MODEL bwd 603 MINI-LAB

BWD ELECTRONICS PTY. LTD.
VICTORIA, AUSTRALIA

INSTRUMENT HANDBOOK

(Issue 2) Applicable from Serial No. 18700

Applicable to Serial No. 18784

MODEL bwd 603 MINI-LAB

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INSTRUMENT HANDBOOK

MODEL bwd 603 MINI-LAB

1. GENERAL

The MINI-LAB provides six independent instruments in a single compact cabinet for use in the laboratory or classroom to supply signals and power for a wide range of measurements and experiments in the fields of electronics, chemistry and bio-medical engineering.

The functions available include : -

(a) A sine, square and triangular generator with symmetry and DC offset controls to produce pulses, amplitude modulation and frequency modulation.

(b) A power amplifier which doubles as a bi-polar power supply.

(c) An operational amplifier for use in analog experiments and as a variable gain voltage amplifier.

(d) A variable ±15V, floating power supply.

(e) A +200V variable power supply.

(f) A 12.6V AC centre tapped supply, and

(g) Numerous instrument combinations by link interconnection.

2. PERFORMANCE

2.1 Function Generator

Sine, square and triangular waveforms available by switch selection.

Frequency Range :	0.01Hz to 1MHz.
Calibration :	±3% of full scale above 10Hz.
Output Voltage :	10V p-p continuously variable to <0.1V open circuit, 600Ω source impedance. 5V p-p into 600Ω load.
Output DC Offset :	Continuously variable from zero to + or - 5V.
Output Level :	< ±2% over calibrated range in 600Ω load.
Sine Distortion :	< 1.5% 10Hz to 50kHz. < 3% at 1MHz.
Square Wave Rise Time :	< 100nSec. into 600Ω load and < 50pF capacitance.
Triangle Linearity :	> 95% within calibrated range on dial up to 100kHz.
Triangle Symmetry :	Better than 2% within calibrated range on dial up to 100kHz.

2. PERFORMANCE (Cont'd)

Pulse Output :	Variable mark-space ratio up to 10-1 for frequencies to 100kHz.
Frequency Modulation :	Maximum sweep range 100-1 with 0 to +10V input into 33KΩ. Linearity 2% DC to 10kHz modulation range.
Amplitude Modulation :	0-95% modulation of all waveforms for an input of 10V p-p. Carrier bandwidth 10Hz to 1MHz.

2.2 Power Amplifier / Bi-Polar Power Supply

Either facility available by switch selection.

Amplifier Gain :	Voltage fixed x10. Current approx. 3000.
Amplifier Frequency Response :	DC to >20kHz.
Amplifier Rise Time :	< 20uSec. for ±10V output. 1V/uSec. slew rate.
Amplifier Input Impedance :	10KΩ.
Amplifier Output :	30V p-p, 1 Amp. current overload. 7 Watts into 8Ω load.
Hum and Noise :	60db below max. output.
Power Supply Output Voltage :	Continuously variable from -15V through zero to +15V. 1 Amp. current overload.
Output Impedance :	< 0.2Ω.
Hum and Noise :	< 25mV at max. output.

2.3 Operational Amplifier

Voltage Gain :	Continuously variable from x1 to x100.
Input Polarity :	Inverting and non-inverting input available.
Slew Rate :	0.5V/uSec. at unity gain.
Frequency Response :	DC to 40kHz, gain <10, output <5V. DC to 5kHz, gain <80, output <15V.
Output Impedance :	< 1Ω.
Output Noise :	20mV p-p with open circuit inputs and maximum gain.

2. PERFORMANCE (Cont'd)

2.4 Low Voltage Power Supplies

Output Voltage :	Two variable outputs with common isolated from chassis to 200V DC. Outputs are +1 to +15V and -1 to -15V or ±1 to ±30V.
Output Current :	1 Amp maximum at each output with constant current overload.
Regulation :	1% for a 10% line change or a 0 to 1 Amp. load change.
Hum and Noise :	5mV rms at full load.

2.5 High Voltage Power Supply

Output Voltage and Current :	0 to +200V DC at 20mA. 0 to 175V at 25mA. Current overload approximately 40mA. Output referred to ground.
Regulation :	1% for a 10% line change or 0-25mA load change at 150V output.
Hum and Noise :	< 25mV rms at full output.

2.6 AC Supply

Output Voltage :	6.3V - 0 - 6.3V AC, centre tap to chassis.
Output Current :	1 Amp each side, separately fused.

2.7 Power Requirements

90 - 135V
190 - 265V
50 - 60Hz
150 Watts max.

3. OPERATION AND USE

3.1 Function Generator

Set controls as follows : -

(a) Range switch to x1kHz.

(b) Symmetry to centre.

(c) Offset to zero.

(d) Function to square.

(e) AM to OFF.

(f) Output amplitude to 10.

(g) Dial to 1.

Connect an oscilloscope to the function generator output terminals and set the oscilloscope vertical attenuator at 0.5V/cm, and the time base to 0.5mSec/cm. The square wave visible on the oscilloscope should be swinging evenly either side of zero volts with a mark space ratio of 1:1 and should be 1cm for each half cycle horizontally and approximately 2cm in amplitude.

Vary the symmetry control from one extreme to the other and note the effect on the waveform. Return the symmetry control to zero.

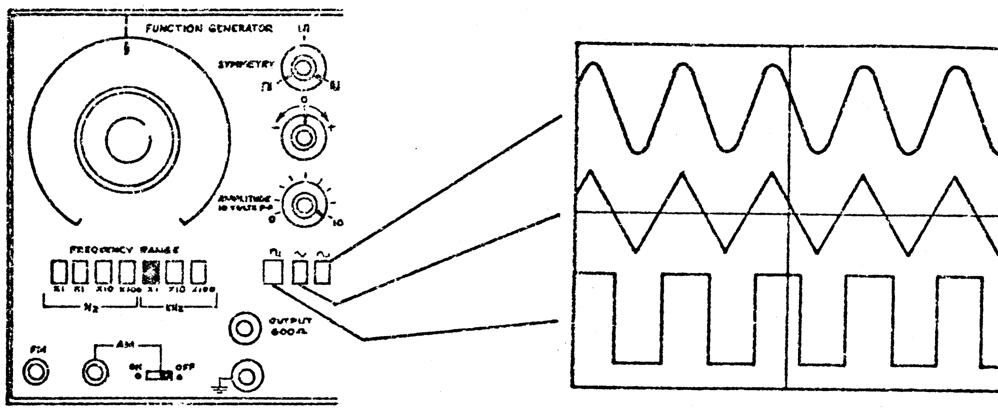
Vary the DC offset control from one extreme to the other and note that the DC level of the waveform changes. Return the offset control to zero.

Select triangle and then sine and note the effect on the waveform of the offset control.

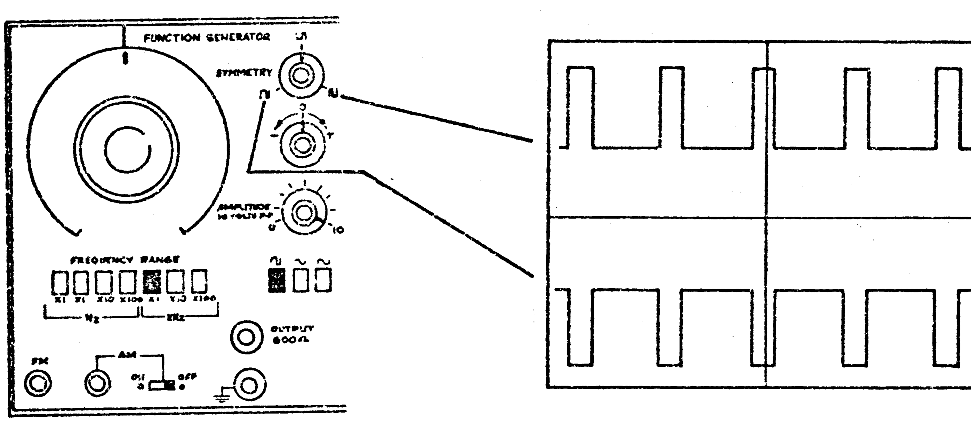
Vary the frequency vernier and note the change in frequency of the waveform.

Interconnections, waveforms and oscilloscope settings for basic signals are shown in the following diagrams. Selected push-buttons are shown shaded and control positions marked.

3.1.1 Sine, Square, Triangle

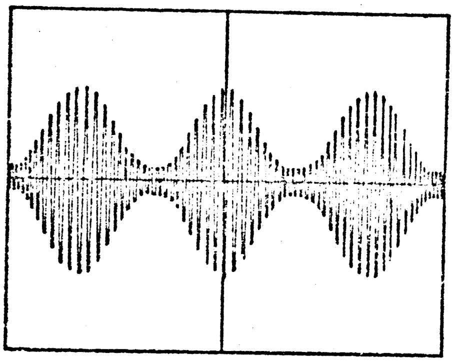


3.1.2 Pulse

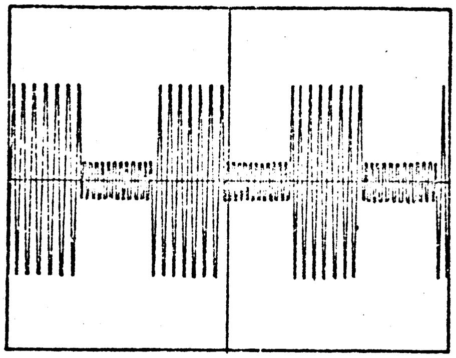


3.1.3 Amplitude Modulation

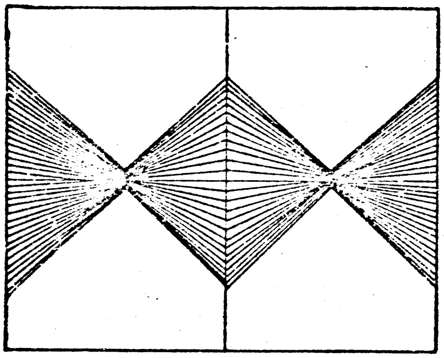
The function generator output can be amplitude modulated by an external signal applied to the AM socket and the AM switch to ON.



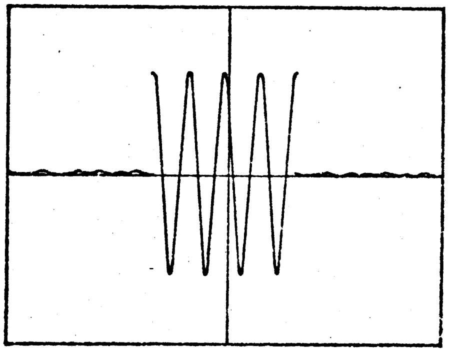
Sine Wave Modulation
10V p-p Input.



Square Wave Modulation
10V p-p Input



Ultra Low Frequency Modulation



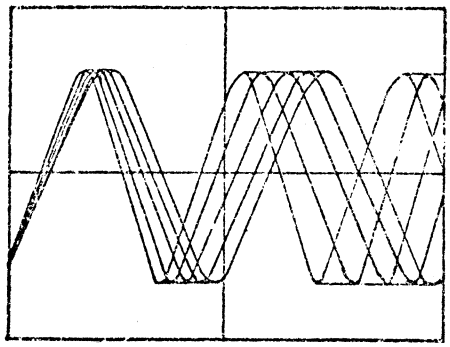
Tone Burst Modulation using a Square Wave

A 50Hz modulating signal is available from the 6.3V AC supply but needs to be reduced in amplitude to prevent over modulation. The 6.3V AC supply amplitude can be reduced by using a series resistor of about 15KΩ.

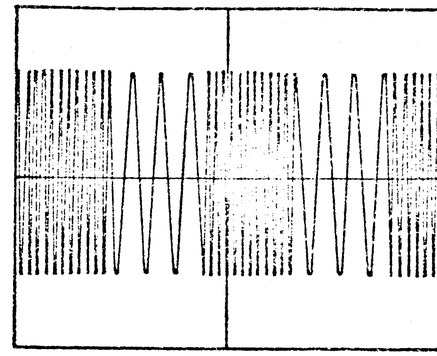
Sine wave modulation is available at other frequencies by using the Op-Amp as a sine wave oscillator or square wave generator. See application notes.

3.1.4 Frequency Modulation

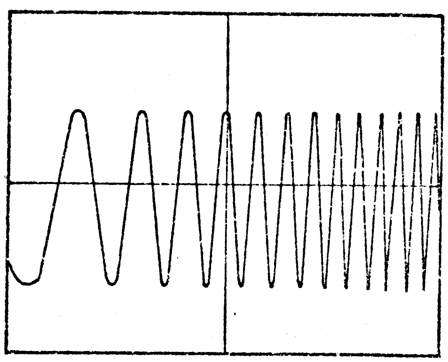
The function generator output can be frequency modulated by the application of an external signal to the FM input socket. The modulating signal can obtained from the same sources as discussed in the amplitude modulation paragraph.



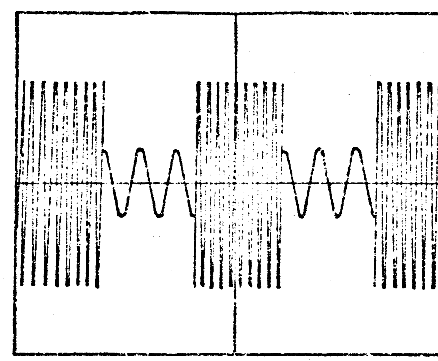
Sine Wave Modulation
Signal



Square Wave Modulation
Signal



Ramp Modulating Signal



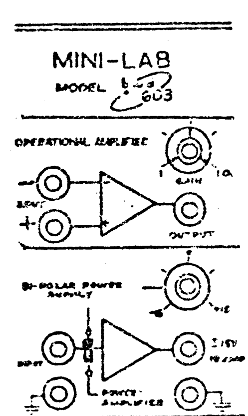
Square Wave Modulating Signal
applied to both AM & FM Inputs
simultaneously

3.2 Bi-Polar Power Supply

Set Controls as follows : -

(a) Output voltage control to zero.

