BNC

Instruction Manual

Model BH-1

Tail Pulse Generator

3060 Kerner Blvd., #2 San Rafael, CA 94901 Ph: 415-453-9955 Fx: 415-453-9956
www.berkeleynucleonics.com

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Warranty

Berkeley Nucleonics Corporation warrants all instruments, including component parts, to be free from defects in material and workmanship, under normal use and service for a period of one year. If repairs are required during the warranty period, contact the factory for component replacement or shipping instructions. Include serial number of the instrument. This warranty is void if the unit is repaired or altered by others than those authorized by the Berkeley Nucleonics Corporation.

SPECIFICATIONS

SECTION 1

FREQUENCY: 10 Hz to 1 MHz, continuously adjustable.

EXTERNAL TRIGGER: Requires 1 volt, positive pulse.

SINGLE CYCLE: One pulse occurs each time the push-button is pressed.

SINGLE/DOUBLE PULSE: This toggle provides for a pulse pair whose separation is varied by the delay controls. Minimum separation is 50 ns.

RISE TIME OF OUTPUT (10-90%): 20 ns to 50 µs (in 11 steps), exponential shape and independent of decay time.

DECAY TIME CONSTANT OF OUTPUT (100-37%): 50 ns to 1000 µs (in 11 steps), exponential shape and independent of rise time.

TRIGGER OUT: Positive 2 volt pulse, 30 ns rise time, 0.2 µs width, 50 ohms output impedance.

DELAY: –50 ns advance to 10 ms delay (between Trigger Out and leading edge of output pulse).

OUTPUT AMPLITUDE: Zero to 9.99 volts maximum. Adjustable by ten-turn potentiometer.

ATTENUATOR: X10 and X100 providing up to 1000 : 1.

INTEGRAL LINEARITY OF OUTPUT: ±0.1%.

DUTY FACTOR EFFECT: Amplitude shift less than 0.1% below 30% duty factor. Duty factor in per cent for tail pulses is defined as: (8 decay time constants/pulse spacing) X100.

OUTPUT POLARITY: Positive or negative.

OUTPUT IMPEDANCE: 50 ohms.

EXTERNAL REFERENCE INPUT: 10 volts max. Positive.

JITTER OF FREQUENCY AND DELAY: Less than 0.1%.

TEMPERATURE COEFFICIENT OF OUTPUT: Less than 0.03%/° C.

AMPLITUDE JITTER (RESOLUTION): Less than 0.01% peak, 0.002% rms of pulse amplitude.

POWER REQUIRED: +24 V at 50 mA, –24 V at 50 mA, +12 V at 175 mA, –12 V at 80 mA.

MECHANICAL DIMENSIONS: Double-width AEC module, 2.70 inches wide by 8.70 inches high. Conforms to AEC Report TID-20893 (Rev. 2).

WEIGHT: 3½ lbs. net, shipping 7 lbs.

2.1 INTRODUCTION

The Model BH-1 Tail Pulse Generator is a precision pulse generator which provides a broad range of tail pulses encountered in the nuclear and life science areas. Several Model BH-1's may be synchronized together to provide test pulses of various shapes and amplitudes to check out a system. Typical applications of the Model BH-1 include: determining the proper timing of linear gates and coincidence units, linearity measurements of amplifiers, threshold setting of discriminators and single channel analyzers, and measuring resolution of low noise preamplifiers.

2.2 FUNCTION OF CONTROLS & CONNECTORS

FREQUENCY: Concentric switch and potentiometer control repetition rate of output pulses. When switch is in the EXT/S.C. position, an output pulse will occur if the SING CYC (single cycle) button is pressed. Also, output pulses will occur if an external trigger is connected to the EXT TRIG connector.

DELAY: Concentric switch and potentiometer control time delay between TRIG OUT (trigger out or synchronizing) pulse and tail pulse.

RISE TIME: Controls 10% - 90% rise time of output pulse.

FALL TIME: Controls decay time constant, 100% - 37%, of output pulse.

AMPLITUDE: Ten-turn potentiometer controls amplitude of output pulse.

SING PULSE/DBL PULSE: When this toggle is in the SING PULSE position, one output pulse will occur for each trigger pulse at the TRIG OUT connector. When it is in the DBL PULSE (double pulse) position, two output pulses occur for each trigger pulse. The separation between these two pulses is adjusted by the delay controls.

REF - EXT/INT: This toggle connects the pulse forming circuitry either to an internal dc reference voltage or an external reference. In the EXT REF (external reference) position the reference voltage is applied to the EXT REF connector. NOTE: The maximum external reference voltage is 10 V and must be positive polarity. The Berkeley Nucleonics Model LG-1 Ramp Generator is designed to be connected to the EXT REF connector to provide a sliding pulse train.

POL: This toggle provides either positive or negative polarity output pulses.

ATTENUATOR: These toggles provide X10 and/or X100 attenuation of the output pulses.

CONNECTORS:

1. PULSE OUT: The output pulse appears at this connector. If the rise time is 50 ns or less, the output cable should be terminated in 50 ohms to avoid reflection and distortion of the pulse.

