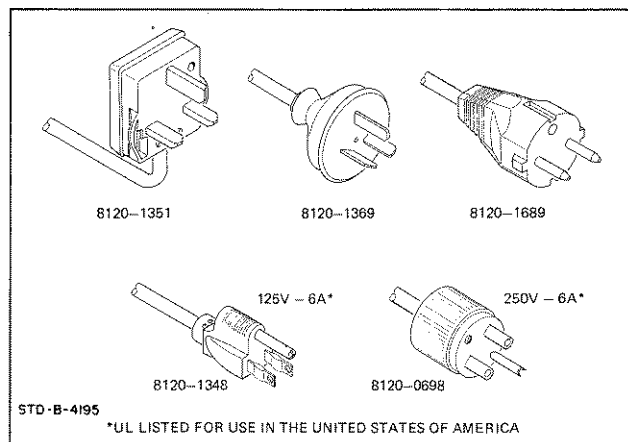


Figure 2-1. Power Plugs.

2-8. GROUNDING REQUIREMENTS.

2-9. For the safety of operating personnel, the instrument must be grounded. The offset pin on the power cable grounds the instrument when plugged into the proper receptacle.

2-10. INSTRUMENT MOUNTING.

2-11. Bench Use.

2-12. The front of the 3312A may be elevated for operating convenience by flipping down the bails which are attached to the two front feet of the instrument.

2-13. REPACKAGING FOR SHIPMENT.

2-14. The following paragraphs contain a general guide for repackaging the instrument for shipment. Refer to Paragraph 2-15 if the original container is to be used or 2-16 if it is not. If you have any questions, contact the nearest -hp- Sales and Service Office (see Appendix A for office locations).

NOTE

If the instrument is to be shipped to Hewlett-Packard for service or repair, attach a tag to the instrument identifying the owner and indicating the service or repair to be accomplished. Include the model number and full serial number of the instrument. In any correspondence, identify the instrument by model number and full serial number.

2-15. Place instrument in original container with appropriate packing material and seal well with strong tape or metal bands. If original container is not available, one can be acquired from your nearest -hp- Sales and Service Office.

2-16. If original container is not to be used, proceed as follows:

- a. Wrap instrument in heavy paper, or plastic before placing in an inner container.
- b. Place packing material around all sides of instrument and protect panel face with cardboard strips.
- c. Place instrument and inner container in a heavy carton or wooden box and seal with strong tape or metal bands.
- d. Mark shipping container "DELICATE INSTRUMENT," "FRAGILE," etc.

C

C

C

SECTION III

OPERATING INSTRUCTIONS

3-1. INTRODUCTION.

3-2. This section contains complete operating instructions for the Model 3312A Function Generator. Included is a brief description of the instrument, a description of controls and connectors, general operating information, and a basic operating procedure.

3-3. DESCRIPTION.

3-4. The 3312A Function Generator combines two separate function generators in one instrument – a main generator and a modulation generator. The frequency range of the main generator is 0.1 Hz to 13 MHz in eight decade ranges. The modulation generator frequency range is 0.01 Hz to 10 kHz. Both the main generator and the modulation generator provide sine, triangle, square, pulse and ramp outputs. The symmetry of all waveforms can be varied over a range of 80:20 to 20:80 on the main generator and is set at 10:90 on the modulation generator.

3-5. The main generator can be modulated or triggered by the modulation generator to provide AM, FM, sweep or burst. The main generator can also be modulated by an external source connected to the MOD connector on the modulation generator. The frequency of the main generator can be externally controlled by applying an ac or dc voltage to the VCO input.

3-6. The output attenuator has a range of more than 1000:1 so that output levels ranging from 1 mV p-p to 10 V p-p into 50 ohms can be obtained.

3-7. The 3312A has a dc offset capability which allows the dc operating point of the main generator output to be adjusted from -10 V to +10 V dc (as long as the dc offset plus instantaneous ac does not exceed ± 10 V). The dc offset can be adjusted using the front panel OFFSET control or set to 0 V by pushing the associated CAL button.

3-8. CONTROLS AND INDICATORS.

3-9. Figures 3-1 and 3-2 illustrate and describe the function of all front and rear panel controls, connectors and indicators. The description of each item is keyed to the drawing within the figure.

3-10. GENERAL OPERATING INFORMATION.

3-11. Grounding.

3-12. To protect operating personnel, the 3312A chassis must be grounded. All Hewlett-Packard instruments are equipped with a three-conductor power cord, which, when

plugged into the proper receptical, grounds the instrument. The offset pin of the power plug is the ground connection. All input and output commons are connected directly to outer chassis (frame) ground through the offset pin on the power cord.

WARNING

The outer shells of all input and output BNC jacks are connected to the chassis. To protect the operator from electrical shock, DO NOT float this instrument.

3-13. Main Generator Outputs.

3-14. The main generator has two outputs, a main signal output and a sync output. The main signal output (labeled V p-p) provides the sine, square and triangle outputs. The sync output (Paragraph 3-19) provides a pulse which can be used for external timing purposes. Both outputs are BNC connectors located on the front panel of the instrument.

3-15. Main Signal Output.

3-16. The output of the main generator is dc coupled to supply both ac and dc components of the output waveform. The main generator output level is 10 V p-p into 50 ohms. The SYNC output level is .25 V p-p into 50 ohms. Output impedance of both outputs is 50 ohms nominal.

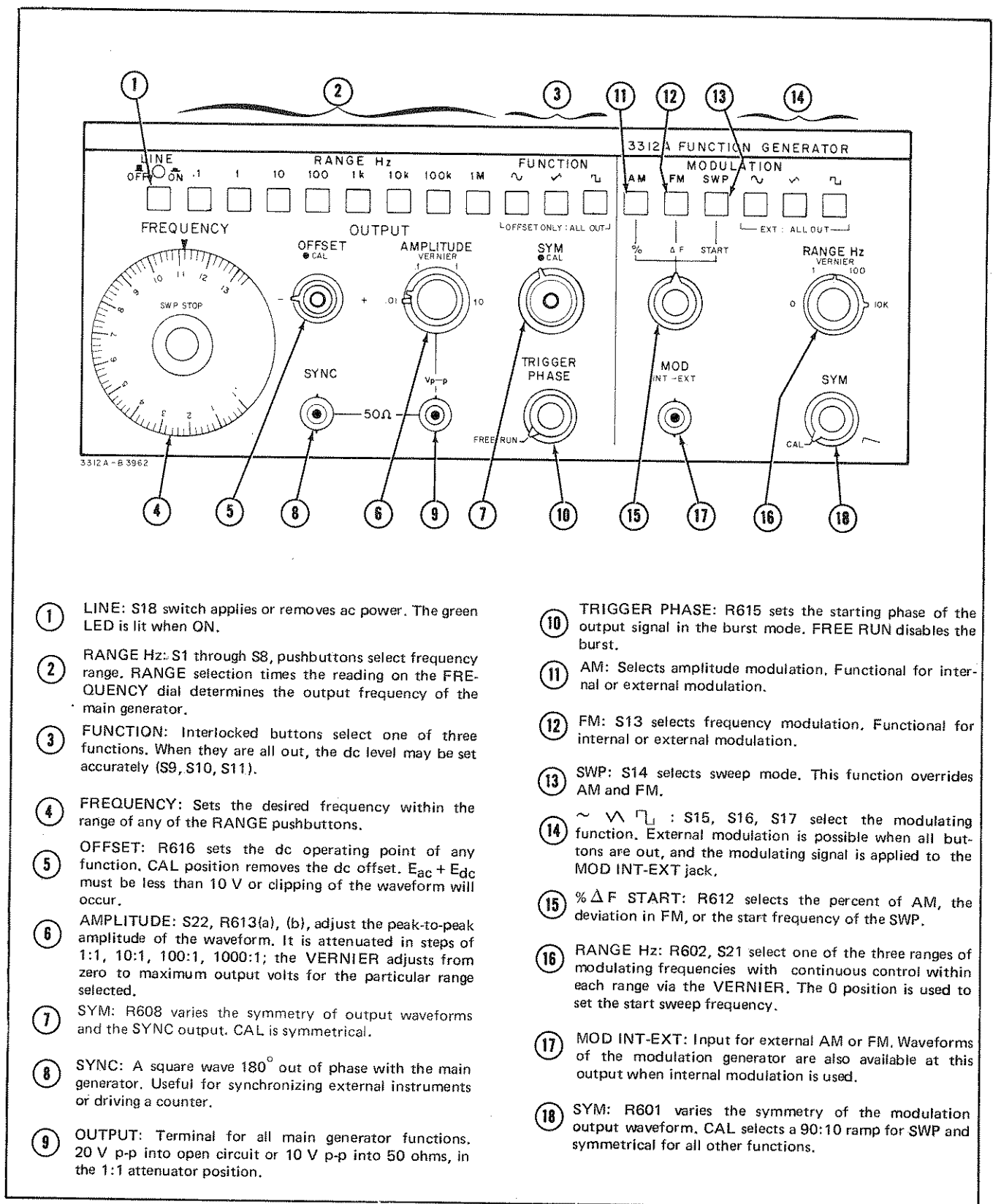
3-17. Connections to this output should be made using shielded cables equipped with BNC connectors. Table 3-1 is a list of recommended -hp- cables. In order for the 3312A to meet the specifications listed in Table 1-1, the main signal output must be terminated into 50 ohms. The -hp- Model 11048C 50 ohm Feedthru Termination is recommended. Always place the termination at the load end of the transmission line.