(b) Bi-polar/amplifier switch, fully up.



Monitor the amplifier output terminals with a meter set to DC and on a voltage range greater than or equal to 20V and note the effect of varying the voltage control from one extreme to the other.

3. OPERATION AND USE (Cont'd)

NOTE : The change in output polarity will necessitate reversing the meter leads to obtain correct meter deflection if not using a centre zero meter.

3.3 Power Amplifier

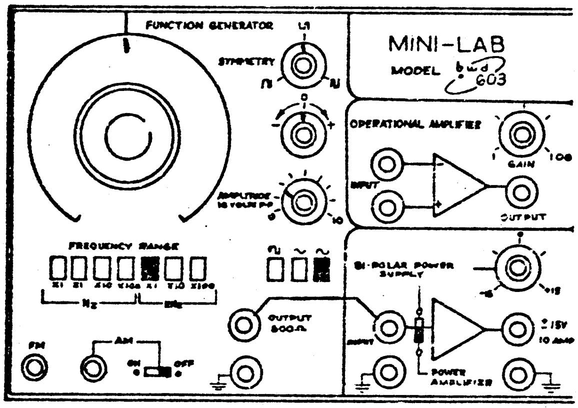
Set controls as follows : -

(a) Bi-polar/amplifier switch fully down.

(b) Connect a link from function generator output to amplifier input terminal.

(c) Power amplifier gain control fully clockwise.

(d) Set function generator output amplitude to zero, set frequency to 1kHz, function switch to triangle.

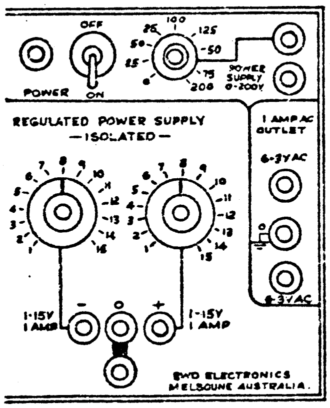


With an oscilloscope connected to the amplifier output, rotate the function generator output level control clockwise until the amplifier output is approximately 20V peak to peak. Now measure the amplitude of the signal at the amplifier input with the oscilloscope and note that the ratio of the amplifier input and output signals is approximately 10.

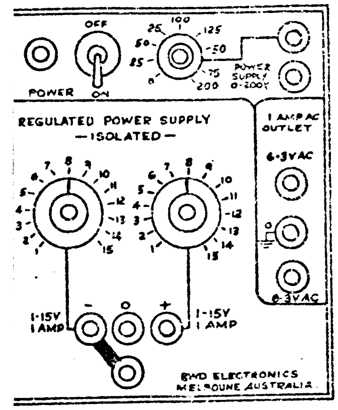
A 15Ω permanent magnet loud-speaker can be connected across the amplifier output to obtain an audible signal.

3.4 Regulated Power Supply

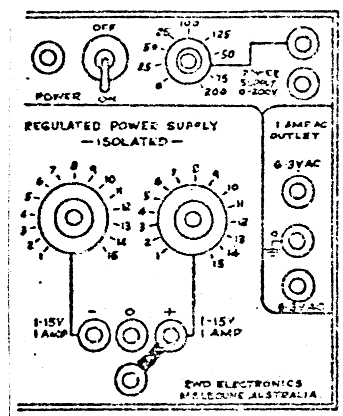
With a link connected between 0 and earth monitor the positive and negative outputs with a meter while varying the output voltage controls. Each output should vary from 1V to 15V.



3. OPERATION AND USE (Cont'd)

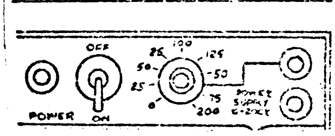


Remove the link between 0 and earth and connect a link from the negative terminal to earth and monitor the positive terminal with respect to earth. The zero terminal will vary with the negative control from +1 to +15V and the positive terminal will vary from +2 to +30 depending on the setting of both the positive and negative output controls.



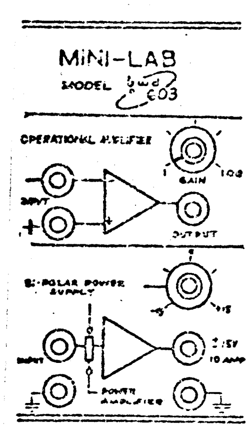
Remove the link between the negative terminal and earth and place between the positive output terminal and ground. Repeat the measurements set out in previous paragraph, but note opposite polarities.

3.5 Variable 200V Power Supply



Monitor the output with a multimeter and note output voltage change while varying the 200V output control.

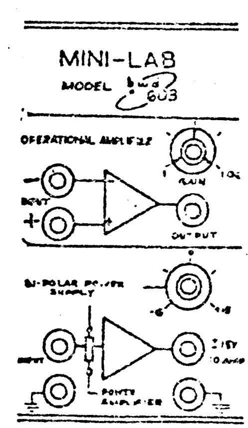
3.6 Operational Amplifier (OA)



Set controls as follows : -

(a) Operational amplifier gain to 1.

(b) Connect a link between the function generator output and the (-) input terminal of the OA. Set frequency to 1kHz, select triangle and adjust signal level into the OA so that the output is free from clipping.

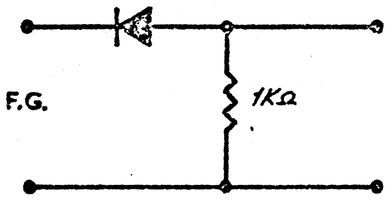


Vary the OA gain control and note the change in gain and that the output is clipped at high gain levels. Clipping is reduced as the OA input signal amplitude is decreased.
Applying the input signal to the (+) input has the same effect as when applied to the (-) input except that the phase change across the amplifier is changed from 180° to 0°.

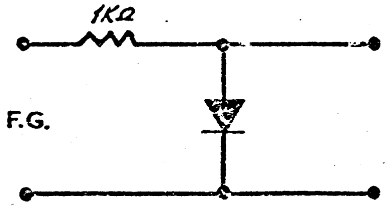
4. APPLICATIONS

4.1 Clippers

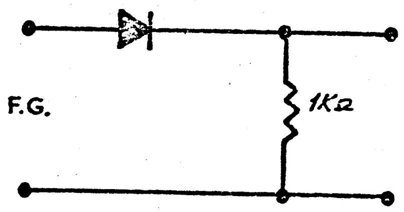
The action of various clipping circuits can be demonstrated with the circuits shown. The circuits are fed from the function generator set to full output, 1kHz and OFFSET to 0. The output is monitored with an oscilloscope.



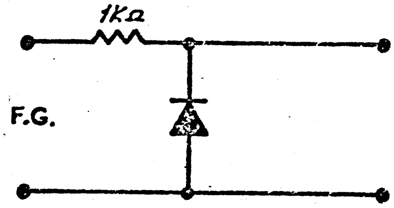
Series and Shunt



Positive Clippers



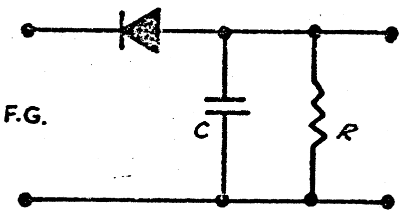
Series and Shunt



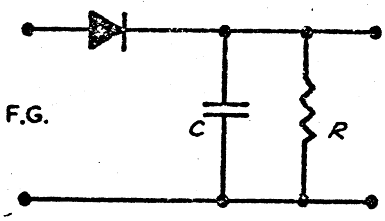
Negative Clippers

4.2 Clampers / DC Restorers

The action of clamping circuits can be studied using the circuits shown. The output of the function generator can be either a sine, square or triangle and the OFFSET can be set at various levels to show that the clamper output is not changed except for a few cycles while the capacitor charge changes.



Positive Clamper
(Positive peaks clamped to zero)



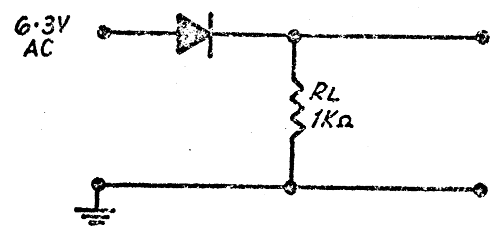
Negative Clamper
(Negative peaks clamped to zero)

4.3 Rectifiers

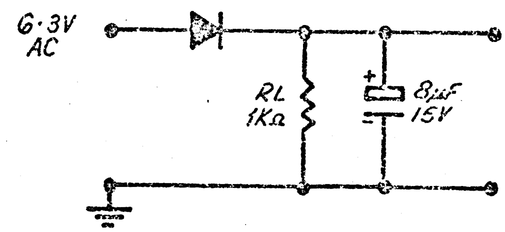
Half wave and full rectifier circuits can be driven by the 6.3V AC outputs. The rectifier outputs are monitored with an oscilloscope. Record wave-shapes for filtered and non-filtered output and note the effect of reducing the value of the load resistor.

4. APPLICATIONS (Cont'd)

4.3.1 Half Wave Rectifier



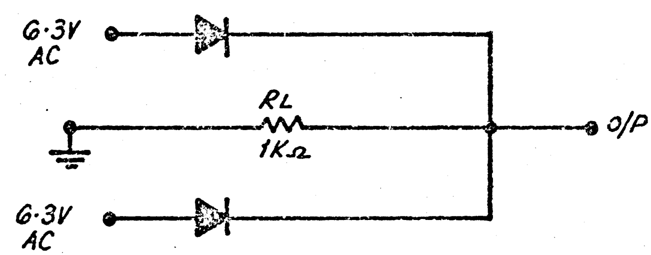
Non-Filtered



Filtered

4.3.2 Full Wave Rectifier

Add 8uF/15V electrolytic capacitor between O/P and ground for filter.

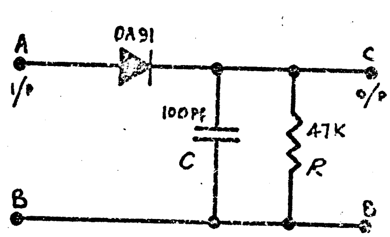


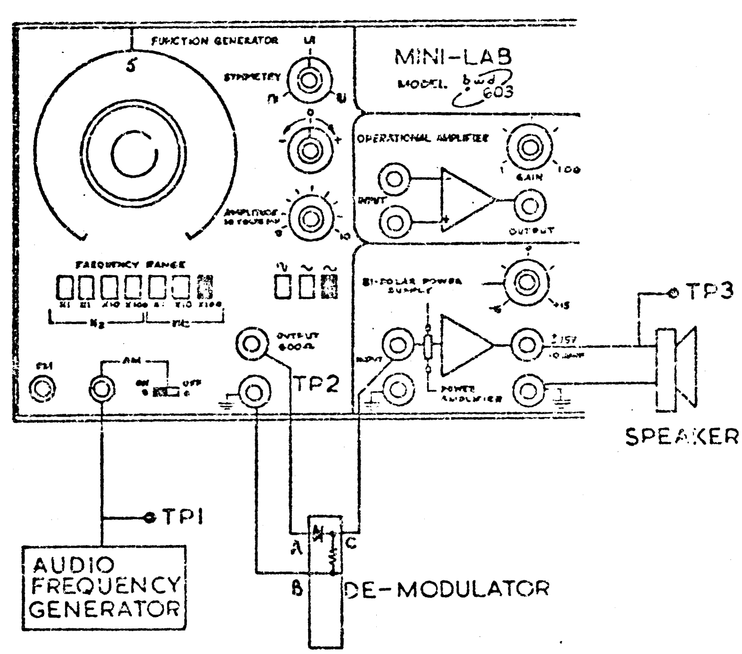
Non-Filtered

4.4 Demodulation A.M.

The diode demodulator can be demonstrated visually on an oscilloscope and audibly using a loud-speaker as shown.

The signals at each test point can be monitored with the oscilloscope.



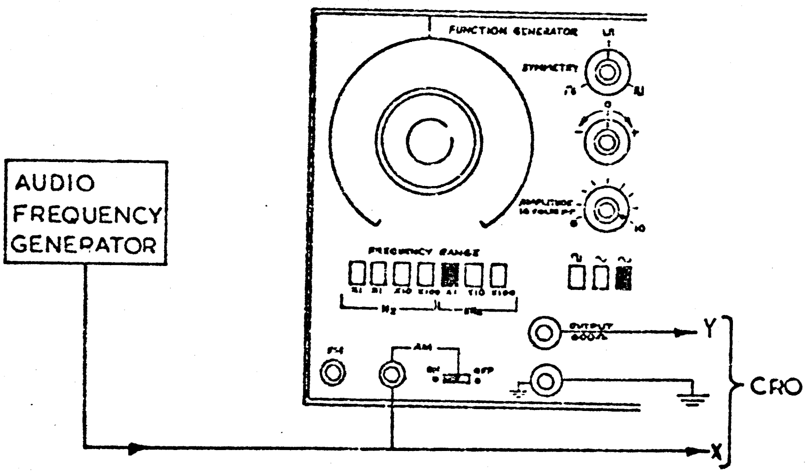


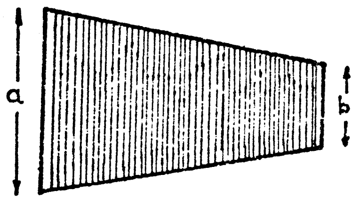
4. APPLICATIONS (Cont'd)

4.5 Trapazoidal Diagram

The trapazoidal diagram on an oscilloscope is used to determine the depth of modulation of an AM signal.

$$\% \text{ modulation} = \frac{a - b}{a + b} \times 100\%$$

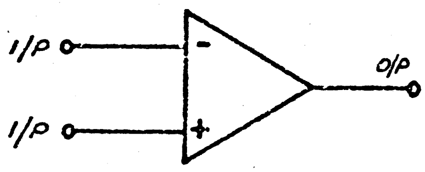




4.6 Operational Amplifier (O/A)

4.6.1 Basic Theory

The basic element of analog computors is the operational amplifier which consists of a differential amplifier, directly coupled. The general characteristics of the OA are high input impedance, low output impedance, high gain and wide bandwidth.