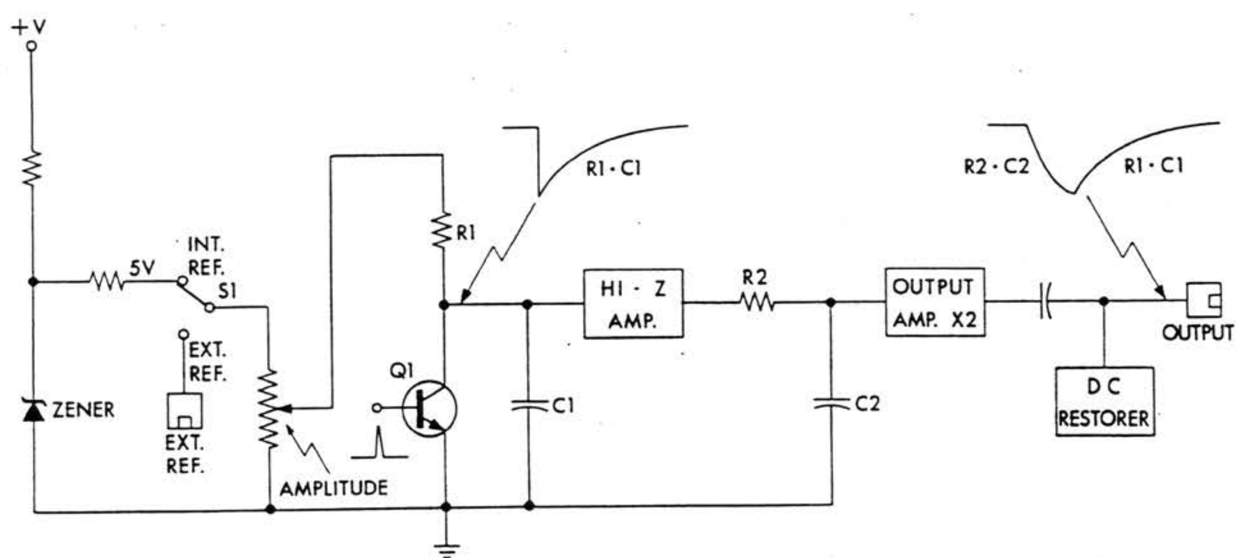

Fig. 1. Simplified schematic of the Model BH-1

2. TRIG OUT: This connector provides a synchronizing pulse which precedes the output pulse.

3. EXT TRIG: This connector is provided to connect an external trigger to set the output repetition rate.

4. EXT REF: This connector is to provide an external reference to the instrument. It may be either dc or time varying, such as a ramp. Maximum amplitude of the external reference is 10 volts, positive polarity only.

2.3 PRINCIPLE OF OPERATION

The principle of operation of the Model BH-1 is explained by referring to Fig. 1. The AMPLITUDE control is connected to either a zener diode regulated dc supply or an external reference by switching S1. The output of the AMPLITUDE control is the collector voltage for transistor Q1. A short drive signal at the base of Q1 causes the transistor to saturate for a very brief time, essentially applying an impulse charge to C1. The voltage on C1 then recovers to the original level with the time constant R1·C1, producing the tail pulse shown. The signal on C1 passes to a high impedance amplifier which decouples the impulse charge circuits from the rise time integrator R2·C2. After passing through the rise time integrator, the signal is amplified by a factor of two in the output amplifier. The output amplifier is capacitively coupled to the output connector, and an active dc restorer maintains the signal baseline at zero volts.

2.4 LINEARITY VS. DUTY FACTOR

As the duty factor of the output pulses is increased, there will be a change of both linearity and amplitude. The duty factor should be kept below 30% for specified linearity of ±0.1%.

Since a tail pulse does not have a defined end point, its pulse width is defined herein as equal to 8 fall time constants. Therefore, the output duty factor of the Model BH-1 is:

$$\text{Duty Factor (\%)} = \frac{8 \text{ X Fall Time Constant}}{\text{Pulse Spacing}} \text{ X } 100$$

2.5 OPTIMUM PERFORMANCE

The Model BH-1 is a precision instrument, and certain care must be observed in operation to obtain optimum performance. The following paragraphs discuss various factors which contribute to this performance.

1. Termination: The output of the BH-1 should be terminated in 50 ohms when the rise time control is set at 20 ns or 50 ns. Otherwise, reflection will distort the pulse top.

2. Duty Factor: The duty factor must be kept below 30% (see paragraph 2.4 above) for specified accuracy. As the duty factor limitation is exceeded the pulse shape will deteriorate. Therefore, it is useful to monitor the waveform on an oscilloscope while setting up the controls of the Model BH-1.

3. Baseline Restorer Operation: The output amplifier is capacitively coupled to the output connector. An active dc restorer is provided to maintain the baseline at zero volts. As the duty factor is increased, a "corner" on the tail of the pulse near zero volts will become more apparent. This is the normal result of baseline restoration. At low duty factors the "corner" becomes quite small.

4. Temperature Coefficent of Output Pulses: The rated temperature coefficent of less than 0.03%/°C applies to a worst case condition in the Model BH-1. This occurs with the longest tail time of 1 millisec. The temperature coefficent will be two to three times better as the fall time is reduced.

5. Transients: During the time that pulses are being formed, switching transients will unavoidably be produced. In the design of the instrument these have been reduced so that they will have negligible effect in the majority of applications. However, if the AMPLITUDE control is reduced to near minimum, the transients may become an appreciable fraction of the pulse amplitude. Consequently, it is recommended that the AMPLITUDE control be operated near maximum and the ATTENUATOR switched in to obtain the cleanest small pulses.

2.6 DOUBLE PULSE OPERATION

When the DBL/SING PULSE toggle is in the DBL (double) PULSE position, two pulses will appear at the output where separation is controlled by the DELAY controls. The pulses will be identical in shape and amplitude. One of the applications of this function is to check double pulse resolution of scalers.

As the pulse separation is reduced, the second pulse will not ride up the tail of the first pulse. If it is desired to provide a ride up of pulses, it is necessary to connect the outputs of two BH-1's together. Minor interaction between the two Model BH-1's will be minimized by throwing in the attenuators.

3.1 MEASURING DIFFERENTIAL NONLINEARITY (DNL) IN A PHA

The Model BH-1 is designed to be used with the Berkeley Nucleonics Model LG-1 Ramp Generator to measure differential linearity of a pulse height analyzer (PHA).

Differential nonlinearity (DNL) in a PHA describes the change in relative width of one or more channels with respect to the average width of all the channels. DNL can be determined by manually setting a pulse amplitude to both edges of each channel and calculating the width of each channel individually. DNL may be much more conveniently and quickly determined by using the sliding pulser method, where a constant frequency pulse is swept in amplitude at a constant rate. Where the channel widths are identical, the pulses will fall in each channel for an equal length of time and the number of counts accumulated in each channel will be equal. The PHA display for zero DNL would then be a horizontal straight line.