Table 3-1. Cable Assemblies.

10502A	9" Cable Assembly
11086A	24" Cable Assembly
10519A	72" Cable Assembly

3-18. SYNC Output.

3-19. The SYNC output supplies a one volt rectangular wave which is 180° out of phase with the main generator output signal. The leading edge and the trailing edge of the SYNC pulse occur at the zero crossing point of the output waveform. The frequency and duty cycle of this pulse vary with the main output signal.



- ① **LINE:** S18 switch applies or removes ac power. The green LED is lit when ON.
- ② **RANGE Hz:** S1 through S8, pushbuttons select frequency range. RANGE selection times the reading on the FREQUENCY dial determines the output frequency of the main generator.
- ③ **FUNCTION:** Interlocked buttons select one of three functions. When they are all out, the dc level may be set accurately (S9, S10, S11).
- ④ **FREQUENCY:** Sets the desired frequency within the range of any of the RANGE pushbuttons.
- ⑤ **OFFSET:** R616 sets the dc operating point of any function. CAL position removes the dc offset. $E_{ac} + E_{dc}$ must be less than 10 V or clipping of the waveform will occur.
- ⑥ **AMPLITUDE:** S22, R613(a), (b), adjust the peak-to-peak amplitude of the waveform. It is attenuated in steps of 1:1, 10:1, 100:1, 1000:1; the VERNIER adjusts from zero to maximum output volts for the particular range selected.
- ⑦ **SYM:** R608 varies the symmetry of output waveforms and the SYNC output. CAL is symmetrical.
- ⑧ **SYNC:** A square wave 180° out of phase with the main generator. Useful for synchronizing external instruments or driving a counter.
- ⑨ **OUTPUT:** Terminal for all main generator functions. 20 V p-p into open circuit or 10 V p-p into 50 ohms, in the 1:1 attenuator position.
- ⑩ **TRIGGER PHASE:** R615 sets the starting phase of the output signal in the burst mode. FREE RUN disables the burst.
- ⑪ **AM:** Selects amplitude modulation. Functional for internal or external modulation.
- ⑫ **FM:** S13 selects frequency modulation. Functional for internal or external modulation.
- ⑬ **SWP:** S14 selects sweep mode. This function overrides AM and FM.
- ⑭ **~ ∇ □ :** S15, S16, S17 select the modulating function. External modulation is possible when all buttons are out, and the modulating signal is applied to the MOD INT-EXT jack.
- ⑮ **% Δ F START:** R612 selects the percent of AM, the deviation in FM, or the start frequency of the SWP.
- ⑯ **RANGE Hz:** R602, S21 select one of the three ranges of modulating frequencies with continuous control within each range via the VERNIER. The 0 position is used to set the start sweep frequency.
- ⑰ **MOD INT-EXT:** Input for external AM or FM. Waveforms of the modulation generator are also available at this output when internal modulation is used.
- ⑱ **SYM:** R601 varies the symmetry of the modulation output waveform. CAL selects a 90:10 ramp for SWP and symmetrical for all other functions.

Figure 3-1. Front Panel.

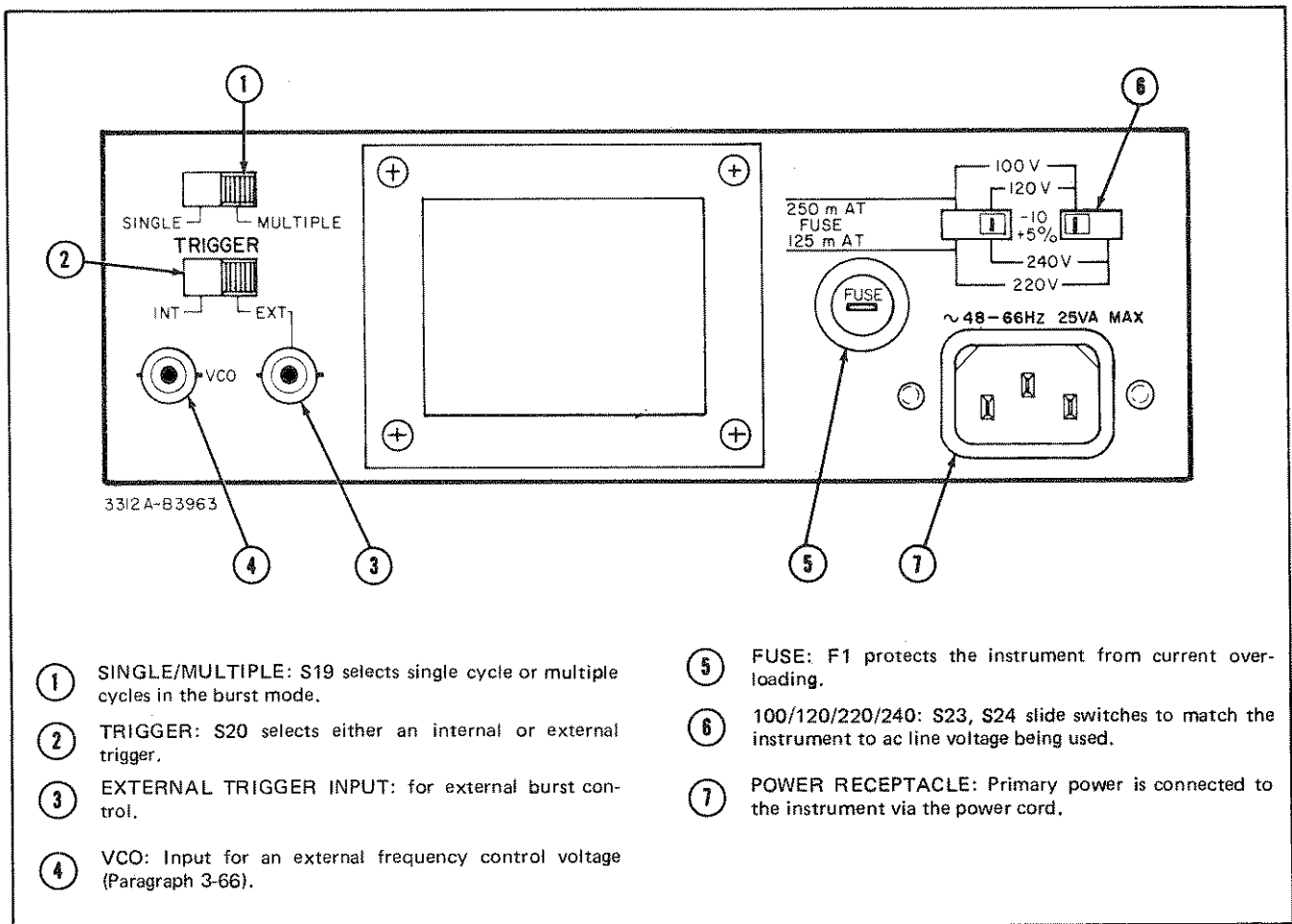


Figure 3-2. Rear Panel.

By connecting the SYNC output to the input of an appropriate frequency measuring device, the output frequency can be set with greater accuracy and resolution. The SYNC output can also be used to trigger an oscilloscope or synchronize an external oscillator.

3-20. Input Constraints.

3-21. The 3312A inputs and outputs are dc coupled. The maximum instantaneous ac plus dc voltages which can be safely applied to the inputs are ± 10 V. In some applications it may be necessary to connect one of the 3312A outputs to an ac or dc source node in a circuit. In these cases, the dc plus instantaneous value of external signal level applied to the 3312A outputs must not exceed ± 10 V.



Exceeding input or output voltages of ± 10 V (dc plus instantaneous ac) can cause damage to the input or output circuitry of the 3312A.