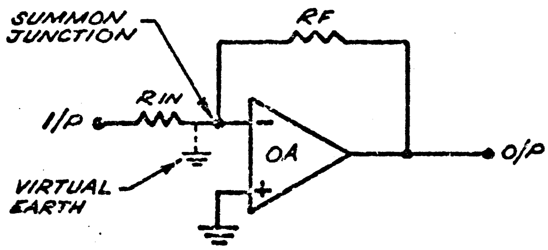


The OA can perform mathematical operations such as additions and multiplications by the use of external circuitry. An important point to note is that because of the high gain available in the OA a very small signal between the two input terminals will produce a large signal at the output. If the OA had a gain of say 10^6 then 5uV at the input will produce 5V at the output.

The significance of the (+) and (-) inputs is that a signal applied to the (-) input appears at the output phase reversed and applied to the (+) input suffers no phase reversal across the amplifier.

4.6.2 Fixed Gain Amplifier

The circuit shown will produce a fixed gain amplifier.



Let +1V be applied to the input terminal causing a current to flow in Rin. Since the input impedance of the OA is IDEALLY infinity then all the current in Rin must flow in Rf, also, since the OA has very high gain the potential difference between the (+) and (-) inputs is very small thus we can say that the summing junction is near earth or zero potential. The current in Rin can now be calculated as Iin = Ein/Rin. This current also flows in Rf to give -Eout = Iin Rf. The overall gain between the input and output terminals is given by :

$$\frac{Eout}{Ein} = \frac{-Iin\ Rf}{Iin\ Rin} = \frac{-Rf}{Rin}$$

The gain of system is thus the ratio of two external, passive components of known accuracy. The negative sign indicates the phase reversal across the amplifier.

Example of Gains :

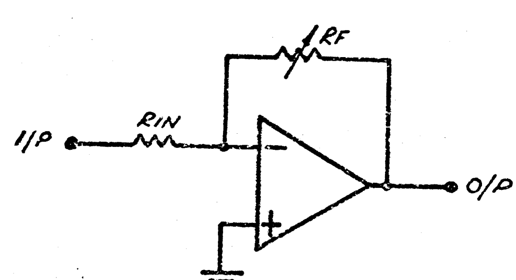
Rf	Rin	Av
100K	100K	-1
10K	10K	-1
100K	10K	-1
10K	100K	-1
50K	25K	-2
5K	25K	-0.2

4.7 Variable Gain Amplifier

Two methods of varying the gain are shown. The first simply varies the value of the feedback resistor and has the limitation that for high gain, Rf needs to be a high value potentiometer. The second method allows gain control over very wide limits but has the disadvantage that the gain control is non-linear. The gain of the second configuration is given by :

$$Av = \frac{Rf}{Rin} \times A$$

where A is the ratio of the total potentiometer resistance to the resistance between the slider and earth.



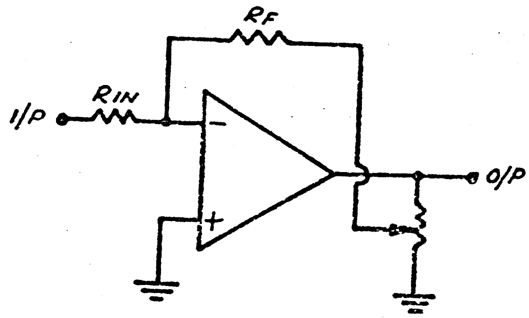
4. APPLICATIONS (Cont'd)

When the slider is in the top position A = 1 giving the gain simply as Rf/Rin; with the slider at mid position $A = 1/\frac{1}{2} = 2$, therefore the gain is :

$$Av = \frac{Rf}{Rin} \times 2$$

with the slider near the bottom where A = 100 then the amplifier gain is :

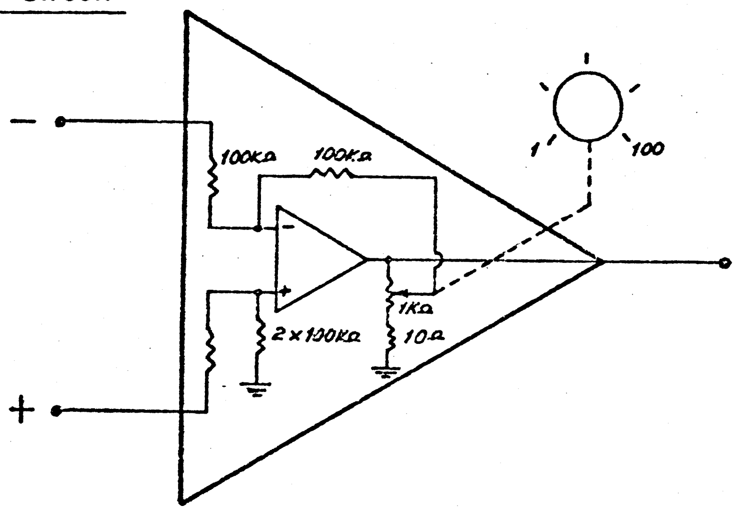
$$100 \times \frac{Rf}{Rin}$$



Ideally, with the slider at the earth position, A would be infinity and hence the gain would be infinity but is of course limited by the gain of the basic OA.

4.8 The Mini-Lab Operational Amplifier Circuit

The circuit configuration used in the Mini-Lab is as shown. The 10Ω resistor in the earth leg of the potentiometer is to limit the maximum gain to 100.



$$Av = \frac{Rf}{Rin}\left(\frac{1}{A}\right) = 100.$$

The Mini-Lab operational amplifier serves two functions : -

(a) A General purpose, variable gain voltage amplifier.

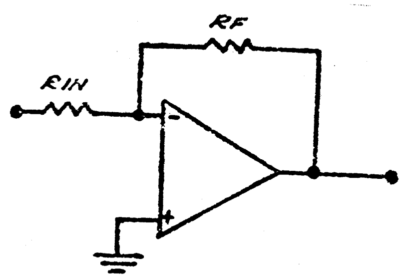
(b) An amplifier suitable for demonstrating many ANALOG techniques.

4.9 Using the Mini-Lab Operational Amplifier

The foregoing circuit descriptions and gain equations only apply to the ideal OA. The Mini-Lab circuit configuration is not ideal due to limited gain and finite input impedance, nevertheless, it is quite adequate to demonstrate the various uses of the OA.

4.10 Multiplying by a Constant

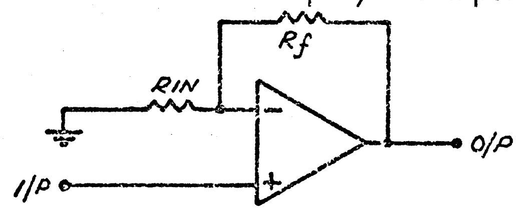
The multiplying configuration can be investigated by applying various positive and negative voltages from the bi-polar power supply.



NOTE : The output of the OA is limited to about ±15V, thus any output reading that is near + or -15V must be checked in case the amplifier is saturated. Resistor values used should not exceed about 10KΩ in order to achieve accurate results and the gain control must be set at maximum clockwise.

4.11 Non-Inverting Amplifier

The configuration shown will amplify the input signal by $\frac{Rf}{Rin} + 1$.



If Rf = Rin = 1K then the gain will be 2 whereas with the inverting configuration the gain would be 1.

NOTE : 1. For high values of gain the gain can be approximated to $\frac{Rf}{Rin}$.

2. Mini-Lab, OA gain to maximum.

4.12 Summing Amplifier

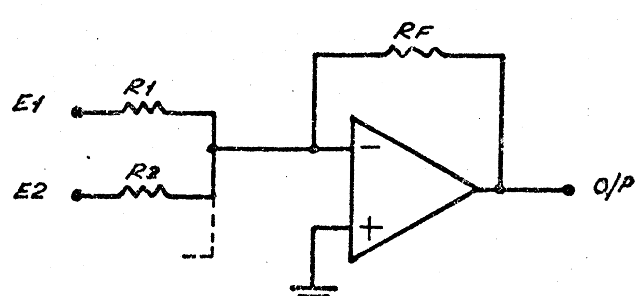
The summing amplifier will algebraically add together the input signals $E_1 + E_2$ +----

The output voltage $-Eout = E_1 \times \frac{Rf}{R_1} + E_2 \times \frac{Rf}{R_2}$ + ----

If Rf = 1KΩ, R_1 = 500Ω, R_2 = 250Ω, E_1 = +2V and E_2 = -3V, then

-Eout = 2 x 2 + (-3) x 4 = 4 + (-12) = -8.

Eout = +8V.

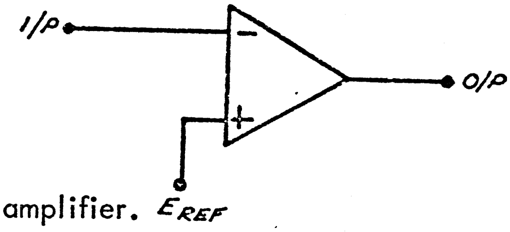


Many complex waveforms can be produced by using the summing amplifier to add together a number of simple waveshapes. Quite complex mathematical equations can be solved using several summing amplifiers together.

4.13 Comparator

The comparator is used to detect whether or not an input signal is greater or less than some reference voltage.

4. APPLICATIONS (Cont'd)



Assume that the input is at zero volts and that Eref is set to +2V (obtained from the +15V power supply).

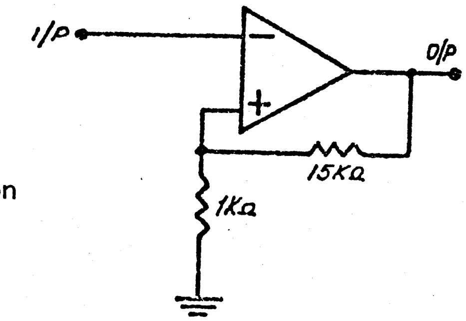
The output voltage will be saturated at approximately +15V because of the gain of the amplifier.

Let the input signal (from the bi-polar power supply) be increased in a positive direction. When the input signal is slightly above the reference voltage the amplifier output will swing to approximately -15V, and when the input is reduced to slightly less than the reference voltage the output will swing maximum positive.

The converse of this is that when the output is up, or positive, then the input is less than the reference and when the output is down, or negative, then the input is greater than the reference.

Experiment by applying the reference to the (-) input and the signal to the (+) input. Compare the results obtained with the above. Also experiment with various reference voltages with a high amplitude 1kHz sine wave applied to the input and observe the output on an oscilloscope.

4.14 Schmitt Trigger



The operation of the Schmitt Trigger is similar to the comparator except that the reference voltage is derived from the saturated amplifier output.

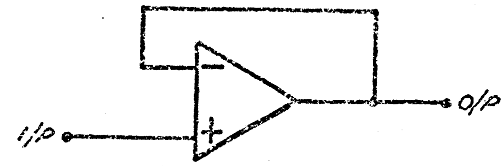
The reference voltage is determined by the saturation voltage and the voltage divider. With the circuit shown the reference voltage will be about 1V either positive or negative depending on the output voltage polarity.

Let the input signal be -5V, thus making the output saturate at approximately +15V and making the reference voltage at the (+) input approximately +1V. Now increase the (-) input in a positive direction until it reaches a little more than +1V. The amplifier output will change polarity and so will the reference at the (+) input. The input signal must now be reduced to below -1V for the output polarity to change again.

The difference between the two input signal levels required to change the output polarity is known as HYSTERESIS.

Other values for the voltage divider, or a potentiometer may be used to achieve different triggering points.

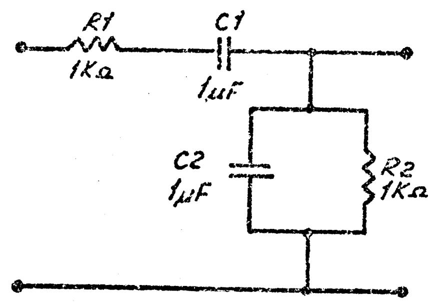
4.15 Voltage Follower



The voltage follower is similar to the familiar cathode, source or emitter follower in that it provides a unity gain amplifier with high input impedance and low output impedance.
The voltage follower has many applications as an impedance transformer between high and low impedance devices such as transducers and amplifiers.

4.16 Wein Bridge Network

The Wein Bridge network is commonly used in audio oscillator circuits to produce sine waves. The network has zero phase shift at one particular frequency and if used in the positive feedback path of an amplifier oscillations can be produced.



The network is best demonstrated by plotting the frequency and phase response, and its gain.

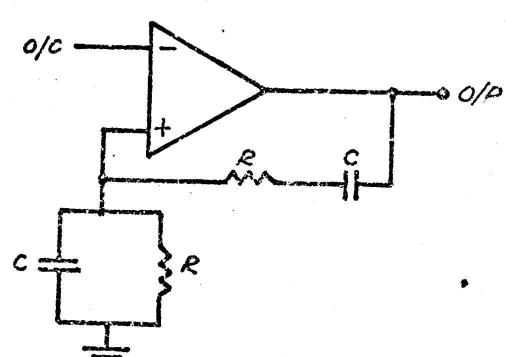
Zero phase shift occurs when the frequency is given by : -

$$F = 1/2\pi CR \text{ where } C_1 = C_2 \text{ and } R_1 = R_2$$

and the gain of the circuit at this frequency is 1/3.