DNL measurements on a PHA are typically made as follows:

1. Connect the ramp generator OUTPUT to the EXT REF (external reference) connector of the Model BH-1. Throw the REF - EXT/INT toggle to the EXT position. Throw the POL switch of the Model LG-1 into the positive position.

2. Connect the output of the Model BH-1 to an amplifier preceding the analyzer or the analyzer input. Note: The pulse shape being analyzed is important for optimum linearity tests. Some analyzer inputs may require input pulse shapes other than the tail pulse provided by the Model BH-1. In this case, pre-shaping in an amplifier may be required.

3. Set the PERIOD switch of the Model LG-1 to 5 secs. and press the reset button.

4. Set the FREQUENCY control of the Model BH-1 to the desired rate, 1 KHz for example. The maximum usable frequency is determined by the maximum dead time in the PHA.

5. Set the POLARITY, RISE TIME and FALL TIME controls of the Model BH-1 to the desired positions.

6. Erase the storage in the PHA and then set it in the STORE mode.

7. Press the START button on the Model LG-1 and observe the highest channel counting at the peak of the sliding pulse train. Adjust the PHA gain and the Model BH-1 AMPLITUDE control so that the pulse amplitude sweeps beyond the highest channel.

8. Select the desired LG-1 ramp period. Erase the PHA memory and reset the Model LG-1.

9. For a single triangular amplitude sweep, set the REP-SINGLE CYCLE switch to SINGLE CYCLE. When the START button is operated, the ramp will complete one cycle and then stop. For multiple ramp cycles, set the switch to the REP position.

10. Erase the storage in the PHA and again set it in the STORE mode.

11. Press the START button of the LG-1 and accumulation of counts in the PHA will begin.

12. When sufficient counts have been accumulated for the statistical accuracy desired, press the STOP button on the Model LG-1. The ramp cycle will stop at the next zero crossing of the ramp.

The maximum error of the DNL measurement will be inversely proportional to the square root of the number of counts accumulated in each channel plus the error in the sliding pulse train. The differential linearity of the Model BH-1 is $\pm 0.25\%$ above 100 mV with reference to the 11.6 volt ramp. This specification corresponds to the upper 99% of the sliding pulse train. If the maximum sliding pulse amplitude is reduced by the BH-1 AMPLITUDE control, the 100 mV minimum for $\pm 0.25\%$ linearity still applies. Consequently, it is preferred to keep the AMPLITUDE control near maximum and use the attenuators for reduced amplitude, when possible.

The differential nonlinearity (DNL) of the analyzer may then be computed by:

$$DNL = 100 \left[1 - \frac{N_x}{N(av)} \right] \%$$

where N_x = number of counts in channel x

$N_{(av)}$ = average number of counts in all channels

N_x is generally taken as the worst case deviation from the average. In some cases one channel address may be defective, and it is not included in the measurement.

The choice of the ramp speed is usually a matter only of convenience, though some PHA manufacturers may specify a particular time range for linearity measurements. Visual verification of correct operation is easier on the 5 second ramp period and should theoretically produce the same results as with 50 second period. Different results for DNL (with the same number of counts per channel) may be attributed in some cases to channel boundary anomalies. The channel boundary profile will vary with different analyzers.

Ramp speeds faster than provided for by front panel controls may be obtained by using smaller timing capacitors. The factory should be consulted before making any such change, as there are a number of factors and tradeoffs to be considered when changing the ramp speeds beyond the normal range.

3.2 EXT REFERENCE INPUT

The EXT REF connector accepts only positive polarity. A negative external reference will not provide a pulse output. The polarity of the output pulses is controlled only by the front panel POL toggle. The amplitude of the external reference should not exceed 10 volts; beyond this level the specified linearity of the Model BH-1 will no longer hold. The EXT REF input is protected against overload inputs to ±25 V.

The input impedance of the EXT REF connector is 1K. When using an external reference the effect of this loading should be considered. The Model LG-1 Ramp Generator is designed to be directly connected to the EXT REF without deterioration of its specifications.

3.3 RESOLUTION TESTS ON A SYSTEM

A useful application of the Model BH-1 is to measure the resolution of a preamplifier, amplifier and other elements in a high resolution system.

The test signal from the pulser is injected into the input of the preamplifier via a 1 or 2 pf capacitance. This capacitance is effectively in parallel with the detector capacitance but is so much smaller that it will not effect the noise. The amplitude jitter (or noise) of the pulses from the Model BH-1 is less than 0.002% rms. This is orders of magnitude less than noise in existing (1969) preamplifiers. Consequently, the FWHM spread of the pulser signal on a pulse height analyzer is a true indication of the noise --and limiting resolution of the system.

This section of the manual contains a description of the circuits used in the Model BH-1 Pulse Generator. A simplified schematic, Fig. 1, shows the general relationship of the circuits, and schematic BH-101 at the back of this manual shows the circuit details.

4.1 FREQUENCY CIRCUITS

Refer to Schematic BH-101. A free-running multivibrator, Q1 - Q2, generates the internal clock frequency when S1 is in one of the continuous frequency positions. The frequency range of the multivibrator is selected by C1 - C5 on S1. R4 provides a continuously variable adjustment of frequency. The signal on the collector of Q2 is differentiated by C6 - R7 and passes through diode D2 to the base of Q5 in the Trigger Delay One-Shot, Q5 - Q6.

External trigger signals of +0.5 V or more applied to the Ext. Trig. Input connector operate the External Trigger Schmitt, Q3 and Q4. R9, D3 and D4 protect the input circuits from excessive voltages. The external trigger signal passes to the base of Q3 in the Schmitt, Q3 and Q4. Q3 and Q4 are connected as a one-shot, but their operating points are chosen such that they function as a Schmitt Trigger. The signal on the collector of Q4 is differentiated by C8 - R16 and passes through D5 to the base of Q5 in the Trigger Delay One-Shot Q5 - Q6.