3-22. Modulation Generator Input/Output.

3-23. The BNC connector of the modulation generator

(labeled MOD) serves as both an input and an output. The waveforms from the internal modulation generator (sine, square or triangle) are available at the MOD connector and are useful for synchronizing an oscilloscope when using the AM, FM, or sweep modes. When none of the modulation generator's function buttons is pressed, an external modulation source can be applied through the MOD connector. Refer to Paragraph 3-46 for information concerning external operation.

3-24. The modulation generator input/output is dc coupled and the impedance is a nominal 8 kilohms. Refer to Table 3-1 for recommended cable assemblies to use with the modulation generator.

3-25. Output Characteristics.

3-26. The main generator and the modulation generator supply five different output waveforms.

- a. Sine
- b. Square
- c. Triangle
- d. Ramp
- e. Pulse

3-27. Sine Wave Output.

3-28. The Total Harmonic Distortion (THD) of the main sine wave, including spurious and harmonics, is less than 0.5% from 10 Hz to 50 kHz and greater than 30 dB below fundamental from 50 kHz to 13 MHz. The modulation sine wave distortion is less than 2% THD from 10 Hz to 10 kHz.

3-29. Square Wave Output.

3-30. The RMS value of a symmetrical (50% duty cycle) square waveform is equal to its peak value. The rise or fall time is less than 18 nanoseconds between the 10% and 90% points of the p-p output square wave. The aberrations, or deviations from the final settling amplitude of the square wave after overshoot, will not vary more than $\pm 10\%$ of the final value.

3-31. Triangle Output.

3-32. The RMS value of the triangle waveform is 0.557 times the peak value. The triangle ramp will not deviate from a straight line any more than 1% of the total peak-to-peak value of the ramp. Non-linearity is, therefore, negligible.

3-33. Ramp.

3-34. A ramp output can be obtained from the main generator by selecting the triangle waveform and adjusting the symmetry control knob. The ramp output of the main generator can be varied in amplitude with the AMPLITUDE knob. The ramp output of the modulation generator has a fixed amplitude, however, the slope or retrace time can be varied with the SYM knob on the modulation generator.

3-35. Pulse.

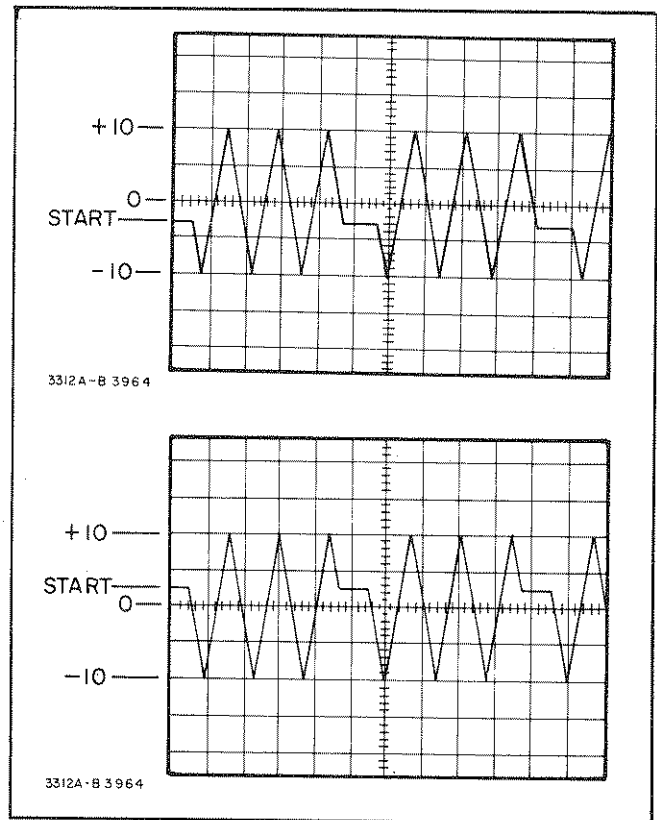
3-36. A pulse with a variable amplitude from 0 V to 20 V p-p into an open circuit, is possible with the main generator. This involves selecting single cycle burst set to start at the zero point with the TRIGGER PHASE knob, and determining the pulse width with the FREQUENCY dial. The SYNC output can deliver a <10 nsec rise time pulse by changing the symmetry of the main generator.

3-37. Gate or Burst.

3-38. The usable frequency range of the burst function is from 0.1 Hz to 10 MHz. The trigger phase can be started anywhere from -80° to $+90^\circ$. The stop will be at that point at the termination of the burst (see Figure 3-3).

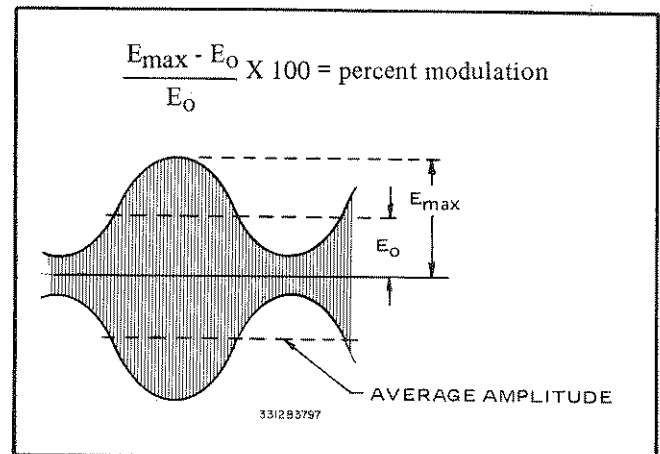
3-39. AM.

3-40. The Main Generator output can be amplitude modulated up to 100%. The modulation frequency ranges from 0.01 Hz to 10 kHz. Any of the modulation generator's functions can be used to AM.

**Figure 3-3. Phase Control of Burst.****NOTE**

The 3312A is capable of $>100\%$ modulation, i.e., the strength of the modulating signal can be greater than needed to just bring the carrier level to zero. Overmodulation may cause distortion of the modulating information.

3-41. The extent of the amplitude variation is expressed as the percentage of modulation. The following formula defines the relationship between F_c and F_m (see Figure 3-4).

**Figure 3-4. Percent Modulation.**

3-42. FM.

3-43. The frequency of the main generator can be varied up to $\pm 5\%$ by the modulation generator. The modulation frequency can be set from 0.01 Hz to 10 kHz, and any of the modulation waveforms can be used to FM.

3-44. SWP.

3-45. When the SWP button is pressed, the modulation generator produces a linear ramp which sweeps the frequency of the main generator. With the RANGE Hz knob in the 0 Hz position, the "Sweep Start" frequency can be set. The stop frequency, or the frequency at which the sweep terminates, is set with the main frequency dial. The rate of sweep is governed by the SYM knob.

3-46. External Control.

3-47. The front panel MOD INT-EXT input/output connector is to be used for external amplitude modulating or frequency modulating the main generator. For AM operation, an external input of less than 10 V p-p will give 100% modulation. For FM operation, the external frequency may be varied from dc to greater than 50 kHz. The AM and FM pushbuttons must still be used.

3-48. The frequency of the main generator can be tuned remotely by applying 0 V to -2 V dc to the VCO connector on the rear panel. With the dial set to 10, any range can be varied over the entire dial range within the limit set by the range pushbuttons. Frequency modulation can also be accomplished by applying an ac voltage to the VCO terminal. Simultaneous AM and FM is possible with the VCO input used to vary frequency and the MOD input used for the AM signal.

3-49. Frequency.

3-50. The frequency range of the main generator is 0.1 Hz to 13 MHz in eight overlapping ranges. The dial accuracy is $\pm 5\%$ of full scale which means that the greatest accuracy will be obtained at the high end of the dial. For instance, if the dial were set to "1" on the 1 kHz range, the output frequency would be 1 kHz ± 650 Hz. If, on the other hand, the dial were set to "10" on the 100 Hz range, the output frequency would be 1 kHz ± 65 Hz.

3-51. The frequency range of the modulation generator is 0.01 Hz to 10 kHz. The RANGE Hz knob selects the upper frequency limit and the VERNIER is used to select frequencies within the selected range.

3-52. Amplitude.

3-53. The amplitude of the main generator can be adjusted from 0 to 20 V p-p into an open circuit or from 0 to 10 V p-p into 50 ohms. Amplitude of the modulation generator is fixed at 1 V p-p into an open circuit, except in SWP operation (Paragraph 3-45).