For the values given $F \approx 160Hz$.

4.17 Wein Bridge Oscillator

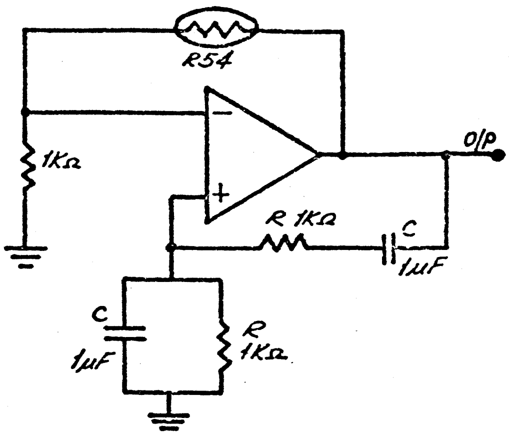


The application of positive feedback to the (+) input via a selective network will produce oscillations at the amplifier output. The frequency of oscillation is given by : $F = 1/2\pi CR$, and the gain of the feedback network is 1/3.

With the network as shown the Mini-Lab OA gain should be varied and the effect noted. When the OA gain is set less than 3, no oscillations occur and when the OA gain is set above 3, a square wave results. A sinusoidal output is only obtained when the OA gain is set at exactly 3 and is very critical to adjust (x3 gain occurs on the OA gain control a little past its centre of travel).

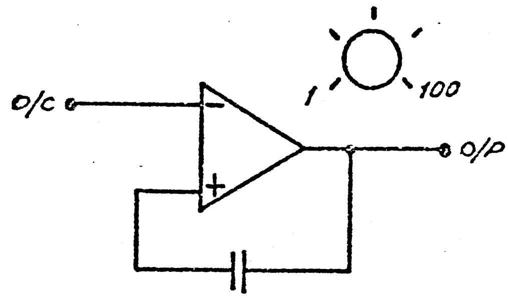
4. APPLICATIONS (Cont'd)

To obtain a constant amplitude, sinusoidal output as shown in the second circuit. The addition consists of a thermistor and a resistor to set the gain at 3. If the amplifier output amplitude increases, then the thermistor resistance decreases, reducing the gain and holding the output amplitude constant. The output frequency can be made continuously variable, by replacing the 2 resistors with a 2 gang potentiometer or replacing the two capacitors with a 2 gang capacitor.

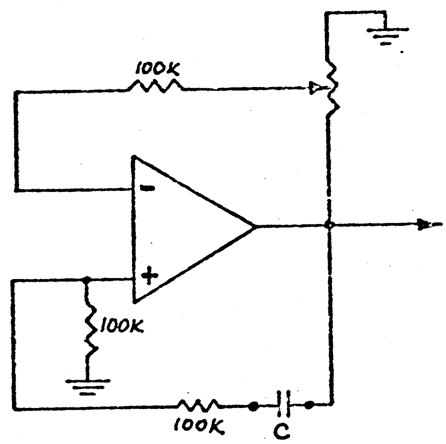


4.18 Simple Square Wave Generator

A simple square generator is available by simply connecting a capacitor between the output of the OA and its (+) input. Frequency of oscillation depends upon the setting of the gain control and the value of the capacitor. Start experiments with a capacitor value of about 0.1 to 0.01uF.



The second diagram is the complete circuit when the internal components of the Mini-Lab are shown. A brief description of the circuit follows with reference to the waveform diagram.

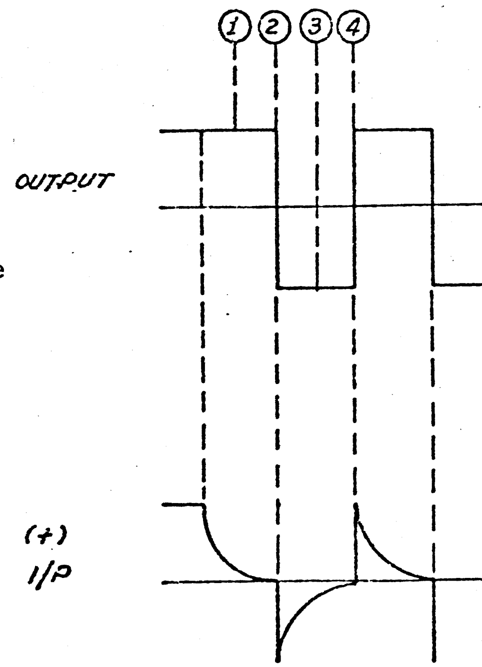


Initial conditions : O/P = +15, capacitor voltage Vc = 0, (+) 1/P = +15. The capacitor now charges which allows the (+) 1/P to fall towards zero (time 1). The (-) 1/P is held positive by the feedback resistor and the potentiometer. When the (+) 1/P becomes more negative than the (-) 1/P, the output goes to -15V. The step change in the output also appears at the (+) 1/P (time 2). The (-) 1/P will also go negative with the output via the feedback resistor.

During time 3 the capacitor discharges until the (+) 1/P goes more positive than the (-) 1/P and the output then again changes state to +15V (time 4).

The cycle of events continues indefinitely to produce the required square wave at the output. Varying the OA gain control, changes the reference voltage on the (-) 1/P and hence changes the frequency.

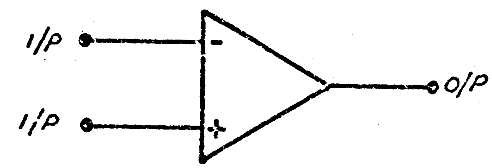
The output amplitude can be controlled by connecting a 1KΩ potentiometer between the OA output terminal and earth.



4. APPLICATIONS (Cont'd)

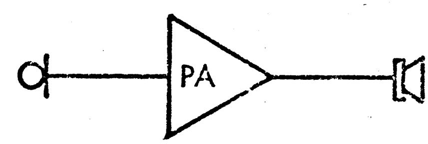
4.19 Common Mode Rejection Ratio - CMRR

The CMRR of a differential amplifier is the ability of the amplifier to reject, or not amplify a signal applied simultaneously to both inputs.

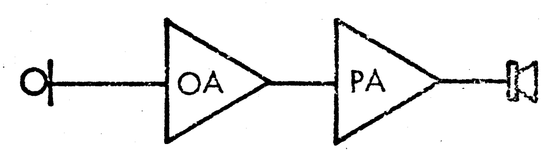


Apply a square of 1kHz to each input alternately and note the output. Now apply the same waveform to both inputs simultaneously and note the change in the output. The CMRR is defined as the ratio of the output signal (both inputs tied together) to the input signal, i.e. CMRR - $\frac{Vout}{Vin}$ and is usually expressed in decibels.

4.20 Public Address System of Record Player Amplifier



The output of a microphone or a record player pick-up can be amplified using either of the systems shown. The first system requires a high level input and does not have a volume control. The second system will amplify most simple microphones or pick-ups and the OA gain control acts as a volume control. The speaker should be on 8Ω or 15Ω permanent magnet loudspeaker capable of handling up to 10W.



NOTE : Switch at power amplifier input must be switched to amplifier.

4.21 Acoustic Feedback

Acoustic feedback in a public address system occurs when the output from the speaker reaches the microphone with sufficient amplitude to cause audible oscillations. This effect can be demonstrated using the previous system and moving the speaker towards the microphone.

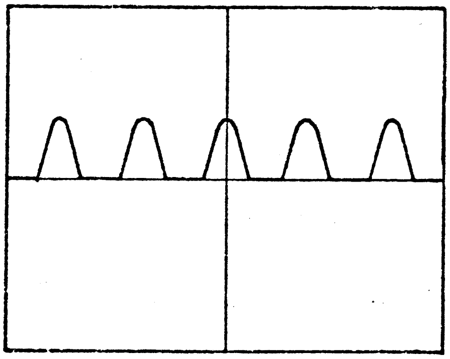
4.22 Waveform Study

A comparison can be made between various physiological effects of low frequency waveforms. The frequency range needs to be restricted to the range 1Hz - 20Hz. The power amplifier is driven by the function generator and the amplifier output is connected to a speaker, a 15W lamp and an oscilloscope. The audible and visual effects are obvious and physical movement can be felt by placing the fingers very lightly on the speaker cone.

4. APPLICATIONS (Cont'd)

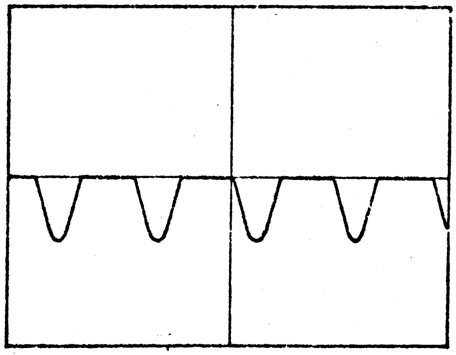
4.23 Miscellaneous Waveforms

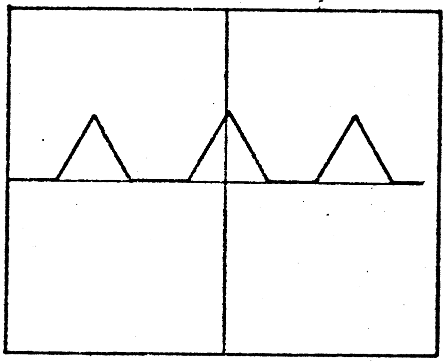
Many waveforms can be generated using the operational amplifier to modify the function generator output. The frequency must be limited to 1kHz to remain inside OA limits.



Half Sine

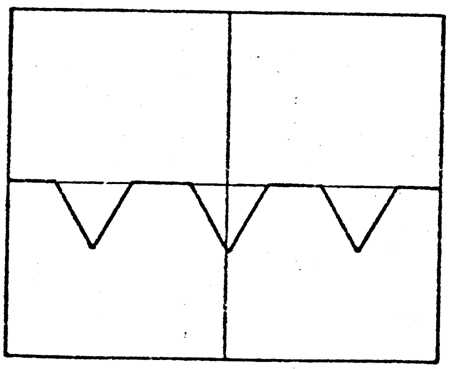
OA gain = 3/4CW
Fn Gen output = 3/4CW
Function = Sine
Offset = + or -2V

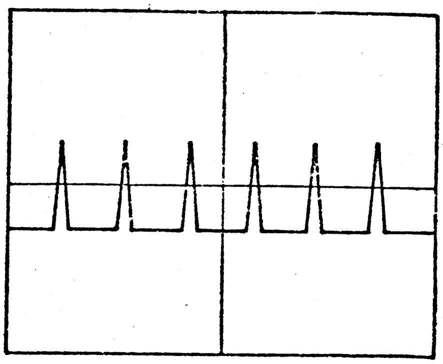




Half Triangle

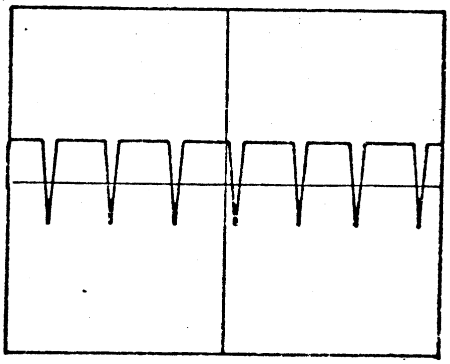
OA gain = 3/4CW
Fn Gen output=3/4CW
Function = Triangle
Offset = + or -2V





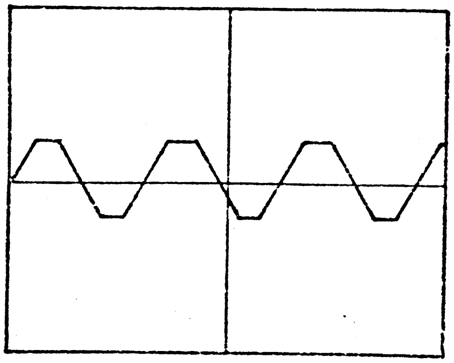
Narrow Pulse

OA gain = 3/4CW
Fn Gen output=3/4CW
Function = Triangle
Offset = max. + or -



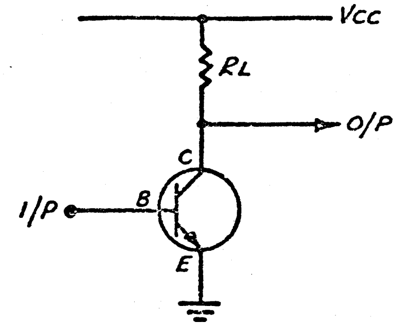
Clipped Triangle

OA Gain = 3/4CW
Fn Gen output = max. CW
Function = Triangle
Offset = Zero.