In Single Cycle operation C9 is charged through divider R20 - R21 and discharged through the Single Cycle switch S2. The resulting positive pulse is differentiated by C10 - R19 and passes through D6 to the base of Q5 in the Trigger Delay One-Shot, Q5 - Q6.

4.2 DELAY CIRCUITS

A positive pulse on the base of Q5 from diodes D2, D5 or D6 starts the Trigger Delay One-Shot, Q5 - Q6. The leading edge of the one-shot signal passes through C12 and D9 to the base of Q10 in the Delay Generator One-Shot, Q10 - Q11. This signal is differentiated by C12 - R34. The trailing edge of the Trigger Delay signal passes through C12 and D8 to the base of Q7 in the Trigger Generator one-shot Q7 - Q8. The delay produced by the Trigger Delay One-Shot Q5 - Q6 is necessary to offset the delays in the pulse output signal path. A negative pulse on the base of Q7 starts the Trigger Generator One-Shot, which has a period determined by C13 - R30 and the voltage swing across R27. The signal on the collector of Q8 passes to the base of Q9, saturating Q9 for the duration of the trigger pulse. R32 - R33 form a voltage divider to produce a +2 V pulse at the Trigger Out connector. R32 - R33 also form a 50 ohm reverse termination during the time Q9 is saturated.

At the base of Q10 the leading edge (positive) signal from Q6 starts the Delay Generator One-Shot, Q10 - Q11. The delay range is controlled by C15 - C20 on S3. R38 provides a continuously variable adjustment of the delay. The trailing edge (negative) of the signal at the collector of Q11 is differentiated by C21 - R37 and passes through D11 to inverter Q12. Divider R2 - R37 provides a reverse bias on D11 to avoid spurious triggering of Q12. The collector of Q12 produces a positive signal at the end of the Delay Generator One-Shot cycle. This signal is differentiated by C22 - R43 and passes through D12 to the base of Q13 in the Impulse Drive Shaper Q13 - Q14. When S4 is in the Single Pulse position, D13 is reverse biased by divider R44 - R45 so that the signal from the collector of Q11 is blocked. When S4 is in the Double Pulse position, the reverse bias is removed and the leading edge (positive) of the signal at the collector of Q11 passes through D13 to the base of Q13. The signal at the base of Q13 will then consist of two pulses separated by the period of the Delay Generator One-Shot, Q10 - Q11.

4.3 IMPULSE DRIVE CIRCUITS

Q13 - Q14 are connected as a one-shot, but function as a Schmitt trigger, as in Q3 - Q4. Q13 - Q14 provide a fast-rising, constant amplitude signal from the preceding timing circuits. The signal on the collector of Q14 passes via C26 to the base of switch transistor Q15. Q15 saturates and the resulting signal on its collector is differentiated by C27, C28 - R56, R57. This negative pulse passes to the base of Q16, which is normally biased into saturation by R56. Q16 turns off during this pulse, allowing the current in R58 to pass through Q17, which is connected as a fast diode. The signal at the emitter of Q17 is a short current pulse, which passes through R81 and R82 to the bases of Q20 and Q21.

The reference voltage for determining the output pulse amplitude is obtained from the Reference Emitter Follower pair, Q18 - Q19. Q18 and Q19 are connected so that their base-emitter voltage drops are compensated for temperature change. When the Reference switch is in the "Internal" position, the reference voltage is derived from zener diode D16. The ten turn Amplitude potentiometer R65 provides a continuously variable adjustment of the output pulse amplitude. The minimum pulse amplitude available when using the internal reference voltage is set by R121, R150 and potentiometer R140. When the Reference switch is in the "External" position, the voltage at the Ext. Ref. connector, multiplied by the attenuation of R66 and R65 determines the output pulse amplitude. The 10 V maximum Ext. Ref. voltage is divided by a factor of two in R65 - R66, to provide a maximum of 5 V at the Reference Emitter Follower, Q18 - Q19. A gain of two in the Negative Amplifier restores the pulse amplitude (open circuit) to the level of the Ext. Ref. voltage.

When the Fall Time switch S6 is set in the range of 50 ns to 10 μs, Q21 is disconnected, and only Q20 functions in the Impulse Charge circuit. In this range, operation is as follows:

C35 charges to the reference voltage on Q19 through R70 - R75. The positive current pulse from Q17 via R81 saturates Q20 for a period of about 10 ns. C35 discharges through R83 and Q20, producing the rising part of the output pulse. When Q20 turns off, C35 charges back to the reference voltage at a rate determined by C35 and the fall time resistor R70 - R75. The fall time switch S6 selects the appropriate fall time resistor. This produces the falling part of the pulse, or the "tail". The peak of the pulse is always at the same dc point, so that the amplitude of the pulse is changed by varying its baseline, which is the reference voltage from Q19. The pulse is capacitively coupled in the amplifier system, and the baseline is restored to ground level at the output.

When the Fall Time switch S6 is set in the range of 50 μs to 1 ms, C34 is switched in parallel with C35 and Q21 is switched into the circuit to provide the additional discharge current for C34. D18 provides compensation for the leakage current in Q20 and Q21 at elevated temperatures.

4.4 HI IMPEDANCE AMPLIFIER

The signal pulse on C35 passes through C36 to the gate of Field Effect Transistor Q22 in the High Impedance Amplifier, Q22 - Q24. The High Impedance Amplifier is a source follower, Q22, followed by an emitter follower, Q23. Q24 is a current source for the source of Q22 and the emitter of Q23. The source of Q22 is bootstrapped by returning R89 to the junction of R90, C37 and the current source Q24. The drain of Q22 is bootstrapped by returning it to the junction of R92, R93 and C38. Thus the operating point of Q22 is kept constant regardless of the instantaneous signal voltage applied to its gate. The quiescent level of the High Impedance Amplifier is set by returning R87 to +12 V. Due to the high impedance at the gate of Q22 (essentially 25 Megohms) this point cannot be measured with a conventional oscilloscope probe without drastically shifting the operating point of the amplifier.