3-54. BASIC OPERATING PROCEDURES.**3-55. Instrument Turn-On.**

- Check the line voltage at the point of installation.
- Refer to Figure 3-5. Set the rear panel Line Selector switches to the setting that corresponds with the line voltage to be used. Line voltage must be within -10% to +5% of the selected voltage setting. Line frequency must be within the range of 48 Hz to 66 Hz.

Line Voltage	S1	S2
100	Left	Left
120	Right	Left
220	Left	Right
240	Right	Right

Figure 3-5. Line Selector Switches.

- Verify that the proper fuse is installed in the rear panel fuse holder.

Line Setting	Fuse Type	-hp- Part No.
100 V/120 V	.25 A 250 V Slo Blow	2110-0201
220 V/240 V	.125 V 250 V Slo Blow	2110-0318

- Connect the detachable ac power cord to the rear panel power receptacle.

- Set the LINE switch to the ON position. The green light will illuminate.

3-56. Fuse Replacement.

3-57. The main ac line fuse is located on the rear panel next to the line power receptacle. Remove the line power cord before attempting to remove the fuse. Figure 3-6 shows how to replace the fuse.

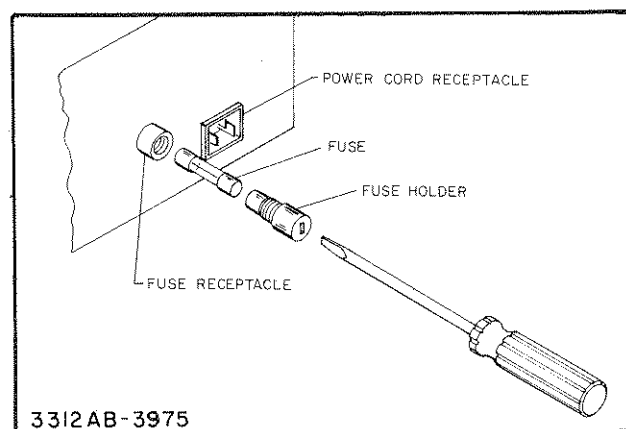


Figure 3-6. Fuse Replacement.

3-58. Main Generator Operation.

3-59. The sine triangle and square waveforms, selected with interlocking pushbuttons, are available at the BNC output jack. The RANGE Hz pushbuttons and frequency dial select frequencies from 0.1 Hz to 13 MHz in eight overlapping ranges. The frequency dial scale must be multiplied by the RANGE Hz setting to obtain the frequency.

3-60. With the AMPLITUDE knob in the 10 position and no load, a 10 volt peak signal is selected. The VERNIER control adjusts the voltage from greater than 10 volts to 1 volt at that setting. In the 1 position the voltage is adjustable from 1 volt to .1 volts; in the .1 position the voltage is adjustable from .1 volts to .01 volts; and in the .01 position from .01 volts to 0.

3-61. The symmetry of any waveform can be varied with the SYM knob. The square waveform can be varied from symmetrical to a ratio of 80:20 to 20:80 up to 1 MHz.

3-62. OFFSET changes the dc level of the waveform. The CAL button eliminates dc offset. The peak ac voltage plus the dc offset should not exceed 10 V to avoid clipping of the output waveform.

3-63. Burst.

3-64. With the rear panel TRIGGER switch (2) set to INT, the upper slide switch (1) set to either SINGLE or MULTIPLE, and TRIGGER PHASE (10) out of the FREE RUN position, internal burst is initiated. The TRIGGER PHASE knob controls the starting and stopping phase of the output waveform. The SINGLE-MULTIPLE switch selects a single cycle or multiple cycles respectively. Pulses are obtained only when the square wave function is pushed.

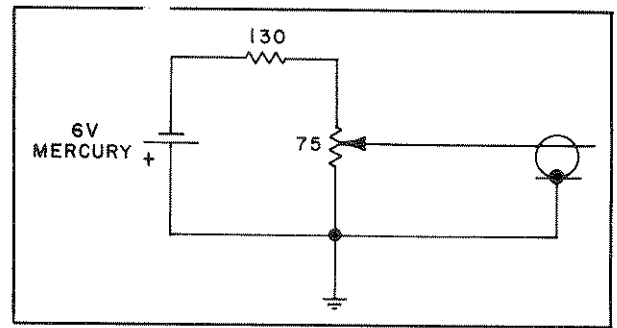


Figure 3-7. External VCO.

The pulse width is set by the main generator's FREQUENCY dial and the modulation generator's RANGE Hz knob sets the repetition rate. The TRIGGER PHASE knob in the FREE RUN position disables the burst (see Figure 3-11 for burst operation).

3-65. With the rear panel slide switch (2) set to EXT, an external burst may be applied in either single or multiple cycles. TRIGGER PHASE is still operational. The external gating signal frequency range is from dc to 1 MHz. The input voltages must be TTL compatible.

3-66. VCO.

3-67. A dc voltage from 0 V to -2 V applied to the rear panel VCO connector is sufficient to vary the frequency of the main generator over three decades. Since some dc power supplies induce some noise, a supply similar to the one in Figure 3-7 works well.

3-68. Modulation Generator Operation.

3-69. Figures 3-8 through 3-10 are operating illustrations containing step-by-step operating procedures indexed to the

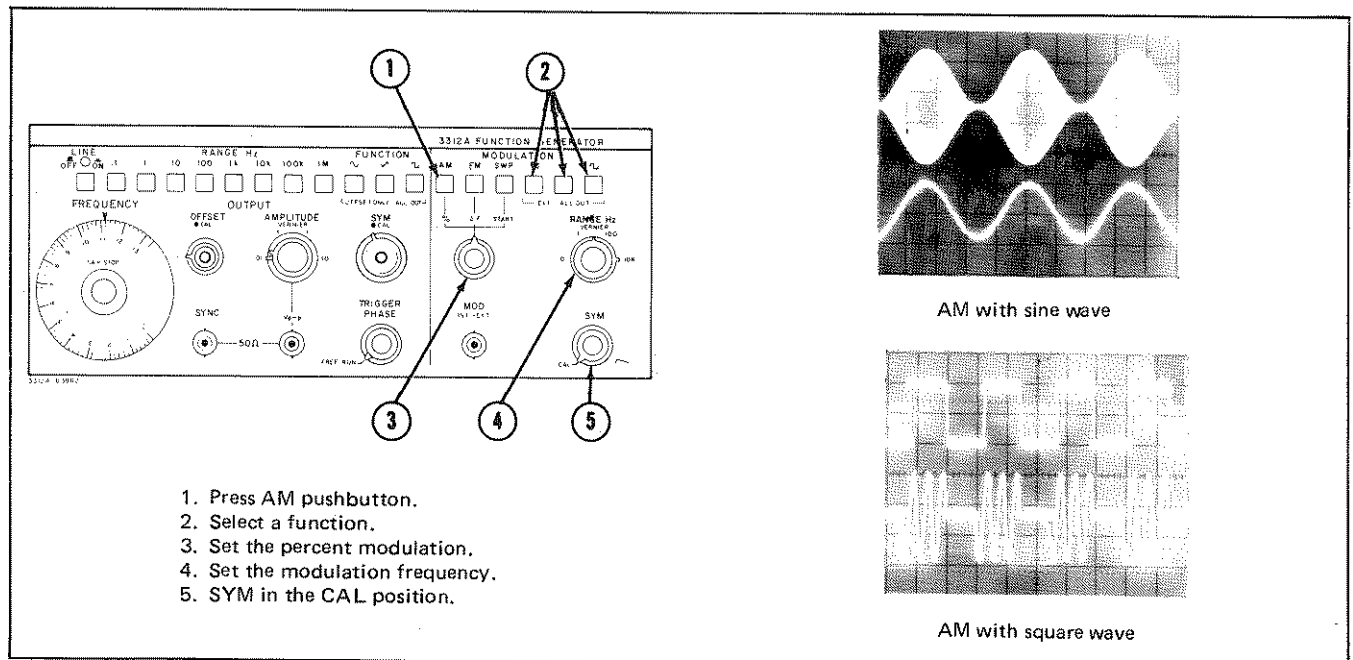


Figure 3-8. AM Operation.

illustrations. The figures describe the operations to be accomplished in achieving the different modes of operation.

3-70. The operating procedure must be performed in the

sequence given, as succeeding steps may depend on control settings and results of previous steps. In all cases, it is assumed that the main generator is set to the frequency and amplitude desired and that *all* modulation generator function pushbuttons are in the OUT position.