4.24 Transistor Amplifier

4.24.1 Basic Calculations

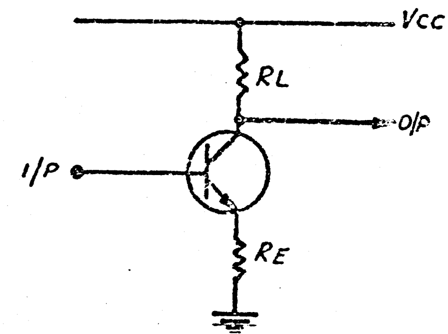


The voltage gain of a transistor amplifier is given by : -

$$Av = \frac{R_l}{r_e} \quad - (1), \text{ where } r_e = \frac{1}{g_m} = \frac{25}{I_{E(mA)}} \quad - (2)$$

If the emitter current is 2.5mA and the load resistor R_l is 1KΩ then the voltage gain is approximately given by :

$Av = 1000/10 = 100$, $r_e = 25/2.5 = 10$



When an emitter resistor is used the gain formula is modified to :

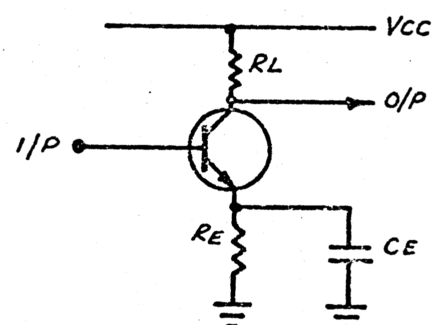
$$Av = \frac{R_l}{r_e + R_e} \quad - (3)$$

and if Re is very much larger than r_e then $Av = R_l/Re$ - (4)

i.e. the gain is determined quite accurately by two resistors and is independent of the transistor.

For R_l = 1KΩ, Re = 100Ω, Ie = 2.5mA (r_e = 10Ω) then Av = 100/110

Compare with first example.



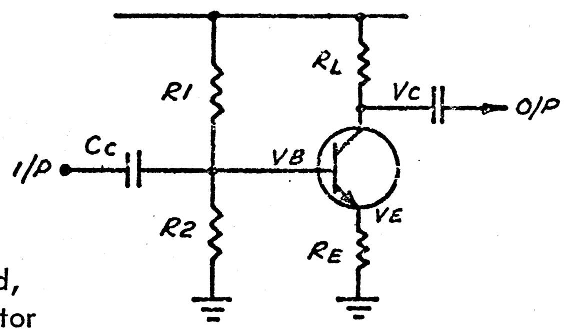
In some cases Re is necessary for bias but maximum possible gain is required. This requirement is met by bypassing Re with a large value capacitor which does not effect the DC bias conditions but is a low impedance to AC signals, thus short circuiting Re.

The gain now becomes $Av = \frac{R_l}{r_e}$ and using the previous resistor values the gain is now 100.

Compare the results of the three circuits.

4.24.2 Transistor Circuit Analysis - Common Emitter - DC Conditions

The typical common emitter circuit shown can be readily analysed to show the voltages and currents in the circuit.



The following assumptions are made : the base current is very small and ignored, and the emitter current all flows through to the collector.

Since the base current can be ignored, the voltage at the base of the transistor with respect to earth is determined by the voltage divider R_1 and R_2 and the supply Vcc.

$$V_b = \frac{Vcc \times R2}{R1 + R2} \text{ volts - (5)}$$

The voltage difference between the base and the emitter is approximately 0.5V due to the forward bias on the base - emitter diode.

$Ve = (V_b - 0.5)$ volts - (6)

and if V_b is large then

$Ve \approx V_b$ - (7)

The current through Re is determined by the voltage

Ve, $Ie = Ve/Re$ - (8)

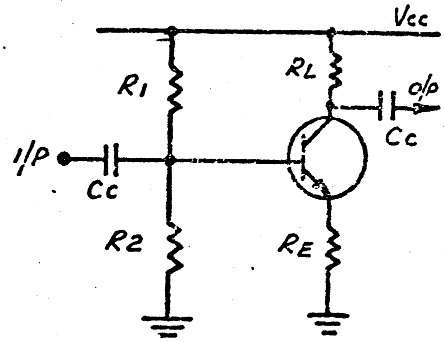
and since nearly all the emitter current flows through to the collector then

$Vc = Vcc - IcR_l$ - (10)

$\quad = Vcc - IeR_l$ - (11)

4.24.3 Simplified Transistor Amplifier Design

The simple design procedure outlined below will help in understanding the operation of transistor amplifiers.



Data : Gain, Av = 10
Vcc = +15V
$Vc \approx \frac{1}{2}$ Vcc
Ie < 2mA

Transistor - any small signal NPN silicon type.

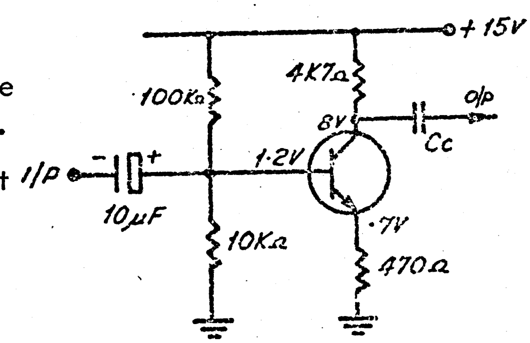
603
239

For Vcc = 15V, Vc = 8V and Ie = 1.5mA, then R_l = 7V/1.5mA 4700Ω, and for a gain of 10, Re = 4700/10 = 470Ω

Since Ie ≈ Ic and Re = 470Ω then
Ve = 470Ω x 1.5mA = 0.7V
Vl = 0.7V + 0.5V = 1.2V

The values of R1 and R2 can be found from $V = \frac{Vcc\ R2}{R1 + R2}$ Volts

Let R2 = 10KΩ which gives R1 ≈ 100KΩ.



Build and test the amplifier and compare the calculated figures with the measured results.

The coupling capacitors shown in the circuit are necessary to prevent alteration of the DC conditions by the signal source.

The simplified design procedure is meant only to demonstrate the basic simplicity of transistor amplifiers, and no attempt has been made to achieve wide bandwidth, current economy or low distortion.

A number of questions come to mind and these are left to the reader to answer.

Q1 : Why is Vc specified as approximately half the supply voltage. Two reasons.

Q2 : How can the gain be increased without changing the resistor values

Q3 : The bandwidth of the amplifier was found to be 300kHz, and when a small capacitor of 1000pf was connected across Re the bandwidth increased to >1mHz. Explain this.

Q4 : If the amplifier was designed to operate on a very low current, would the ratio of R_l : Re still be 10 : 1.

4.25 Frequency Response Measurements Using Sweep Facility

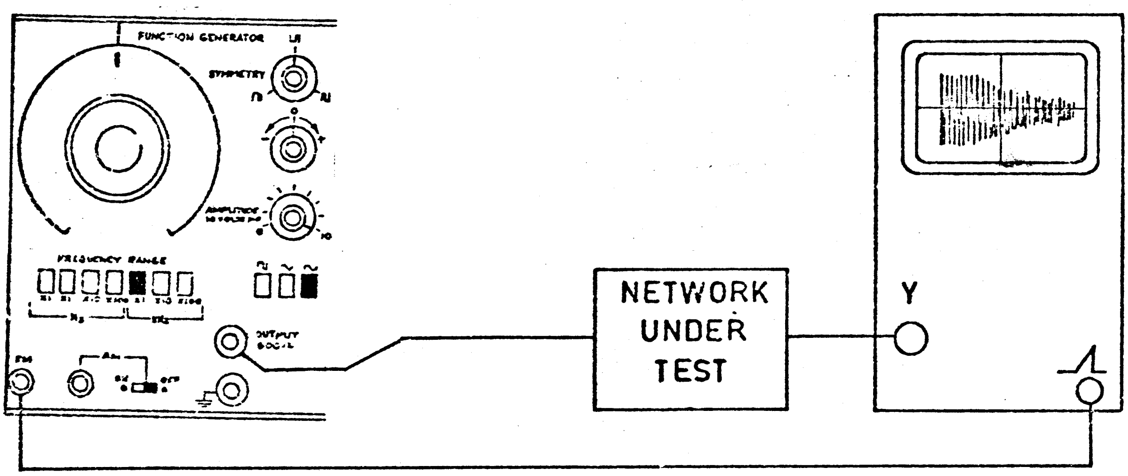
The frequency response of amplifiers, filters, coupling networks, etc. can be displayed on an oscilloscope using the sweep facility of the function generator.

A positive voltage applied to the FM input socket will increase the frequency and a negative voltage will decrease the frequency. An ideal sweep signal source is the time base output of an oscilloscope. If the sweep signal applied to the function generator swings from a 0V to +10V and the dial is set to 1, then the output will be swept over a 10:1 range. A negative going sweep signal will sweep the frequency from the 10 position on the dial to the 1 position. By increasing the amplitude of the negative swept signal the sweep range can be extended to the equivalent of a 0.1 position of the dial giving a 100:1 sweep range. The actual frequency coverage depends on the frequency range switch that is selected.

The display on the oscilloscope can be approximately calibrated in frequency, since equal increments of the sweep input produce equal frequency changes. Assuming a 0 to 10V sweep signal, with the dial set at 1 and the trace positioned to start at the left hand graticule line, then this line represents 1, the second graticule line represents 2, and the tenth graticule line represents 10.

Sweep waveforms other than sawtooth may be used provided the horizontal axis of the oscilloscope is driven by the same waveform.

A typical test set up is shown in the following diagram.



5. CIRCUIT DESCRIPTION

5.1 Triangle Generator

The triangle waveform is generated by charging a capacitor with a constant current. The constant current generators Q6 and Q8 are alternatively switched on to charge the timing capacitor (C8 - C15), firstly in a positive direction and then in a negative direction. When the triangle amplitude reaches a pre-determined level in a positive direction, Q1 conducts and produces a pulse that changes the state of the bistable circuit Q5 to Q8.

This action switches off constant current source Q6 and switches on constant current source Q8 to charge the timing capacitor in a negative going direction. When the negative amplitude reaches the desired level, Q2 conducts and switches the bistable to the original condition, and the capacitor is now charged in a positive going direction. This cycle of events repeats itself to produce the triangular waveform.

Variable frequency is obtained by changing either the timing capacitor with the frequency range switch or varying the charging current with the frequency vernier RV2.

The frequency vernier RV2 determines the voltage across R5 and hence sets the current through Q3 and hence through D4, D5, R6 and R7. The voltage developed at the base of Q4 determines the current through R9 and R10 which then sets the current in Q5 or Q7 depending on which one is conducting and this in turn sets the current in Q6 and Q8 which supplies the timing capacitor.

Q9, Q10 and Q11 form a buffer amplifier to prevent loading of the triangle generator. RV5 presets the triangle amplitude fed to the waveform selector switch.

RV1 sets the bias on Q1 and Q2 and thus determines the amplitude which the triangle must reach before triggering the constant current bistable takes place.

Frequency modulation is achieved by an external signal being fed to the emitter of Q3 and thus modulating the current in Q3 and hence modulating the current fed to the timing capacitor from the constant current sources.

5.2 Square Wave Generator

The square wave is generated by a Schmitt Trigger consisting of Q21, Q22 and symmetry control RV22. The drive signal is obtained from the triangle generator and varying the symmetry control RV22 determines the amplitude the triangle waveform must reach before the Schmitt Trigger changes state. The output from Q22 is taken to the waveform selector switch.

5. CIRCUIT DESCRIPTION (Cont'd)

5.3 Sine Wave Generator

The sine wave is generated by applying the triangular waveform to an amplitude sensitive voltage divider. The series element of the divider consists of R39 and R40, and the shunt element consists of a number of diodes and associated resistors. As the triangle increases in say a positive direction, D42 conducts when the input voltage is equal to the voltage drop across R54 and D42.

When D42 conducts the shunt leg of the voltage divider now consists of R45 and R46 and hence reduces the amplitude or slope of the triangle waveform. Further increases in the input amplitude causes diodes D41, D40, D39, D38 and D37 to conduct successively and each time further reducing the slope of the output waveform. The output waveform actually consists of a number of straight lines that approximate the shape of a sinusoid. The shape of the negative half of the waveform is determined by diodes D31 to D36. The Distortion is adjusted by presets RV81 and RV82 and the output amplitude feed to the waveform selector switch is preset by RV33.

5.4 Amplitude Modulator

The carrier signal (fc) is fed to the bases of Q62 and Q64 via RV61. The collectors of Q61, Q62, Q64 and Q65 are connected in such a way that the signals at the common collector points tend to cancel because they are in anti-phase.

If the gain of either differential amplifier is varied by changing the value of the constant current sources with RV62, then the carrier signals at the collectors can be cancelled or set at any desired amplitude. If RV62 is set at approximately mid-position, the carrier signal at the collectors is near zero, and with RV62 at either extreme, maximum carrier appears at the collectors. The phase of the carrier at the collectors can be varied by setting RV62 either at one extreme or the other.

A modulating signal applied to one of the constant current sources will vary the gain of that particular differential carrier at the collectors, and hence produce an amplitude modulated signal.

The Mini-Lab is factory preset to produce double side band amplitude modulation, but double side band suppressed carrier modulation can be produced by resetting RV62 to approximately mid position.

5.5 Function Generator Output Amplifier

The selected waveform from Q81 is amplified by differential amplifier Q82, Q83 and common emitter driver Q84. The complementry output stage Q85 and Q86 supplies the output via R92. R92 sets the output impedance at approximately 600Ω and also protects the amplifier from short circuit loads. The negative feedback via R94 mains stable voltage gain, and output amplitude is determined by potentiometer RV81.

DC offset control RV8 varies the bias on Q83 and thus sets the output DC level in the range +5 to -5V.

5.6 Power Amplifier

Pre-amplifier IC101 feeds the B class output stage via bias network D102, D103 and RV101. Q101 and Q203 amplify the positive going signals and Q102 and Q104 amplify the negative going signals. Total amplifier gain is set by the ratio of R104 and R103 to approximately 10 times. Diode D101 protects IC101 from excessive input voltage, if the +200V supply is accidentally connected to the amplifier input. Diodes D108 and D109 protect the output transistors from excessive voltage being applied to the amplifier output.

5.7 Bi-Polar Power Supply

When S101 is switched to the power supply position, the input to the power amplifier is derived from a variable DC voltage source via RV101. The negative feedback of the amplifier maintains the output voltage constant for varying load currents.