The signal pulse, now at a low impedance level, passes through C39 to the rise time integrator R95 and C40 - 49. The Rise Time switch S7 selects the appropriate capacitors for the desired rise time. At this point the signal pulse is fully shaped.

4.5 NEGATIVE AMPLIFIER

The signal pulse then passes through R97 to the base of Q25 in the Negative Amplifier Q25 - Q28. R91 and R94 bias the amplifier to its proper operating point of 7.2 V at its output. The Negative Amplifier is non-inverting, with a gain of 2.3. The input is high impedance to minimize effects on the pulse shape. Q25 is a current amplifier, with virtually no collector voltage swing. The inverted input signal passes from the collector of Q25 to the base of Q26. D19 limits the swing at the base of Q26. Q26 provides the voltage gain and a second stage of inversion for the amplifier and drives the output emitter followers, Q27 and Q28. D20 and D21 provide a voltage drop which insures that both Q27 and Q28 are turned on at all times. R104 limits the current between the emitters of Q27 and Q28. C53 bootstraps the collector load, R102, of Q26 to provide high voltage gain and sufficient frequency response to high amplitude signals. R99 is the feedback resistor, producing at the emitter of Q25 a signal "following" the input signal at the base of Q25. Due to the high open loop voltage gain of the amplifier, there is very little current change in Q25. Since the emitter voltage of Q25 tracks its base voltage, the base of Q25 is then a high impedance point. The closed loop voltage gain of the Negative Amplifier is determined by the ratio of the values of R96 and R99 according to the following relationship: Gain = (R96 + R99) / R96. C50 provides high frequency compensation for the amplifier.

4.6 BASELINE RESTORER CIRCUITS

The negative signal pulse passes from the emitter of Q28 through C55, through the Polarity switch S8, and through R141 to the output attenuators, S9 - S10 and R143 - R148. The negative signal pulse also passes to the base of Q33 in the Negative Baseline Restorer, Q33 - Q35. Assuming for the purpose of discussion that the base-emitter voltage drops of Q33 and Q34 are equal and that the forward voltage drops of D25 and D26 are equal, the level at the base of Q34 would be set to 0 V by potentiometer R130 and divider R126 - R127. When the base of Q33 (the negative signal line) is more negative than the base of Q34, Q33 will be turned on and Q34 will be turned off except for 2 mA of idle current from R122. This current will flow through R123 to the base of Q35. However, 3.3 mA flows in the opposite direction through R124, causing Q35 to be turned off. D27 limits the voltage swing at the base of Q35. When Q35 is off, no current flows through R133 into the negative signal line. Since the signal pulse is capacitively coupled through C55, the baseline of the signal will shift in a positive direction due to the output load current appearing in C55. As the signal pulse amplitude approaches its new baseline at the end of the pulse tail, it will tend to become positive. Q33 will begin to shut off and Q34 will turn on to the point where the current in R123 exceeds the current in R124. Q35 will turn on, pulling the signal line negative. When the signal line reaches 0 V, the action of the baseline restorer will diminish, thereby maintaining the maximum positive swing of the signal line at 0 V. R133 limits the maximum current that the baseline restorer can provide, and R106, C54 and C63 stabilize the circuit at high frequencies. R117 introduces 0.5 mA of positive current into the signal line to insure that the baseline restorer is active under quiescent conditions or at very low duty factors. It may be noted that the average current supplied by Q35 equals the average load current plus the 0.5 mA supplied by R117.

4.7 POSITIVE AMPLIFIER

The negative signal pulse at the junction of C55 and the base of Q33 also passes to R107, which is the input of the Positive Amplifier, Q29 - Q32. The Positive Amplifier is an operational amplifier with its summing junction at the emitter of Q29. A voltage signal at the input side of R107 is transformed to a current signal and appears at the collector of the grounded base stage Q29. The signal passes to the base of Q30, which provides the voltage gain for the Positive Amplifier. D22 limits the swing at the base of Q30. The single signal inversion necessary for this amplifier configuration takes place in Q30, which also drives the output emitter followers Q31 and Q32. D23 and D24 provide a voltage drop which insures that both Q31 and Q32 are turned on at all times. R115 limits the current between the emitters of Q31 and Q32. C59 bootstraps the collector load, R112, of Q30 to provide a high voltage gain and sufficient high frequency response to high amplitude signals. R109 is the feedback resistor, producing an equal current of opposite polarity to that in R107 at the emitter of Q29. The closed loop gain of the Negative Amplifier is determined by the values of R107 and R109 according to the following relationship: Gain = -R109 / R107. In this case, since R107 = R109, the gain is -1. C69 provides high frequency compensation for the amplifier. The quiescent output voltage level of the amplifier is set by the emitter current required by Q29 in excess of that supplied by R111. This excess current is supplied by R109, thus defining the amplifier output voltage. This voltage is normally -4.8 V.

The positive signal pulse passes from the emitter of Q31 through C61, through the Polarity switch S8, and through R141 to the output attenuators, S9 - S10 and R143 - R148. The positive signal pulse also passes to the base of Q36 in the Positive Baseline Restorer Q36 - Q38. Operation of the Positive Baseline Restorer is identical to that of the Negative Baseline Restorer, except that all polarities are reversed. R141 provides reverse termination for reflected signals. The X10 Attenuator R143 - R145 and the X100 Attenuator R146 - R148 are 50 ohm pi type balanced attenuators, providing both input and output impedances of 50 ohms.