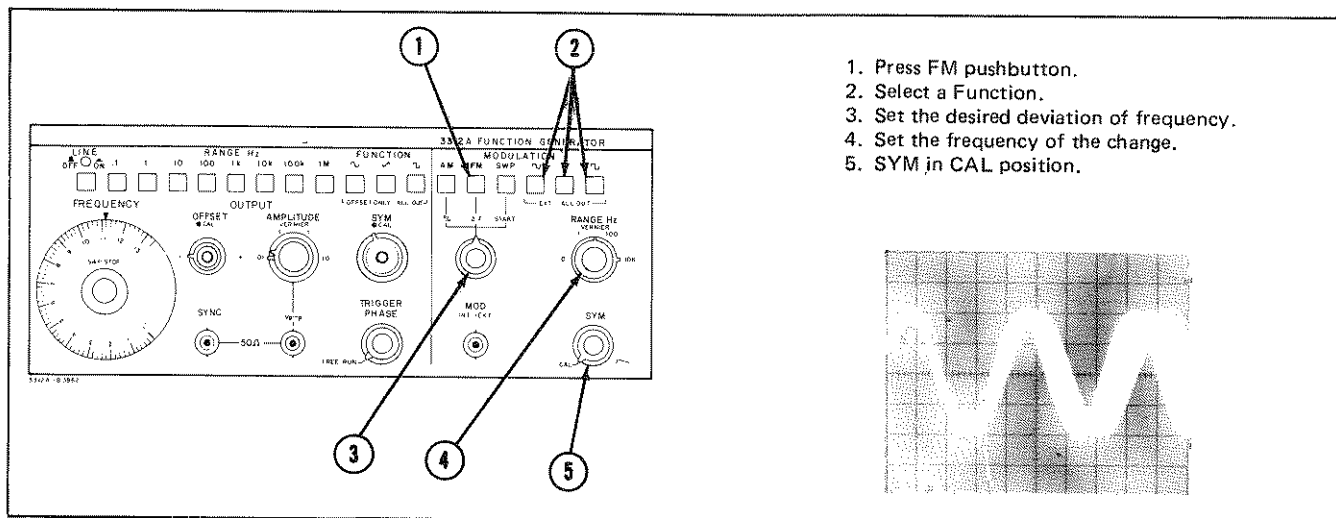


Figure 3-9. FM Operation.

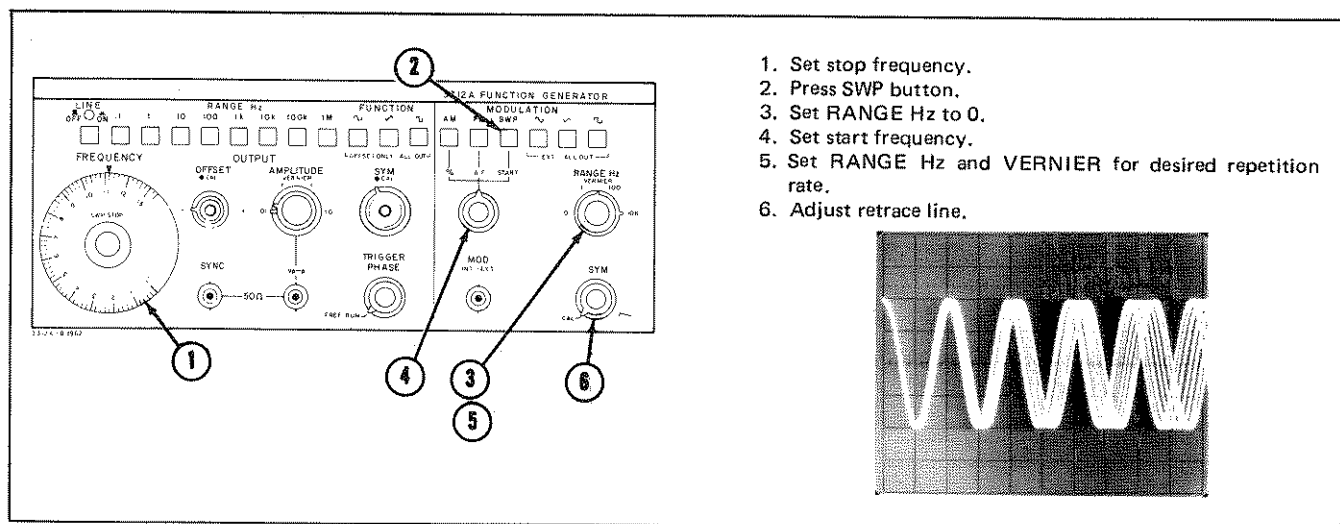


Figure 3-10. Sweep Operation.

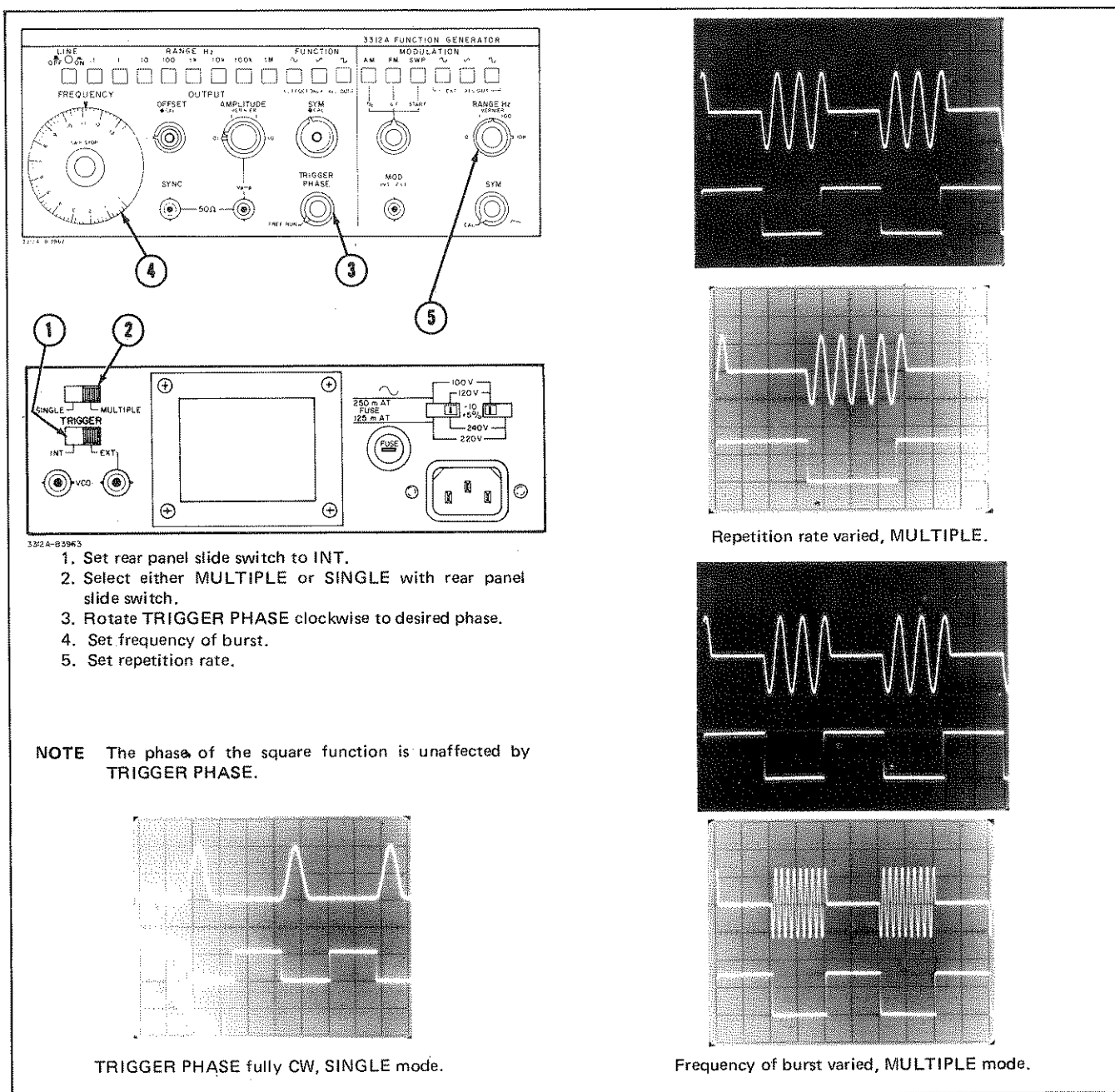


Figure 3-11. Burst Operation.

SECTION IV

THEORY OF OPERATION

4.1. INTRODUCTION.

4-2. This section contains a complete theory of operation for the Model 3312A Function Generator. The theory is divided into two levels:

1. Basic Block Diagram Description
2. Functional Block Diagram Description

Detailed circuit descriptions are given for unique complex circuits. These descriptions may be helpful when troubleshooting the instrument.