5.8 Variable 200V Power Supply

The rectified and filtered output of D205 and C205, C206 is series regulated by Q132 and Q133 which are controlled by reference amplifier Q34. The reference voltage is supplied by the fixed -15V regulator. Output voltage is controlled by variable feedback resistor RV132.

Output current is limited when the voltage across R133, R134 and RV131 causes Q131 to conduct and pull the bases of Q132 and Q133 towards ground.

5.9 Operational Amplifier

The operational amplifier consists of an integrated circuit amplifier with variable feedback. RV121 controls the amount of negative feedback and hence controls the gain from 1 to 100.

Diodes D121 and D122 are for protection against excessive input voltages and diodes D123 and D124 are for protection against excessive voltages applied to the output terminal.

5.10 Variable ±15V Power Supply

The positive output of rectifier D201 and filter capacitor C201 is applied to series regulator Q201 which is controlled by the reference amplifier Q205 via Q203. Positive output voltage control is effected by potentiometer RV211 in the negative feedback path. The positive reference voltage is developed across zener diode D212.

5. CIRCUIT DESCRIPTION (Cont'd)

The negative output series regulator Q210 is supplied from rectifier D202 and filter capacitor C202, reference amplifier is Q206 and output control is RV214.

Output current is limited when the voltage developed across R211 or R218 causes Q204 or Q209 to conduct. When either Q204 or Q209 conducts the output voltage control RV211 or RV214 is shunted, preventing any further increase in current. The current supply for the reference amplifiers is from the auxiliary rectifier - filter networks D224/C125 and D227/C128. The auxiliary filter reduces the amount of ripple in the output.

5.11 Fixed ±15V Power Supply

Operation of the fixed power supply is similar to the variable supply except that the positive supply is fixed and the negative supply has a preset adjustment to allow the positive and negative rails to be set equal.

5.12 6.3 - 0 - 6.3 AC Supply

The AC supply is obtained directly from the power transformer via fuses F201 and F202. The centre tap is connected to chassis.

6. ALIGNMENT AND CALIBRATION

6.1 Equipment Required

The following equipment is required for a complete alignment and calibration of the Mini-Lab. : -

(a) A Multimeter.

(b) An Oscilloscope.

(c) A digital Frequency Meter.

6.2 Fixed ±15V Power Supply

Using a multimeter, adjust RV221 so the positive and negative rails are equal and should be in the range 14 to 16V.

6.3 Variable ±15V Power Supply

Using a multimeter adjust RV212 for +15V on the positive output when positive output control is set at +15V, similarly adjust RV213 for -15V output on negative terminal with negative output control set to -15V.

6. ALIGNMENT AND CALIBRATION (Cont'd)

6.4 200V Power Supply

Set the output control to +200V and adjust RV133 for a reading of +200V on the multimeter. The current limit central RV131 is adjusted to limit the short circuit output current to 35mA. The current is monitored by switching the multimeter to 100mA DC and connecting directly across the 200V output terminals.

6.5 Power Amplifier

The only adjustment required is to adjust RV101 for minimum cross-over distortion. Apply a 1kHz sine wave to the input terminals of the power amplifier and adjust output amplitude to about 20V peak to peak. The crossover distortion is visible on an oscilloscope at the zero voltage points on the sine wave.

6.6 Triangle Generator

Monitor the triangle generator output at the junction of R17 and R18 on an oscilloscope and connect a frequency counter to the function generator output terminals. Set range switch to x1kHz and dial to 10, adjust RV4 for zero volts DC level on triangle, and then adjust RV1 for 10kHz on the frequency counter. Rotate dial to the fully clockwise position and readjust RV3 if the triangle generator has ceased to operate. Repeat the adjustment of RV4, RV1 and RV3 as necessary. The triangle amplitude at the junction of R17 and R18 should be approximately 10V p-p.

6.7 Square Wave Generator

Select square wave output, AM to OFF, frequency to 1kHz, symmetry control RV22 to centre position and adjust RV21 for a 1:1 mark space ratio. Vary the symmetry control over its full range and check for a minimum of 10:1 mark space ratio at each extreme.

6.8 Sine Wave Shaper

Select sine wave output, AM to OFF, frequency range to x1kHz and dial to 5. Monitor the output terminals with a distortion meter and adjust RV31 and RV32 for minimum distortion. Check the 1,5 and 10 positions on the dial for each frequency range and adjust RV31 and RV32 for the best overall result.

6.9 Waveform Amplitudes

Select square wave, AM to OFF and measure the peak to peak amplitude of the square wave on an oscilloscope. Select triangle and adjust RV5 for a peak to peak amplitude equal to the square wave. Select sine and adjust RV33 for a peak to peak amplitude equal to the square wave.

6.10 Amplitude Modulator

Select sine output, AM to ON, frequency to 100kHz, set RV62 to one extreme position and adjust RV61 for a 5V p-p signal at the output. Apply a 50Hz, 10V p-p sine wave signal to the AM input socket and adjust RV62 for approximately 95% modulation depth. Readjust RV61 and RV62 so that the unmodulated carrier is 5V p-p and the modulation depth is 95% with a 10V p-p modulating signal.

7. REPLACEMENT PARTS

Spares are normally available from the manufacturer. When ordering, it is necessary to indicate the serial number of the instrument. If exact replacements are not to hand, locally available alternatives may be used, provided they possess a specification not less than, or physical size not greater than the original components.

As the policy of the supplier is one of continuing research and development, the Company reserves the right to supply the latest equipment and make amendments to circuits and parts without notice.

8. WARRANTY

The equipment is guaranteed for a period of twelve (12) months from the date of purchase against faulty materials and workmanship.

Please refer to Guarantee Registration Card No. ....12153.. which accompanied instrument, for full details of conditions of warranty.

REPLACEABLE PARTS

1. This section contains information for ordering replacement parts, it provides the following details : -

   (a) Description of part (see list of abbreviations).
   (b) Typical manufacturer or supplier of the part (see list of abbreviations).
   (c) Manufacturer's Part Number, and
   (d) Defence Stock Number, where applicable.

2. Ordering - Please quote Model Type No., e.g. bwd 511, Serial No. Circuit Reference No. and component details as listed in parts list.

COMPONENT DESIGNATORS

A	Assembly	H	Heater	RV	Resistor Variable
B	Lamp	J	Jack (socket)	S	Switch
C	Capacitor	L	Inductor	T	Transformer
D	Diode	M	Meter	TH	Thermistor
DL	Delay Line	P	Plug	V	Valve
E	Misc. Elect. Part	Q	Transistor	VDR	Voltage Dependent Resistor
F	Fuse	R	Resistor		

ABBREVIATIONS

Amp	Ampere	L	Inductor
C	Capacitor	lin	Linear
cc	Cracked Carbon	Log	Logarithmic Taper
c	Carbon	m	Milli = 10^{-3}
cd	Deposited Carbon	MHz	Mega Hertz = 10^6Hz
comp	Composition	MF	Metal Film
CDS	Ceramic Disc Capacitor	ma	Milli Ampere
cer	ceramic	MΩ	Meg Ohm = $10^6\Omega$
Com	Common	mfr	Manufacturer
DPST	Double Pole Single Throw	MO	Metal Oxide
DPDT	Double Pole Double Throw	MHT	Polyester/Paper Capacitor
elec	Electrolytic	MPC	Metalised Polyester Capacitor
F	Farad	Ne	Neon
f	Fuse	NPO	Zero temperature co-efficient
FET	Field Effect Transistor	nsr	Not separately replaceable
Ge	Germanium	NC	Normally Closed
H	Henry(ics)	NO	Normally Open
H.S.	High Stability	ns	Nano second
HTC	High Temp Coating	obd	Order by Description
ins	Insulated	OD	Outside Diameter
kHz	Kilo Hertz = 10^3Hz	p	Peak
KΩ	Kilo Ohm = $10^3\Omega$	pf	pico farad = 10^{-12}F

205

COMPONENT ABBREVIATIONS (cont.)

PL	Plug	SPDT	Single Pole Double Throw
PS	Socket	SPST	Single Pole Single Throw
Preset	Internal Preset	S.Shaft	Slotted Shaft
PYE	Polyester	Si	Silicon
pot	Potentiometer	Ta	Tantalum
prec	Precision	tol	Tolerance
PC	Printed circuit	trim	trimmer
PIV	Peak Inverse Voltage	V	Volt(s)
PYS	Polystyrene	var	variable
p-p	Peak to Peak	vdcw	Volts Direct Current Working
P.Shaft	Plain Shaft	w	Watt(s)
Q	Transistor	ww	Wire Wound
R	Resistor	Z	Zener
rot	rotary	*	Factory Selected value, nominal value may be shown
R log	Reverse Logarithmic Taper		
rms	Root Mean Squared	**	Special component, no part no. assigned

MANUFACTURERS ABBREVIATIONS

AC	Allied Capacitors	J	Jabel
AEE	AEE Capacitors	McH	McKenzie & Holland (Westinghouse)
AN	Anodeon	MAS	Master Instrument Co. Pty. Ltd.
AST	Astronic Imports	MUL	Mullard (Aust.) Pty. Ltd.
AWA	Amalgamated Wireless of Aust.	MOR	Morganite (Aust.) Pty. Ltd.
ACM	Acme Engineering Pty. Ltd.	MSP	Manufacturers Special Products (AWA)
AMP	Aircraft Marine Products (Aust.)P/L	McM	McMurdo (Aust.) Pty. Ltd.
AR	A. & R. Transformers	MOT	Motorola
AUS	Australux Fuses	NU	Nu Vu Pty. Ltd.
AWV	Amalgamated Wireless Valve Co.	NAU	A.G. Naunton Pty. Ltd.
ACA	Amplifier Co. of Aust.	PA	Painton (Aust.) Pty. Ltd.
AL	Alpha	PAL	Paton Elect. Pty. Ltd.
ARR	Arrow	PI	Piher Resistors (Sonar Electronics)
BWD	B.W.D. Electronics Pty. Ltd.	PW	Precision Windings Pty. Ltd.
BL	Belling & Lee Pty. Ltd.	PH	Philips Electrical Industries Pty. Ltd.
BR	Brentware (Vic.) Pty. Ltd.	PL	Plessey Pacific
BU	Bulgin	PV	Peaston Vic.
CF	Carr Fastener	RC	Radio Corporation (Electronic Inds.)
CAN	Cannon Electrics Pty. Ltd.	RCA	Radio Corporation of America
CIN	Cinch	RHC	R.H. Cunningham
D	Ducon Condensor Pty. Ltd.	STC	Standard Telephone & Cables
DAR	Darstan	SI	Siemens Electrical Industries
DIS	Distributors Corporation Pty. Ltd.	SIM	Simonson Pty. Ltd.
ELN	Elna Capacitors (Sonar Elec. P/L)	SE	Selectronic Components
ETD	Electron Tube Dist.	TR	Trimax Erricson Transformers
F	Fairchild Australia Pty. Ltd.	TI	Texas Instruments Pty. Ltd.
GRA	General Radio Agencies	TH	Thorn Atlas
GE	General Electric (USA)	UC	Union Carbide
GEC	General Electric Co. (UK)	W	Wellyn Resistors (Cannon Elec.P/L)
GES	General Electronic Services	WH	Westinghouse
GL	Grelco	Y	F.L. Yott Pty. Ltd.
HW	Hurtle Webster	Z	Zephyr Prod. Pty. Ltd.
HOL	R.G. Holloway		
H	Haco Distributors (National)		

CCT Ref.	DESCRIPTION				Mfr. or Supply	PART NO.	
	FUNCTION GENERATOR						
R1	3K3	½W	1%	CC			
R2	1K8	½W	5%	CC			
R3	3K3	½W	1%	CC			
R4	2K2	½W	5%	CC			
R5	39K	½W	5%	CC			
R6	1K	½W	5%	CC			
R7	15K	½W	5%	CC			
R8	33K	½W	5%	CC			
R9	3K9	½W	1%	CC			
R10	3K9	½W	1%	CC			
R11	3K3	½W	1%	CC			
R12	3K3	½W	1%	CC			
R13	5K6	½W	1%	CC			
R14	5K6	½W	1%	CC			
R15	6K8	½W	5%	CC			
R16	560Ω	½W	5%	CC			
R17	22Ω	½W	5%	CC			
R18	22Ω	½W	5%	CC			
R21	4K7	½W	5%	CC			
R22	1K8	½W	5%	CC			
R23	8K2	½W	5%	CC			
R24	Deleted						
R25	1K2	½W	5%	CC			
R26	2K7	½W	5%	CC			
R27	330Ω	½W	5%	CC			
R28	820Ω	½W	5%	CC			
R29	4K7	½W	5%	CC			
R30	3K	½W	5%	CC			
R31	4K7	½W	5%	CC			
R32	39Ω	½W	5%	CC			
R33	330Ω	½W	5%	CC			
R34	33Ω	½W	5%	CC			
R35	47Ω	½W	5%	CC			
R36	82Ω	½W	5%	CC			
R37	33Ω	½W	5%	CC			
R38	100Ω	½W	5%	CC			
R39	2K2	½W	5%	CC			
R40	220Ω	½W	5%	CC			
R41	120Ω	½W	5%	CC			
R42	330Ω	½W	5%	CC			
R43	470Ω	½W	5%	CC			