5.1 PREVENTIVE MAINTENANCE

Preventive maintenance consists of cleaning, visual inspection, lubrication, etc. Preventive maintenance performed on a regular basis will contribute to the continuing specified performance of the instrument.

CLEANING

The Model BH-1 is cooled by convection and will accumulate relatively little internal dirt. Where cleaning is necessary, use a clean brush or cloth to remove loose dirt. Use only clear water or alcohol for cleaning where dirt cannot be removed by wiping or brushing. Final cleaning must always be done with clean alcohol.

LUBRICATION

When the instrument is periodically inspected the switches should be lubricated with a suitable switch lubricant. The switch contacts and detents will have a longer life if they are kept properly lubricated.

VISUAL INSPECTION

The Model BH-1 should be occasionally inspected for such defects as broken connections, damaged parts, etc. The remedy for most visible defects will be obvious; however, care must be taken if heat-damaged parts are located. Usually overheating is only a symptom of trouble. For this reason it is essential to determine the actual cause of the overheating before replacing the part; otherwise the damage may be repeated.

OPERATIONAL CHECK

A detailed check of the operation of the Model BH-1 can be useful in determining and localizing minor trouble which may not be apparent in normal use. In some cases, minor troubles can be corrected by recalibration. (See Section 5.2)

5.2 CALIBRATION

Any needed repairs should be performed before proceeding with calibration. Troubles which become apparent during calibration should be corrected before continuing the calibration.

THE PHYSICAL LOCATION OF THE TRIMMERS IS SHOWN ON SCHEMATIC BH - 101.

The following equipment or equivalent is required for making trimmer adjustments on the Model BH-1. If equipment is substituted, it must meet or exceed the specifications of the recommended equipment.

TEST EQUIPMENT

1. 50 MHz bandwidth oscilloscope, such as a Tektronix Type 546 with a type 1A2 plug-in.
2. 50 ohm interconnecting coaxial cables
3. 50 ohm cable termination
4. Extender cable for power connection.

CAUTION! CALIBRATION MUST BE DONE IN THE SEQUENCE SHOWN OR MISADJUSTMENT MAY RESULT.

PROCEDURE

1. INITIAL

   a. Remove the right-hand side cover. The cover is released by removing the screw at the rear edge of the cover.

   b. Connect the extender cable between the Model BH-1 and a NIM standard power supply. Connect a 50 ohm cable between the Model BH-1 TRIG OUT and the oscilloscope EXT TRIGGER connectors. Connect a 50 ohm cable between the Model BH-1 PULSE OUT and the oscilloscope vertical input connectors. This cable must be terminated in 50 ohms at the oscilloscope.

   c. Set the Model BH-1 controls as follows:

   FREQUENCY: Range, 10 KHz; Variable, Full clockwise
   SING PULSE/DBL PULSE: SING PULSE
   DELAY: Range 10 µS; Variable, Full clockwise
   REF: INT
   POL: Negative
   RISE TIME: .02 µS
   FALL TIME: .05 µS
   AMPLITUDE: Zero (Full ccw)
   ATTENUATOR: Out (Switches down)

2. NEGATIVE BASELINE ADJUST

Set the oscilloscope to display the output pulse in the middle of the screen. Set the vertical sensitivity to 50 mV/div., dc coupled. Check that the trace is exactly on the centerline of the screen when the signal cable is removed. Reconnect the cable and adjust R130 so that the baseline, at a point 1 µs ahead of the output pulse, is within 5 mV of the centerline.

3. POSITIVE BASELINE ADJUST

Set the POL switch to the Positive position.

Following the same procedure used in setting the negative baseline voltage, set the positive baseline by adjusting R139.

4. MINIMUM AMPLITUDE ADJUST

Without changing the settings used in step 3, set R140 to provide a positive pulse amplitude of 50 mv. When making this adjustment, it is essential that the AMPLITUDE helipot be set to minimum, and that the output be terminated in 50 ohms at the oscilloscope.

5. NEGATIVE RISE TIME ADJUST

a. Change the settings on the Model BH-1 as follows:

DELAY: Range, o.1μs; Variable, for best display.
POL: Negative
FALL TIME: 5 μs
AMPLITUDE: Set for 5 volt pulse on the oscilloscope.

b. Set the oscilloscope time base for 10ns/div. Adjust the Variable Delay control on the Model BH-1 to display the leading edge of the output pulse on the oscilloscope screen. Set C50 to provide a risetime of 20ns, 10% to 90% points.

6. POSITIVE RISETIME ADJUST

a. Change the POL switch to Positive.

b. Set C69 to provide a 10% to 90% risetime of 20ns.

7. IMPULSE DRIVE ADJUST

The impulse drive capacitor, C27, is set at the factory for optimum circuit linearity. C27 will not require adjustment unless a component has been replaced in the area from Q13 to Q17 or from Q20 to Q21. In order to check the correct setting of this trimmer special test equipment is required which is not commercially available. Consequently, the Model BH-1 should be returned to the factory for recalibration if a component has been changed in the area mentioned.

Abbreviations

cer	disc ceramic	µH	microhenry
comp	composition carbon	µF	microfarad
dep car	deposited carbon	pF	picofarad
elec	electrolytic	poly	polystyrene
mic	mica	pot	potentiometer
myl	Mylar	tan	tantalum
k	kilohm	V	dc working volts
M	megohm	W	watts
mf	metal film	ww	wirewound