4.3. DESCRIPTION.

4-4. The 3312A combines two separate, independent function generators referred to as the main generator and the modulation generator. The main generator output can be controlled by the modulation generator. The major features of the 3312A are the 0.1 Hz to 13 MHz frequency range of the main generator and the AM, FM, sweep and tone burst capabilities of the modulation generator. A basic block diagram of the 3312A is shown in Figure 4-1.

4.5. BASIC BLOCK DIAGRAM DESCRIPTION.

4-6. The main generator of the 3312A uses a voltage to frequency conversion technique. A triangle waveform is generated by charging and discharging a capacitor from a constant current source. The time required to charge and discharge the capacitor determines the period of one cycle and, therefore, the frequency.

4-7. The triangle waveform from the Triangle Generator is applied to the Voltage Comparator which acts as an amplitude limiter. As the triangle waveform alternately crosses the upper and lower switching levels of the limiter input, a square wave is generated at the output of the Voltage Comparator. This square wave is fed back to the Triangle Generator where it controls the charge/discharge cycle of the triangle output.

4-8. To obtain a sine wave, the triangle wave is shaped by a diode network in the Sine Shaper. The diode network serves as a non-linear load which varies the attenuation of the input triangle according to its level.

4-9. The modulation generator can amplitude modulate, frequency modulate, sweep, or initiate a burst from, the main generator output. Sweep and frequency modulation modes control the voltage output of the tuning amplifier which determines the frequency. In amplitude modulation, the main signal is routed through a balanced modulator where it is mixed with the modulating signal. The percent of modulation is controlled by the level of the modulating signal.

4-10. The tone burst is accomplished by gating the main generator output on and off. Multiple or single cycle operation is determined by the duration of the low state of the Burst Control.

4-11. The output amplifier has separate parallel paths for the high and low frequencies. This gives it wide bandwidth and a high slew rate to maintain good square and triangle wave shape without compromising dc stability and low offset. An integrated-circuit operational amplifier is used

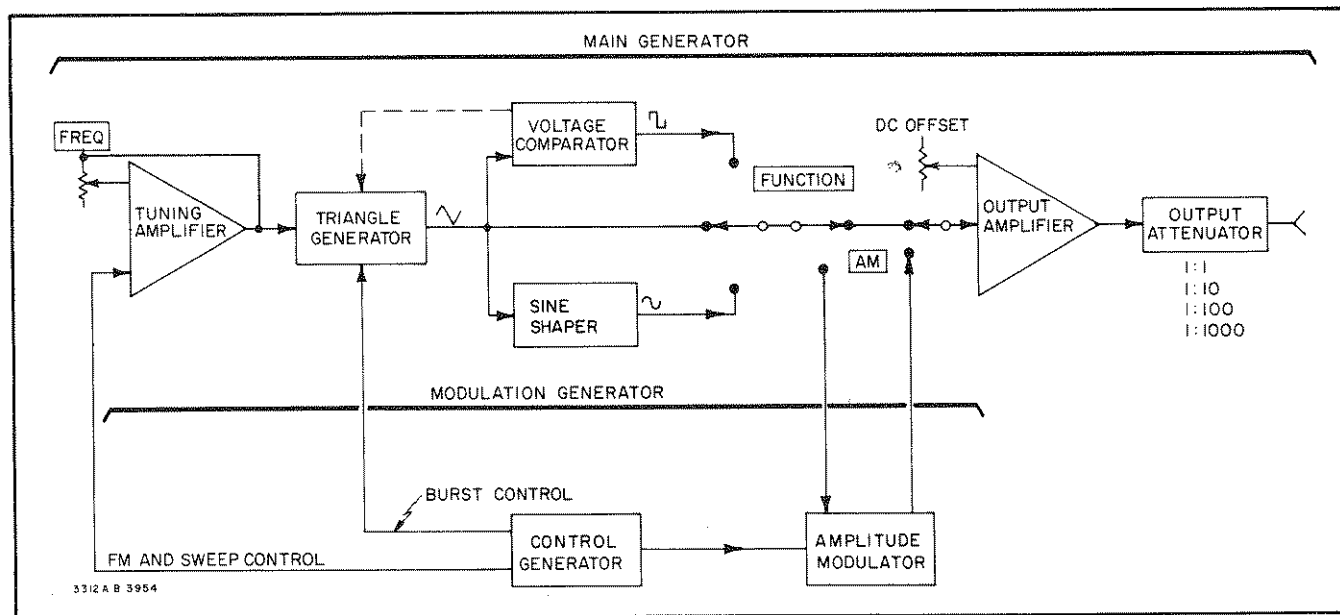


Figure 4-1. Basic Block Diagram.

for the low frequencies while the ac-coupled high-frequency path is optimized for wide bandwidth. The two paths are summed in the final gain stage and then buffered through cascaded emitter-followers to the output.

4-12. The Output Attenuator provides selectable attenuation for the output and an impedance match to the 50 ohm output terminal. The attenuator reduces the amplitude of the output signal by factors of 1, 10, 100, or 1000.

4-13. FUNCTIONAL BLOCK DIAGRAM DESCRIPTION.

4-14. Refer to the Functional Block diagram, Figure 7-1 for the following discussion. Detailed circuit descriptions are referenced to figures or to the circuit diagrams of Section VII.

4-15. The 3312A can be divided into three major sections:

1. Main Generator Section (Paragraph 4-16)
2. Output Section (Paragraph 4-29)
3. Modulation Section (Paragraph 4-33)

4-16. Main Generator Section.

4-17. **Tuning Amplifier.** The Tuning Amplifier is a summing amplifier which sums any current from the VCO INPUT or the modulation source with the current present at the input of the amplifier. The output voltage of the amplifier is a weighted average of the input signal voltages. The Frequency Control (Dial) varies the amount of voltage seen at the output of the Tuning Amplifier, which determines the frequency.

4-18. **Symmetry Switch and Vernier.** The front panel Symmetry Switch operates in two modes. With the front panel control in the CAL position (Figure 4-2) the output of the Tuning Amplifier is connected, through two nominal 5 kΩ resistors, to the non-inverting input of U102 and the inverting input of U103. Because the gain of U102 is equal to that of U103, the magnitude of the voltage at the emitters of Q101 and Q102 is equal, but due to the inversion of U103, the emitter of Q101 is positive with

respect to ground and the emitter of Q102 is negative with respect to ground. In the calibrated position, equal currents flow through R122 and R123.

4-19. During variable symmetry operation (Figure 4-3), the output of the Tuning Amplifier goes to the wiper arm of the symmetry Vernier, and the junction of R122 and R123 is grounded. Adjusting the position of the wiper arm varies the input resistance of U102 and U103 and, therefore, the gain. The emitters of Q101 and Q102 will remain opposite in polarity, but the magnitude of the voltage will differ. In addition, different currents will flow through R122 and R123, which means different currents in the integrating capacitance, so that the output waveform will no longer have a 50% duty cycle. Instead, the duty cycle may be varied from 80% to 20% or 20% to 80%.

4-20. **Positive and Negative Current Sources.** The voltages set up by the symmetry stage are transferred to the integrating current sources through two operational amplifiers. Since amplifier input impedance is near infinity, zero current flows into the amplifier, consequently the voltage across R119 + R121 and R124 will appear across R117 and R126 respectively. The collector diodes of Q106 and Q107 (Figures 7-2) are current sources controlled by the emitter current established by R117 and R126. The RANGE Hz switches change the parallel resistances of R117 and R126 which influence the ramp time of the integrating capacitance and, therefore, the frequency.

4-21. **Diode Switch.** The gating circuit of the Diode Switch (Figure 7-2) allows for the charge or discharge of the integrating capacitance. The high speed comparator, U201 (Figure 7-3), controls the signal path through the switch. When pin 2 of U201 is high, CR204 and CR206 are conducting, CR203 and CR207 are reverse biased, and the integrating capacitor charges. When pin 2 goes low, CR203 and CR207 conduct, CR204 and CR206 are reverse biased, and the integrating capacitor discharges.