CCT Ref.	DESCRIPTION				Mfr. or Supply	PART NO.	
R44	1K	½W	5%	CC			
R45	2K2	½W	5%	CC			
R46	22K	½W	5%	CC			
R47	22K	½W	5%	CC			
R48	39Ω	½W	5%	CC			
R49	33Ω	½W	5%	CC			
R50	330Ω	½W	5%	CC			
R51	47Ω	½W	5%	CC			
R52	82Ω	½W	5%	CC			
R53	33Ω	½W	5%	CC			
R54	100Ω	½W	5%	CC			
R55	680Ω	½W	5%	CC			
R56	12K	½W	5%	CC			
R57	689Ω	½W	5%	CC			
R58	680Ω	½W	5%	CC			
R59	12K	½W	5%	CC			
R60	680Ω	½W	5%	CC			
R61	10K	½W	5%	CC			
R62	10K	½W	5%	CC			
R63	100Ω	½W	5%	CC			
R64	3K9	½W	5%	CC			
R65	3K9	½W	5%	CC			
R66	100Ω	½W	5%	CC			
R67	1K	½W	5%	CC			
R68	15K	½W	5%	CC			
R69	15K	½W	5%	CC			
R70	Deleted						
R71	1K	½W	5%	CC			
R72	100Ω	½W	5%	CC			
R73							
R74	100K	½W	5%	CC			
R75							
R76	470Ω	½W	5%	CC			
R77							
R78							
R79							
R80	4K7	½W	5%	CC			
R81	1K	½W	5%	CC			
R82	470Ω	½W	5%	CC			
R83	470Ω	½W	5%	CC			
R84	6K8	½W	5%	CC			
R85	2K2	½W	5%	CC			
R86	33K	½W	5%	CC			

PARTS LIST - MODEL bwd 603

CCT Ref.	DESCRIPTION				Mfr. or Supply	PART NO.	
R87	33K	½W	5%	CC			
R88	220Ω	½W	5%	CC			
R89	1K8	½W	5%	CC			
R90	10Ω	½W	5%	CC			
R91	10Ω	½W	5%	CC			
R92	560Ω	½W	5%	CC			
R93							
R94	10K	½W	5%	CC			
	CAPACITORS						
C1	100uF	6V	Electro				
C2	100uF	6V	Electro				
C3	22pf	CER					
C4	22pf	CER					
C5	0.001uF						
C6	0.001uF						
C7	180pf	CER					
C8	100uF		Electro				
C9	100uF		Electro				
C10	1uF	1%	Poly				
C11	0.1uF	1%	Poly				
C12	0.01uF	1%	Styro				
C13	0.001uF	1%	Styro				
C14	Deleted						
C15	10-40pf	Trimmer					
C16	80uF	25V	Electro				
C17	80uF	25V	Electro				
C21	22pf	CER					

CCT Ref.	DESCRIPTION			Mfr. or Supply	PART NO.	
C31	100uF	6V	Electro			
C32	100uF	6V	Electro			
C61	80uF	25V	Electro			
C62	80uF	25V	Electro			
C63	80uF	25V	Electro			
C81	56pf	CER				
	SEMI-CONDUCTORS					
Q1	BC147					
Q2	2N4121					
Q3	2N4121					
Q4	BC147					
Q5	2N4121					
Q6	2N4121					
Q7	BC147					
Q8	BC147					
Q9	MPF106	FET				
Q10	BC147					
Q11	2N4121					

PARTS LIST - MODEL bwd 603

CCT Ref.	DESCRIPTION	Mfr. or Supply	PART NO.	
Q21	BC147			
Q22	BC147			
Q31	BC147			
Q32	2N4121			
Q61-66				
Q80	2N4121			
Q81	BC147			
Q82	2N4121			
Q83	2N4121			
Q84	BC147			
Q85	BC147			
Q86	2N4121			
D1-83	IN914 or AN206			
	POTENTIOMETERS			
RV1	1K Preset			
RV2	25K WW 2W TW1			
RV3	2K2 Preset			
RV4	1K Preset			
RV5	2K2 Preset			
RV21	2K2 Preset			
RV22	Linear Carbon			
RV31	1K Preset			
RV32	1K Preset			
RV33	2K2 Preset			

PARTS LIST - MODEL bwd 603

CCT Ref.	DESCRIPTION	Mfr. or Supply	PART NO.	
RV61	22K Preset			
RV62	47K Preset			
RV81	1K Linear Carbon			
RV82	10K Linear Carbon			

CCT Ref.	DESCRIPTION				Mfr. or Suppl.	PART NO.	
	POWER AMPLIFIER - OP AMPLIFIER						
	200V POWER SUPPLY						
	RESISTORS						
R101	2K7	½W	5%	CC			
R102	2K7	½W	5%	CC			
R103	10K	½W	5%	CC			
R104	100K	½W	5%	CC			
R105	10K	½W	5%	CC			
R106	4K7	½W	5%	CC			
R107	4K7	½W	5%	CC			
R108	1K	½W	5%	CC			
R109	1K	½W	5%	CC			
R110	10Ω	½W	5%	CC			
R111	10Ω	½W	5%	CC			
R112	47Ω	½W	5%	CC			
R113	100Ω	1W	5%	CC			
R114	56Ω	1W	5%	CC			
R115	47Ω	½W	5%	CC			
R116	.5Ω	5W		WW			
R117	.5Ω	5W		WW			
R118							
R119							
R120							
R121	100K	½W	5%	CC			
R122	100K	½W	5%	CC			
R123	100K	½W	5%	CC			
R124	100K	½W	5%	CC			
R125	10Ω	½W	5%	CC			
R126							
R127							
R128							
R129							
R130							
R131	15K	6W		WW			
R132	1K	½W	5%	CC			
R133	22Ω	½W	5%	CC			
R134	56Ω	½W	5%	CC			
R135	10Ω	½W	5%	CC			
R136	10Ω	½W	5%	CC			
R137	1K	½W	5%	CC			
R138	5K6	½W	5%	CC			

CCT Ref.	DESCRIPTION	Mfr.or Suppl.	PART NO.	
	CAPACITORS			
C131	1uF			
C132	8uF 350V ELECTRO			
	TRANSISTORS			
Q101	2N3642			
Q102	2N3644			
Q103	MJE 2955			
Q104	MJE 3055			
Q131	BF337			
Q132	MJE 340			
Q133	MJE 340			
Q134	MJE 340			
	INTEGRATED CIRCUITS			
IC101	uA 741			
IC121	uA 741			
	DIODES			
D101	EM404			
D102	In914A			
D103	IN914A			
D104	EM404			
D105	EM404			
D106	EM404			
D107	EM404			
D108	EM404			
D109	EM404			
D121	EM404			
D122	EM404			
D123	EM404			
D124	EM404			
D131	EM404			
D132	IN914A			
D133	IN914A			

CCT Ref.	DESCRIPTION				Mfr. or Suppl.	PART NO.	
	POTENTIOMETERS						
RV101	1K	LINEAR CARBON		POT			
RV102	1K	LINEAR CARBON		POT			
RV121	1K	LINEAR CARBON		POT			
RV131	100Ω	PRESET					
RV132	100K	LINEAR CARBON		POT			
RV133	2K2	PRESET					
	POWER SUPPLIES						
	RESISTORS						
R211	0.5Ω	5W		WW			
R212	1K	½W	5%	CC			
R213	6K8	½W	5%	CC			
R214	10K	½W	5%	CC			
R215	6K8	½W	5%	CC			
R216	10K	½W	5%	CC			
R217	1K	½W	5%	CC			
R218	0.5Ω	½W	5%	CC			
R219	1M	½W	5%	CC			
R220							
R221	1.5Ω	½W		WW			
R222	8K2	½W	5%	CC			
R223	1.5Ω	½W		WW			
R224	5K6	½W	5%	CC			
R225	5K6	½W	5%	CC			
R226	15K	½W	5%	CC			
R227							
R228	10Ω	½W	5%	CC			
R229	10Ω	½W	5%	CC			

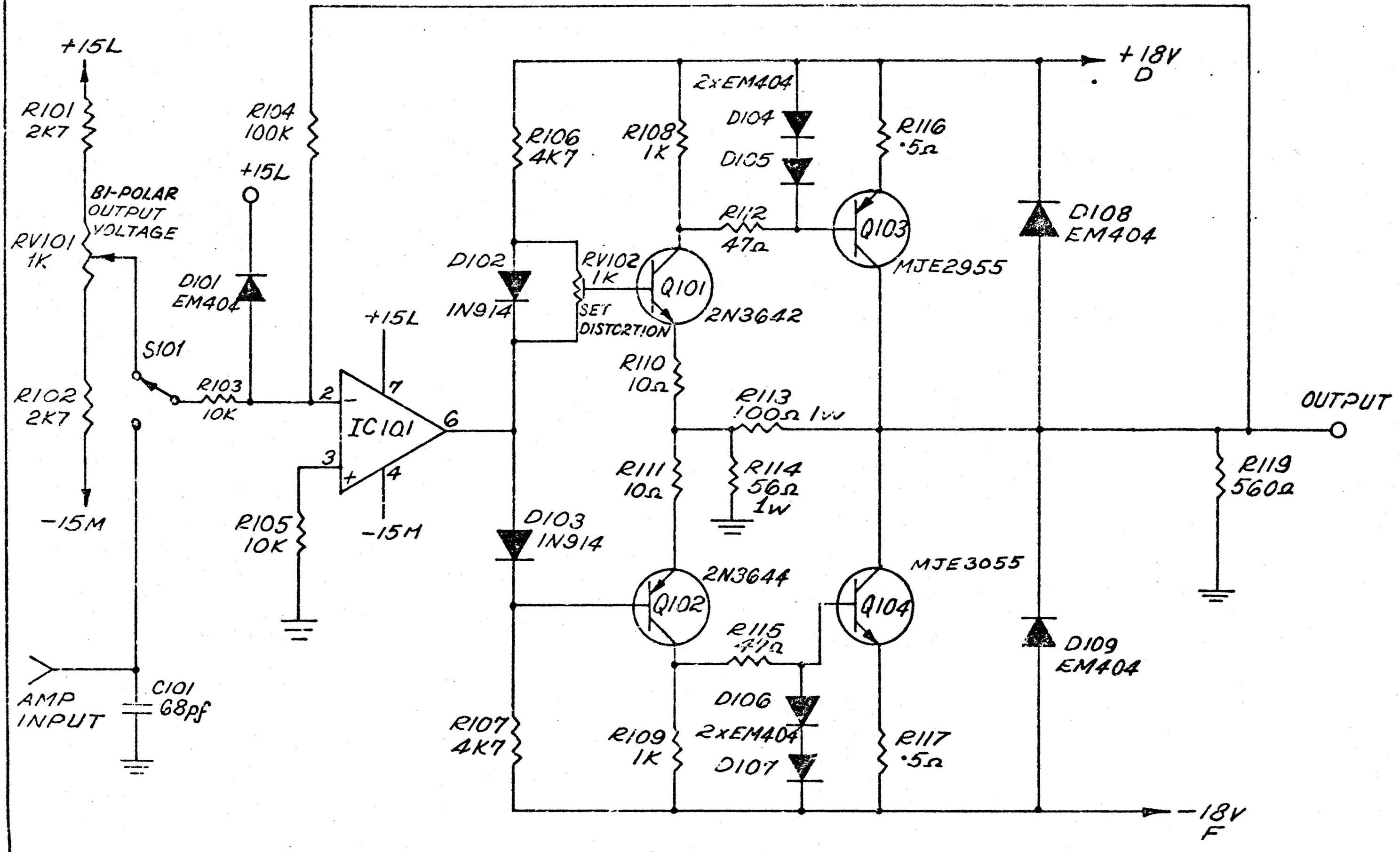
CCT Ref.	DESCRIPTION	Mfr. or Suppl.	PART NO.	
	CAPACITORS			
C201	4000uF 75V ELECTRO			
C202	4000uF 75V ELECTRO			
C203	4000uF 75V "			
C204	4000uF 75V "			
C205	50 uF 150V "			
C206	50 uF 150V "			
C207	640 uF 25 "			
C208	640 uF 25V "			
C209	640 uF 25V "			
C210	640 uF 25V "			
C211	80 uF 25V "			
C212	80 uF 25V "			
C213	.001 uF POLYESTER			
C214				
C221	12.5 uF 25V ELECTRO			
C222	12.5 uF 25V "			
C223	80 uF 25V "			
C224	80 uF 25V "			
C225	80 uF 25V "			
C226	80 uF 25V "			
	TRANSISTORS			
Q201	MJE 3055			
Q202	2N3819 FET			
Q203	MJE 340			
Q204	BC 147			
Q205	BC 147			
Q206	BC 157			
Q207	2N 3819 FET			
Q208	TIP 30A			
Q209	BC 157			
Q210	MJE 2955			
Q221	MJE 340			
Q222	2N 3819 FET			
Q223	BC 147			
Q224	BC 147			
Q225	2N 3819 FET			
Q226	TIP 30A			