Capacitors

C1	470 pF	mic	200 V	5%
C2	.0047 µF	myl	100 V	10%
C3	.047 µF	myl	100 V	10%
C4	.47 µF	myl	100 V	10%
C5	4.7 µF	tan	35 V	10%
C6	180 pF	cer	1 kV	
C7	470 pF	cer	1 kV	
C8	180 pF	cer	1 kV	
C9	5 µF	elec	25 V	
C10	180 pF	cer	1 kV	
C11	50 pF	cer	1 kV	
C12	180 pF	cer	1 kV	
C13	50 pF	cer	1 kV	
C14	5 µF	elec	25 V	
C15	1 µF	tan	20 V	10%
C16	.1 µF	myl	100 V	10%
C17	.01 µF	myl	100 V	10%
C18	.001 µF	myl	100 V	10%
C19	150 pF	mic	200 V	5%
C20	33 pF	mic	200 V	5%
C21	180 pF	cer	1 kV	
C22	180 pF	cer	1 kV	
C23	180 pF	cer	1 kV	
C24	.001 µF	cer	1 kV	
C25	470 pF	cer	1 kV	
C26	470 pF	cer	1 kV	
C27	2.2-20 pF	trimmer		
C28	33 pF	cer	1 kV	
C29	25 µF	elec	25 V	
C30	25 µF	elec	25 V	
C31	25 µF	elec	25 V	
C32	25 µF	elec	25 V	
C33	.01µF	cer	1 kV	
C34	270 pF	mic	200 V	5%
C35	180 pF	mic	200 V	5%
C36	.01 µF	cer	1 kV	
C37	.01 µF	cer	1 kV	
C38	.01 µF	cer	1 kV	
C39	100 µF	elec	25 V	
C40	22 pF	mic	200 V	5%
C41	47 pF	mic	200 V	5%
C42	100 pF	mic	200 V	5%
C43	220 pF	mic	200 V	5%
C44	470 pF	mic	200 V	5%
C45	.001 µF	myl	100 V	10%
C46	.0022 µF	myl	100 V	10%
C47	.0047 µF	myl	100 V	10%
C48	.01 µF	myl	100 V	10%
C49	.022 µF	myl	100 V	10%
C50	2.2 - 20 pF	trimmer		
C51	5 pF	mic	200 V	5%
C52	.01 µF	cer	1 kV	
C53	5 µF	elec	25 V	
C54	10 pF	cer	1 kV	
C55	25 µF	elec	25 V	
C56	.05 µF	cer	25 V	
C57	50 µF	elec	25 V	
C58	.01 µF	cer	1 kV	
C59	5 µF	elec	25 V	
C60	.05 µF	cer	25 V	
C61	100 µF	elec	25 V	
C62	50 µF	elec	25 V	
C63	10 pF	cer	1 kV	
C64	10 pF	cer	1 kV	
C65	10 pF	cer	1 kV	
C66	25 µF	elec	25 V	
C67	100 µF	elec	25 V	
C68	100 µF	elec	25 V	
C69	2.2-20 pF	trimmer		
C70	25 pF	cer	1 kV	
C71	.01 µF	cer	1 kV	
C72	.01 µF	cer	1 kV	
C73	.01 µF	cer	1 kV	
C74	.05 µF	cer	25 V	
C75	100 µF	elec	25 V	

Diodes

D1	1N4154
D2	1N4154
D3	1N4154
D4	1N4154

D5	1N4154
D6	1N4154
D7	1N4154
D8	1N4154
D9	1N4154
D10	1N4154
D11	1N4154
D12	1N4154
D13	1N4154
D14	1N4154
D15	1N4154
D16	1N821
D17	1N4154
D18	1N4154
D19	1N4154
D20	1N4154
D21	1N4154
D22	1N4154
D23	1N4154
D24	1N4154
D25	1N4154
D26	1N4154
D27	1N4154
D28	1N4154
D29	1N4154
D30	1N4154
D31	1N4154
D32	1N4154

Inductors

L1	39 μH
L2	10 μH
L3	10 μH

Resistors

R1	430 ohms	1/2 W	comp	5%
R2	15 k	1/2 W	comp	5%
R3	2.7 k	1/2 W	comp	5%
R4	75 k	2 W	pot	
R5	2.2 k	1/2 W	comp	5%
R6	2.0 k	1/2 W	comp	5%
R7	1 k	1/2 W	comp	5%
R8	15 k	1/2 W	comp	5%
R9	100 ohm	1/2 W	comp	5%
R10	1 k	1/2 W	comp	5%
R11	10 ohm	1/2 W	comp	5%
R12	750 ohm	1/2 W	comp	5%
R13	1.2 k	1/2 W	comp	5%
R14	39 k	1/2 W	comp	5%
R15	1.8 k	1/2 W	comp	5%
R16	1 k	1/2 W	comp	5%
R17	10 ohm	1/2 W	comp	5%
R18	1 k	1/2 W	comp	5%
R19	1 k	1/2 W	comp	5%
R20	39 k	1/2 W	comp	5%
R21	15 k	1/2 W	comp	5%
R22	430 ohms	1/2 W	comp	5%
R23	1.2 k	1/2 W	comp	5%
R24	750 ohm	1/2 W	comp	5%
R25	12 k	1/2 W	comp	5%
R26	1 k	1/2 W	comp	5%
R27	470 ohm	1/2 W	comp	5%
R28	1.2 k	1/2 W	comp	5%
R29	330 ohm	1/2 W	comp	5%
R30	10 k	1/2 W	comp	5%
R31	10 ohm	1/2 W	comp	5%
R32	180 ohm	1/2 W	comp	5%
R33	68 ohm	1/2 W	comp	5%
R34	1 k	1/2 W	comp	5%
R35	430 ohms	1/2 W	comp	5%
R36	1 k	1/2 W	comp	5%
R37	1 k	1/2 W	comp	5%
R38	75 k	2 W	pot	
R39	5.6 k	1/2 W	comp	5%
R40	10 k	1/2 W	comp	5%
R41	750 ohm	1/2 W	comp	5%
R42	1 k	1/2 W	comp	5%
R43	1 k	1/2 W	comp	5%
R44	1 k	1/2 W	comp	5%
R45	2.7 k	1/2 W	comp	5%
R46	1 k	1/2 W	comp	5%
R47	39 ohm	1/2 W	comp	5%
R49	100 ohm	1/2 W	comp	5%
R50	1.2 k	1/2 W	comp	5%
R51	470 ohm	1/2 W	comp	5%
R52	10 k	1/2 W	comp	5%
R53	22 k	1/2 W	comp	5%
R54	470 ohm	1/2 W	comp	5%
R55	470 ohm	1/2 W	comp	5%
R56	1.5 k	1/2 W	comp	5%
R57	220 ohm	1/2 W	comp	5%
R58	330 ohm	1 W	comp	5%
R59	2.2 k	1/2 W	comp	5%
R60	10 ohm	1/2 W	comp	5%
R61	10 ohm	1/2 W	comp	5%
R62	2.15 k	1/2 W	mf	1%
R63	2.15 k	1/2 W	mf	1%
R64	121 ohm	1/4 W	mf	1%
R65	500 ohm	5 W	pot	lin 0.1%
R66	499 ohm	1/4 W	mf	1%
R67	510 ohm	1/2 W	comp	5%
R68	22 k	1/2 W	comp	5%
R69	27 k	1/2 W	comp	5%
R70	280 ohm	1/4 W	mf	1%