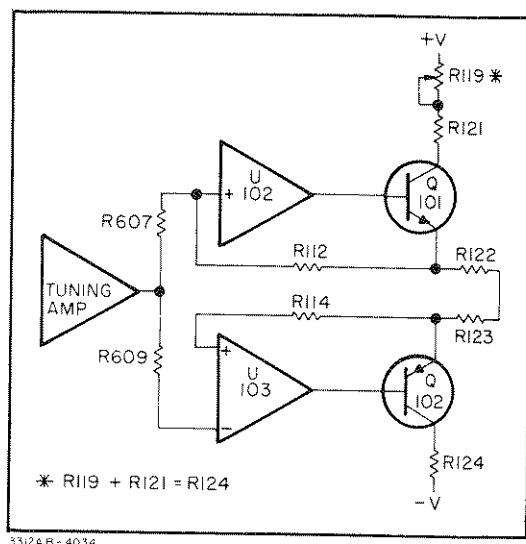


Figure 4-2. Calibrated Symmetry.

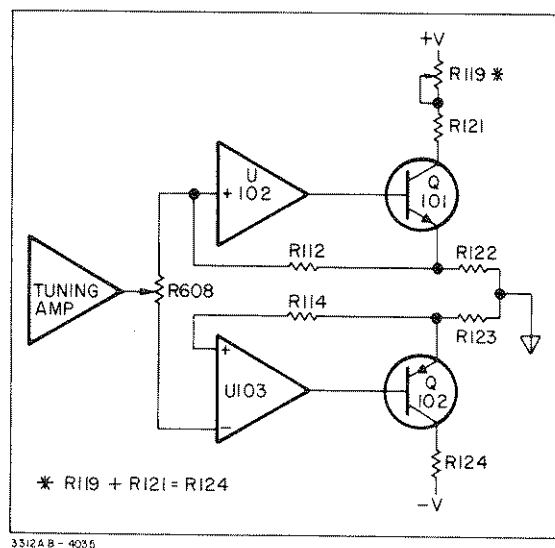


Figure 4-3. Variable Symmetry.

4-22. When the diode switch is reverse biased there is a diode capacitance which distorts the peak of the triangle (see Figure 4-4). This distortion is removed by the level shifting circuit of Q401 and C404. The square wave at the collector of Q401 is passed through the ac voltage divider of C404 and added to the triangle wave to eliminate the "drop-off" caused by diode capacitance.

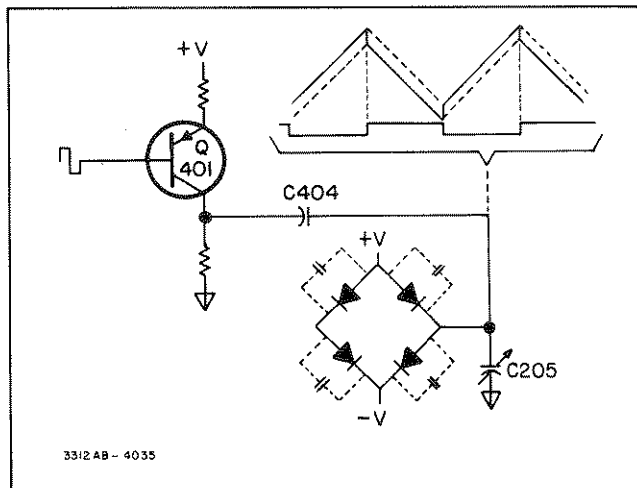


Figure 4-4. Level Shifter.

4-23. Integrating Capacitance. The integrating capacitors are C205, C201, C202, C203, C204, and C206. Because the current charging and discharging is constant, except for direction, the voltage across the integrating capacitance will be triangular. The resulting waveform is varied in frequency by changing the current and capacitance with connections through the RANGE Hz switches and the FREQUENCY dial.

4-24. Buffer Amplifier. The Buffer Amplifier (Figure 7-2) has a gain of one and consists of a FET input and a push-pull output. The high input impedance of the FET provides isolation, and the emitter followers Q202 and Q203, form a push-pull circuit. Diodes CR209 and CR211 are temperature compensating diodes.

4-25. Comparator. While the integrating capacitor is charging, the positive-going ramp is applied to pin 4 of U201 (Figure 7-3). The positive-going ramp is compared in magnitude, to the square wave on pin 2. Upon coincidence, the Comparator changes state, reversing the biasing of the gating diodes, and the integrating capacitance discharges. Coincidence of the negative-going ramp with the square wave now at its negative limit, switches the Comparator back to the original state, completing one cycle of operation.

4-26. The square wave output of U201 pin 5 is processed by a ± 5 V diode clamping network to provide the square wave output.

4-27. Sync Generator. The Sync Generator is a simple divider network which attenuates the output of the ± 5 V

clamp. The sync output is, therefore, always a square wave in phase with the main generator (180° out of phase with the square wave output due to output amplifier inversion) and under the control of the Symmetry Switch.

4-28. Sine Shaper. The triangle wave from the Buffer Amplifier (Figure 7-3) is connected through R257 to the sine synthesizing diodes. The diodes of the sine network are reverse biased by the resistive dividers made up of R259, R262, R263, etc. As the triangle ramp goes positive, the bias is overcome and the diodes in the lower half turn on to produce a non-linear loading effect on the triangle wave. When the ramp reaches a negative level, the upper half of the sine shaping network begins to load the triangle wave thus shaping the negative half of the wave. The diodes in this section are selected for their soft turn-on characteristics to insure a smooth sine-shaped curve.

4-29. Transistors Q216, Q217, Q218 and Q219 compensate for thermal changes. This insures that the proper bias level is maintained over a wide temperature range. In the Model 3312A, the sine shaper is followed by a low-pass LC filter that has a sharp cutoff at 14 MHz. This filter attenuates third harmonics substantially at generator frequencies above 5 MHz, enabling the instrument to produce sine waves with all harmonics more than 30 dB below the fundamental up to its maximum frequency.

4-30. Output Section.

4-31. The output section consists of the Output Amplifier and the Output Attenuator (Figure 7-4).

4-32. The amplifier system has a voltage gain of - X16 and has been impedance matched on both sides. The ac signal is coupled through Q501 to Q502 and Q503. To obtain a frequency response that extends to zero, the main output is direct coupled to U501 and then to the complementary stage of Q504 and Q507. The dc offset is summed into pin 2 of U501 via R504. In the CAL position, R504 is opened and no offset is summed into the output amplifier.

4-33. The output is dc coupled to the output attenuator. The step attenuator consists of resistive attenuator sections of 20 dB steps with an impedance of 50 ohms.

4-34. Modulation Generator.

4-35. Signal Generator. Basic to this circuit are the integrator U301 and the comparator U302 (Figure 4-5). By integrating the square wave at its input the integrator generates a triangle wave. The level of the triangle is then compared to the square wave and when the voltage at the input node to the comparator equals zero $[R_1(E_3 - E_2/R_1 + R_2) = E_2]$ the comparator output switches states. The square wave output from the comparator is then inverted, clamped and fed back to the inverter to control the generation of the triangle wave.

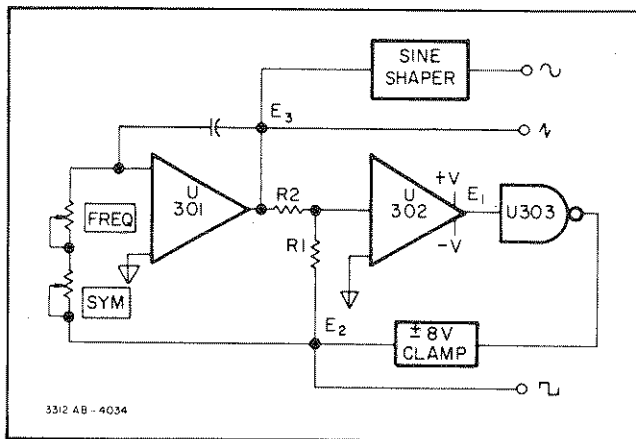


Figure 4-5. Signal Generator.

4-36. Amplitude Modulation. The AM modulator (Figure 7-4) is a balanced modulator which mixes the carrier signal from the main generator with the modulation signal from the modulation generator. The carrier frequency is applied to pin 7 of U404 and the modulation signal is input to pin 4. Modulation amplitude control resistor R612 attenuates the modulation signal to control the envelope of the output signal.

4-37. Frequency Modulation and Sweep. During FM and sweep operation the output of the modulation generator is applied directly to the Tuning Amplifier of the main generator. In FM operation (Figure 4-6), R612 controls the percent of deviation in frequency of the carrier waveform. The change in frequency is limited to $\pm 5\%$ of the carrier frequency by current limiting resistor A1R426. All three functions of the modulation generator are available for modulating the main generator output frequency.

4-38. When the SWP pushbutton is pressed, resistors R303 and R308 are selected. If R601 is in the CAL position, the output of U301 is a 90:10 ramp (Figure 4-7). As R601 is rotated clockwise, t_2 increases and flyback time is increased.