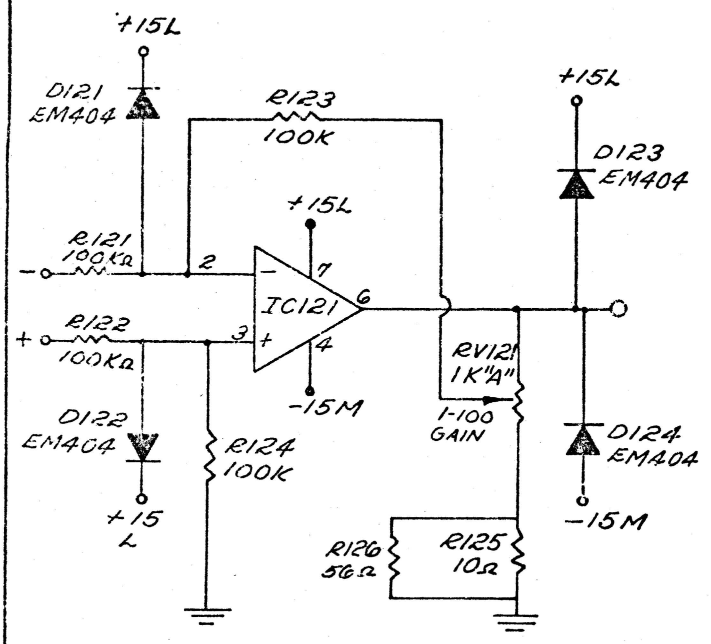
PARTS LIST - MODEL bwd 603

CCT Ref.	DESCRIPTION	Mfr.or Suppl.	PART NO.	
	DIODES			
D201	MR 754			
D202	MR 754			
D203	MR 754			
D204	MR 754			
D205	EM 404			
D206	EM 404			
D207	EM 404			
D208	EM 404			
D209	EM 404			
D210	EM 404			
D211	EM 404			
D212	BZY88 C6V2 ZENER			
D213	BZY88 C6V2 ZENER			
D214	EM 404			
D215	EM 404			
D216	EM 404			
D217				
D218				
D219				
D220				
D221	EM 404			
D222	BZY88 C6V2 ZENER			
D223	EM 404			
	FUSES			
F201	5 AMP 3AG QB			
F202	5 AMP 3AG QB			
F203	1 AMP 3AG DELAY			
	POTENTIOMETERS			
RV211	25K 5W WW			
RV212	4K7 PRESET			
RV213	4K7 PRESET			
RV214	25K 5W WW			
	MISCELLANEOUS			
T201	POWER TRANSFORMER BWD	T110		
B1	NEON 240V			

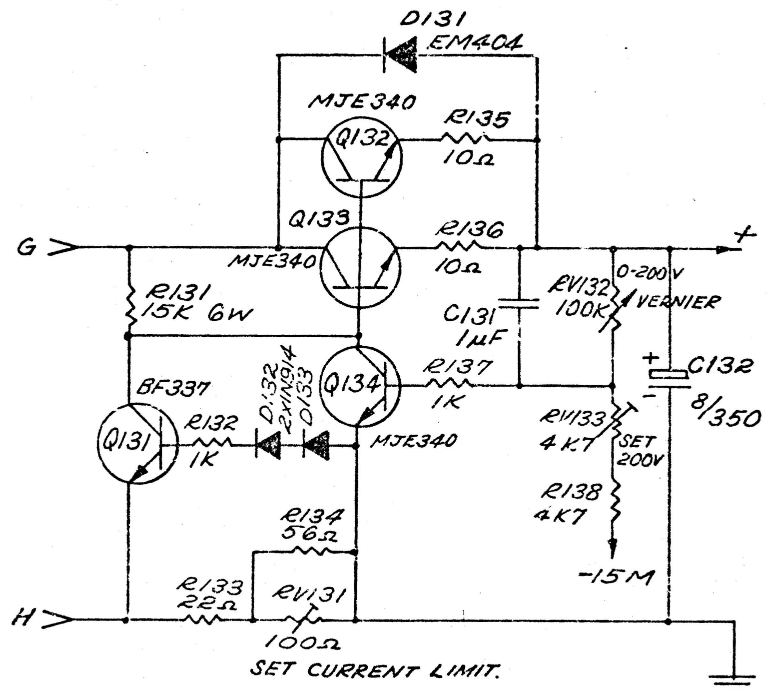
All other items order by description giving S/No. of instrument.

BI-POLAR POWER SUPPLY & POWER AMPLIFIER





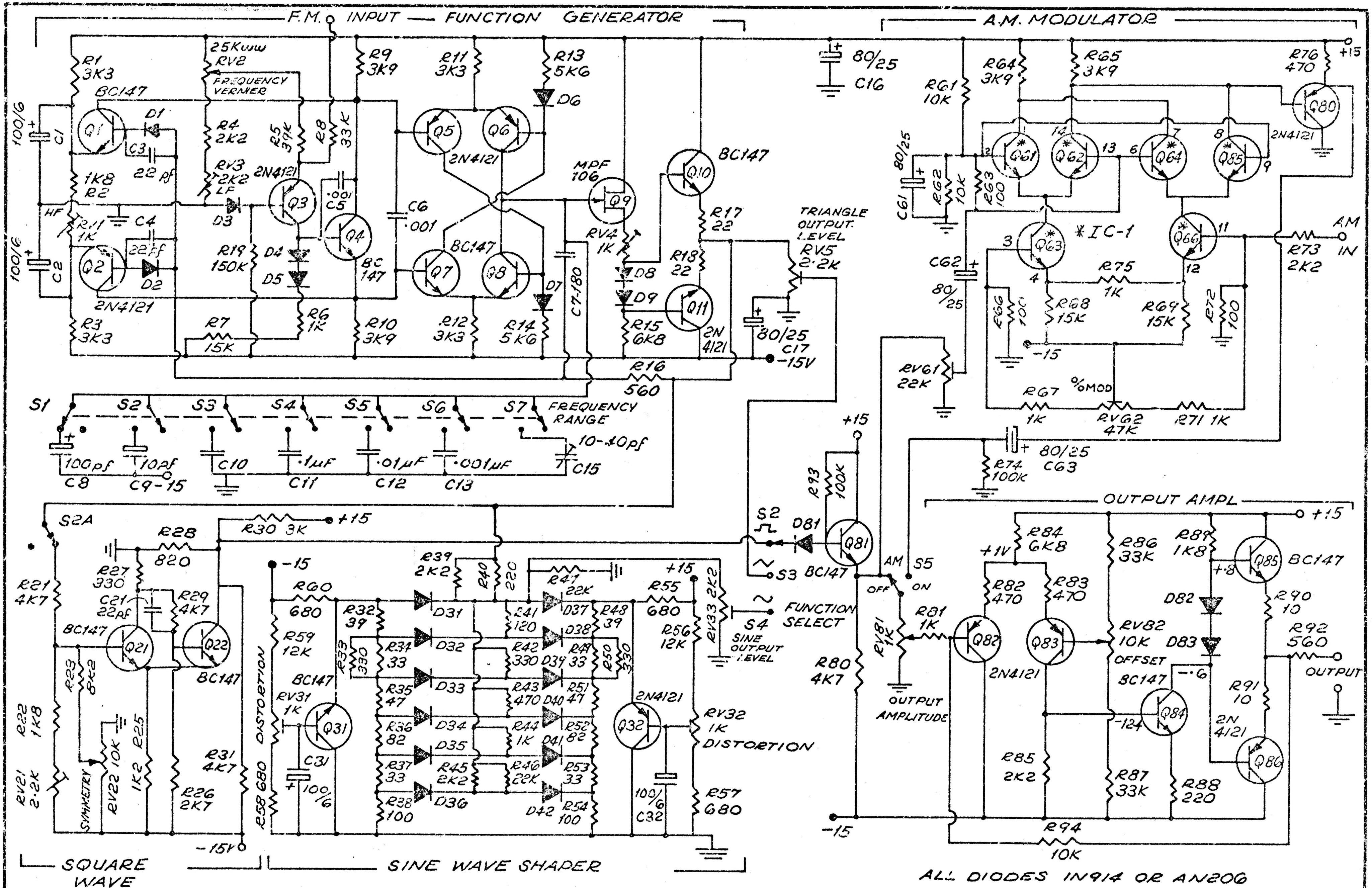
OPERATIONAL AMPLIFIER



VARIABLE 200V POWER SUPPLY

NOTE:-
COMPONENT VALUES MAY VARY FROM THOSE DESIGNATED DUE TO SUPPLY OR TO OPTIMISE PERFORMANCE.

1 / 2-72	DRAWN L.P. TRACED L.P. CHK'D DATE 23-2-72	MODEL 603 MINI-LAB POWER AMPLIFIER BI POLAR POWER SUPPLYS & OP-AMP	938 940	3	DRG.Nº 939



NOTE: COMPONENTS MAY VARY FROM THOSE DESIGNATED DUE TO AVAILABILITY OR TO OPTIMISE PERFORMANCE.

1 / 16-8-72	DRAWN J.B. TRACED. L.P. CHECK'D DATE 27-8-72	MODEL 603 'MINI LAB' FUNCTION GENERATOR	1050

R211 – R228	MODIFICATIONS
C201 – C226	
D201 – D225	
Q201 – 226	

CONTROLS

RV211 +15 VARIABLE OUTPUT.

RV214 −15 VARIABLE OUTPUT.

R101 – R138	MODIFICATIONS
C101 – C132	
D101 – D133	
Q101 – Q134	

CONTROLS

S101 - AMPLIFIER/BI-POLAR

RV101 - BI-POLAR OUTPUT.
RV121 - O.P. AMP. GAIN.
RV132 - 0-200 VOLT OUTPUT LEVEL.

R
1-19
21-59
61-73
80-93

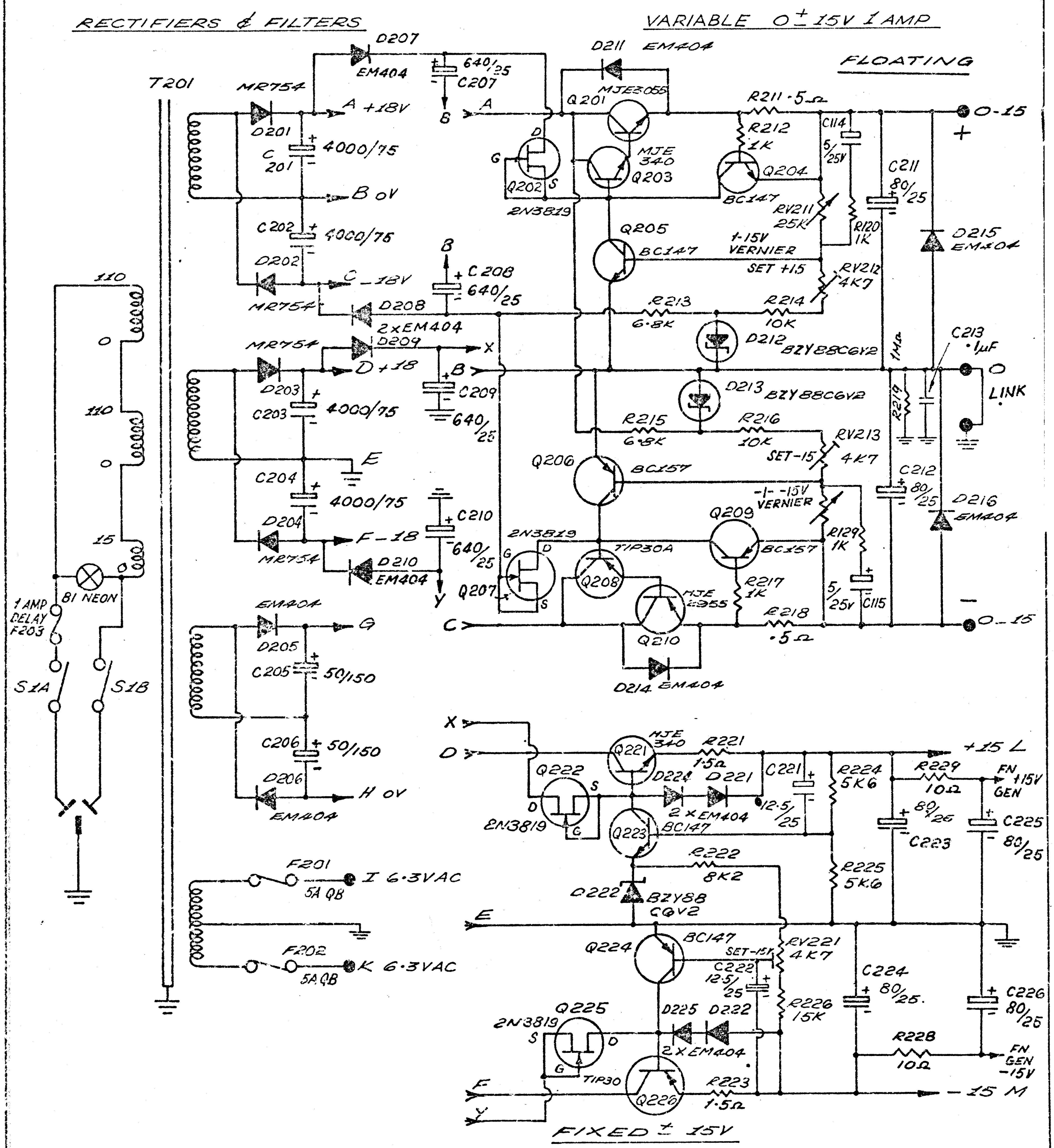
C
1-17
21-32
61-63
81-

D1-9
D31-42
D81-83

MODIFICATIONS

CONTROLS

RV1	HIGH FREQUENCY PRESET.
RV2	FREQUENCY VERNIER.
RV3	LOW FREQUENCY PRESET.
RV4	TRIANGLE DC LEVEL PRESET.
RV5	TRIANGLE OUTPUT LEVEL.
RV21	SQUARE WAVE SYMMETRY PRESET.
RV22	SQUARE WAVE SYMMETRY.
RV31	SINE DISTORTION PRESET.
RV32	SINE DISTORTION PRESET.
RV33	SINE AMPLITUDE PRESET.
RV61	AM CARRIER LEVEL PRESET.
RV62	AM DEPTH PRESET.
RV81	OUTPUT AMPLITUDE.
RV82	DC OFFSET.
S1 -7	FREQUENCY RANGE
S2 -4	FUNCTION SELECT.
S5	AM ON - OFF.



COMPONENTS VALUES MAY VARY FROM THOSE DESIGNATED DUE TO AVAILIBILITY OR TO OPTIMISE PERFORMANCE.

1 / 7-70	DRAWN B.R.L. TRACED L.D.P. CHECKED DATE 25.7.71	MODEL 603 MINI — LAB POWER SUPPLIES	939 940	3	938