R71	562 ohm	1/4 W	mf	1%
R72	2.8 k	1/4 W	mf	1%
R73	5.62 k	1/4 W	mf	1%
R74	28.0 k	1/4 W	mf	1%
R75	56.2 k	1/4 W	mf	1%
R76	110 k	1/4 W	mf	1%
R77	226 k	1/4 W	mf	1%
R78	442 k	1/4 W	mf	1%
R79	1.10 M	1/4 W	mf	1%
R80	3.3 M	1/4 W	mf	1%
R81	100 ohm	1/2 W	comp	5%
R82	100 ohm	1/2 W	comp	5%
R83	39 ohm	1/2 W	comp	5%
R84	10 ohm	1/2 W	comp	5%
R85	1 k	1/2 W	comp	5%
R86	1 k	1/2 W	comp	5%
R87	22 M	1 W	mf	1%
R88	560 ohm	1/2 W	comp	5%
R89	4.7 k	1/2 W	comp	5%
R90	330 ohm	1/2 W	comp	5%
R91	7.5 k	1/2 W	comp	5%
R92	2.7 k	1/2 W	comp	5%
R93	10 k	1/2 W	comp	5%
R94	12 k	1/2 W	comp	5%
R95	909 ohm	1/4 W	mf	1%
R96	2.15 k	1/4 W	mf	1%
R97	220 ohm	1/2 W	comp	5%
R99	2.74 k	1/4 W	mf	1%
R100	2.2 k	1/2 W	comp	5%
R101	1.2 k	1/2 W	comp	5%
R102	750 ohm	1/2 W	comp	5%
R103	10 ohm	1/2 W	comp	5%
R104	22 ohm	1/2 W	comp	5%
R105	10 ohm	1/2 W	comp	5%
R106	330 ohm	1/2 W	comp	5%
R107	2.15 k	1/4 W	mf	1%
R108	2.2 k	1/2 W	comp	5%
R109	2.15 k	1/4 W	mf	1%
R111	2.7 k	1/2 W	comp	5%
R112	750 ohm	1/2 W	comp	5%
R113	1.2 k	1/2 W	comp	5%
R114	10 ohm	1/2 W	comp	5%
R115	22 ohm	1/2 W	comp	5%
R116	10 ohm	1/2 W	comp	5%
R117	47 k	1/2 W	comp	5%
R118	12 k	1/2 W	comp	5%
R119	1 k	1/2 W	comp	5%
R120	4.7 k	1/2 W	comp	5%
R121	560 ohm	1/2 W	comp	5%
R122	12 k	1/2 W	comp	5%
R123	1 k	1/2 W	comp	5%
R124	3.9 k	1/2 W	comp	5%
R125	47 k	1/2 W	comp	5%
R126	180 ohm	1/2 W	comp	5%
R127	10 k	1/2 W	comp	5%
R128	1 k	1/2 W	comp	5%
R129	12 k	1/2 W	comp	5%
R130	10 k	1/4 W	trimmer	
R131	330 ohm	1/2 W	comp	5%
R132	4.7 k	1/2 W	comp	5%
R133	100 ohm	1/2 W	comp	5%
R134	3.9 k	1/2 W	comp	5%
R135	1 k	1/2 W	comp	5%
R136	12 k	1/2 W	comp	5%
R137	10 k	1/2 W	comp	5%
R138	180 ohm	1/2 W	comp	5%
R139	10 k	1/4 W	trimmer	
R140	1 k	1/4 W	trimmer	
R141	49.9 ohm	1/4 W	mf	1%
R142	100 ohm	1/4 W	comp	5%
R143	61.9 ohm	1/4 W	mf	1%
R144	249 ohm	1/4 W	mf	1%
R145	61.9 ohm	1/4 W	mf	1%
R146	51.1 ohm	1/4 W	mf	1%
R147	2.49 k	1/4 W	mf	1%
R148	51.1 ohm	1/4 W	mf	1%
R150	10 ohm	1/2 W	comp	5%

Transistors

Q1	MPS 6531
Q2	MPS 6531
Q3	2N2369
Q4	2N2369
Q5	MPS 6531
Q6	MPS 6531
Q7	2N2369
Q8	2N2369
Q9	MPS 3638
Q10	MPS 6531
Q11	MPS 6531
Q12	2N2369
Q13	MPS 6531
Q14	MPS 6531
Q15	2N2369
Q16	2N2369
Q17	2N2369
Q18	MPS 3638
Q19	MPS 2924
Q20	2N2369
Q21	2N2369
Q22	2N2608
Q23	MPS 6534
Q24	MPS 3638
Q25	2N3906
Q26	2N2219
Q27	2N2219
Q28	2N2905
Q29	MPS 6531
Q30	2N2905
Q31	2N2219
Q32	2N2905
Q33	MPS 6534
Q34	MPS 6534
Q35	2N2369
Q36	MPS 2924
Q37	MPS 2924
Q38	MPS 3638