4-39. The 0 Hz position of the RANGE Hz knob allows pin 5 of U303 (Figure 7-5) to go high producing a low at pin 6 of U303 and at the emitter of Q302. Q302 begins to conduct, turning Q301 on and forming a loop with U302, Q302, Q301 and U301. In SWP the square wave is held at its high level and the triangle wave ramps to -10 V then

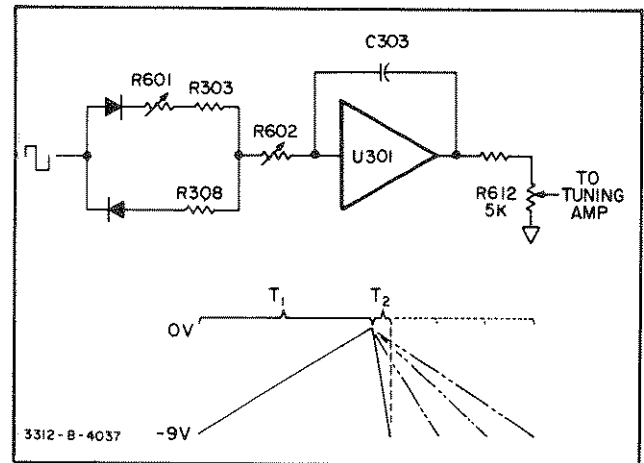


Figure 4-7. Sweep Operation.

stops. Start frequency, for the sweep of the main generator output, can then be selected with R162. R162 affects the frequency of the main generator by determining the negative voltage level at which the ramp starts. Taking the RANGE Hz knob out of the 0 Hz position starts the modulation generator running and, as the ramp voltage approaches zero volts, the output frequency of the main generator approaches the frequency of the dial setting.

4-40. Burst. At any setting other than FREE RUN, the tone burst gate is operable. The start/stop phase of the tone burst is determined by R615 (Figure 4-8) and the transistor array U403. The signal always stops in the same phase as it started.

4-41. When TRIGGER PHASE is in FREE RUN the line from the Burst Control is open and U402A pin 2 is pulled low by the negative supply causing a high at the output of U402A. As a result Q402 and U403(c) turn on and U403(a) and (b) turn off. With U403(a) off, CR408 is reverse biased and no charge is drawn off the integrating capacitor allowing the main generator to free run.

4-42. In TRIGGER PHASE a low from the burst control appears on U402A pin 2 forcing the output of U402A high and starting the burst. When the burst control line goes high again followed by a positive transition of the square wave (at U402A pin 1) the output of U402A goes low. Q402 now turns off allowing TRIGGER PHASE POT, R615, to

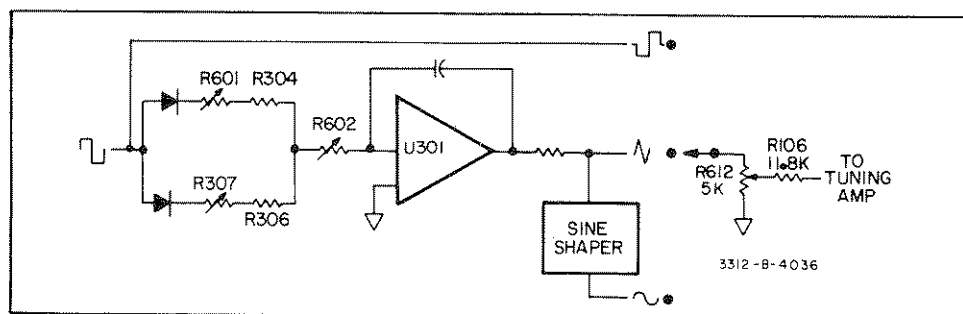


Figure 4-6. FM Operation.

determine the voltage at the base of U403(c) and in turn at the base of U403(b). When the voltage from the main generator (via the BUFFER AMPLIFIER) appearing at the base of U403(b) equals that at the base of U403(c), both U403(a) and (b) turn on and U403(c) turns off. CR408 forward biases and clamps the integrator output to the voltage at the base of U403(c) (which was originally determined by TRIGGER PHASE POT, R16). With the integrator output held at that level the comparator does not switch the current sources resulting in a dc level at the square wave output. When the burst control goes low again the voltage on the integrating capacitor will determine the phase at which the burst restarts. Thus, R615 controls the start/stop phase.

4-43. Multiple Cycle Burst Mode (Figure 7-3). The main generator is gated off when the burst logic sees a positive square wave transition *after* the burst input to U402 pin 2 goes high. If the main square wave is already high, the main generator will not be gated off until the main square wave first goes low then returns high. The waveforms in Figure 4-9 should serve to clarify the operation of the burst logic.

4-44. Single Cycle Burst Mode. In single cycle operation (Figure 7-3), U402A pin 2 is driven from U401, a monostable one-shot multivibrator. After being inverted the output of U402 is normally high. Triggering of U401 causes U402A pin 2 to go low for 40 nanoseconds, after which it returns to its quiescent high state. This 40 nanosecond low pulse is sufficient to start the main generator. Since pin 2

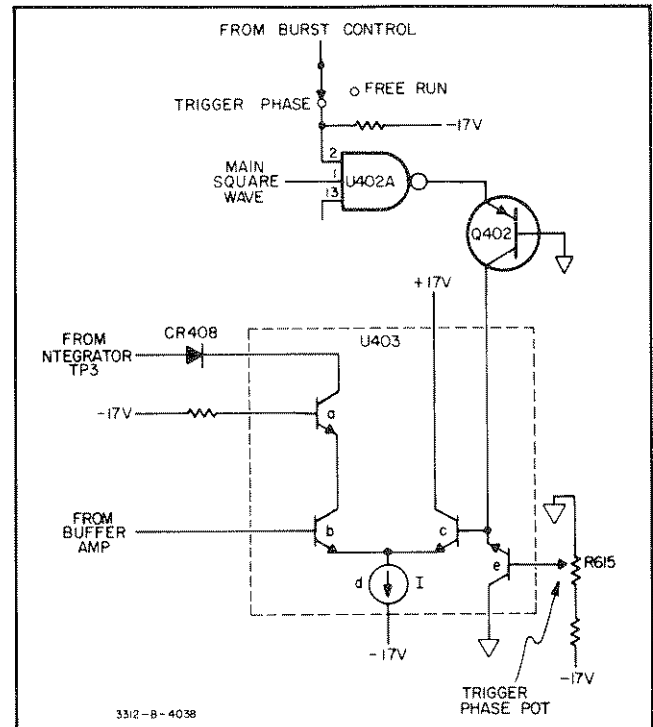


Figure 4-8. U403 Burst Amplifier Array.

almost immediately returns to a high state, the main generator runs until the triangle returns to its start/stop phase position, at which time the generator stops, completing one cycle of operation.

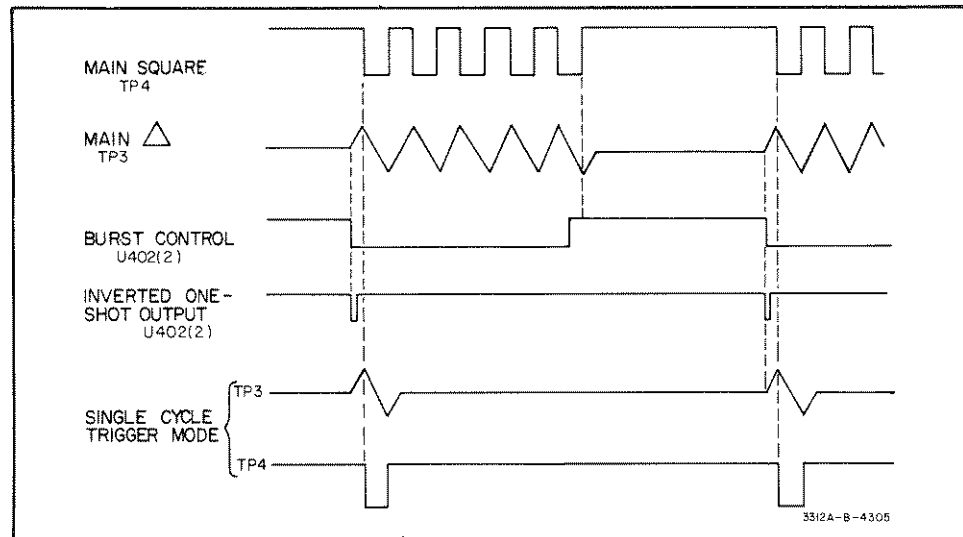


Figure 4-9. Burst Time Relation Waveforms.

C

C

C