BNC Model DB2 Benefits, Random Pulse Generator User Manual

BNC Model DB2 Benefits, Random Pulse Generator User Manual

SPECIFICATIONS

continued

COUNT RATE:	10 Hz to 1 MHz, continuously adjustable.
MODE:	Random or Repetitive.
RANDOM DISTRIBUTION:	Poisson for intervals greater than 1.4 ps.
PULSE SHAPE:	Tail pulse with independently adjustable rise and fall times.
PULSE AMPLITUDE (STEP) CHARACTERISTICS: a) Amplitude Shift with Count Rate: b) Jitter (resolution): c) Temperature Coefficient:	Less than ± 0.05% from 10 Hz to 100 kHz. 0.01% RMS.± 0.02%/ °C.
FREQUENCY JITTER (Repetitive Mode):	Less than 0.1%.
EXTERNAL TRIGGER:	Requires 1 V positive pulse. Input impedance 1 K.
TRIGGER OUT:	Positive 3 V pulse, 20 ns rise time, 100 ns width, 50 a output impedance.
RISE TIME OF OUTPUT (10 – 90%):	0.1 – 20 pa, in 8 steps.
DECAY TIME CONSTANT (100 – 37%):	5 – 1000 As, in 8 steps.Rise and Decay time independent of each other for Decay Time / Rise Time > 10.
OUTPUT AMPLITUDE RANGES:	Repetitive only, *10 V maximum. Repetitive or Random, *1 V maximum.Adjustable by ten-turn potentiometer from zero to maximum. AC coupled.
NORMALIZE:	Ten-turn control varies amplitude by 60%.
OUTPUT IMPEDANCE:	50 a.
ATTENUATION:	4 step attenuators of X2, X5, X10 and X10 for a maximum of X1000.
EXTERNAL REFERENCE INPUT:	+10 V maximum; 10 K input impedance.
POWER REQUIREMENTS:	t 24 V at 65 mA, +12 V at 140 mA,-12 V at 40 mA.
MECHANICAL:	Double-width NIM module, 2.70″ wide by 8.70″ high in accordance with TID-20893 (Rev. 3).
WEIGHT:	3-1/2 **lbs. net**; 7 lbs. shipping.

OPERATING INFORMATION

INTRODUCTION

The Model DB-2 Random Pulse Generator is a precision pulse generator which provides a broad range of calibration and test pulses encountered in the nuclear and life sciences areas. When operated in the random mode, it provides a controlled voltage transition and long decay time constant at average rates up to 1 MHz, allowing accurate simulation of detector signals while retaining a monoenergetic nature. Two or more DB-2's may be connected to a single test point to test over load and pileup response and pulse pair resolution. Typical applications of the DB-2 include:

- rate effect testing including base line shift and analyzer dead time;
- determination of proper gate and coincidence unit timing;
- ratemeter testing for variations between periodic and random inputs;
- linearity measurements of amplifiers and pulse height analyzers at high rates;
- threshold determination of discriminators d sinle-channel analyzers

FUNCTION OF CONTROLS .& CONNECTORS

CONTROL	FUNCTION
FREQUENCY:	Concentric switch and potentiometer control repetition rate of output pulses when the MODE switch is set to REP. When the MODE switch is set to RANDOM, the FREQUENCY con- trols set the ayera e random rate of output pulses. When the FREQUENCY switch is in the EXT position, output pulses will occur if an external trigger is connected to the EXT TRIG connector.
MODE:	This toggle switch controls the clock mode of the pulse generator. When set to REP (Repetitive), the pulse generator produces output pulses with a fixed time interval between them. With the switch set to RANDOM, the output pulses occur randomly; i. e., the time intervals between successive pulses obey the interval distribution function of a Poisson process.
RANGE:	This toggle switch selects the maximum range of voltage transitions produced by the pulse generator.
AMPLITUDE:	Ten-turn potentiometer controls the magnitude of the voltage transition produced by the pulse generator. This control is disabled when an external reference voltage is used.
NORMALIZE:	Ten-turn potentiometer reduces the upper limit of the AMPLITUDE control by up to 80%. When used in conjunction with the ATTEN (Attenuator) switches the NORMALIZE control allows calibration of the AMPLITUDE dial in convenient units, such as MeV of keV of energy loss.

CONTROL	FUNCTION
POL (Polarity):	This toggle switch selects positive or negative polarity for output voltage transitions.
RISE TIME:	Controls the 10% – 90% rise time of the output pulse.
FALL TIME:	Controls the effective decay time constant, 100% – 37%, of the output pulse.
REF – INT/EXT:	This toggle switch connects the pulse forming circuitry either to an internal DC reference voltage or an external reference. In the EXT (external reference) position, the reference voltage is applied to the EXT REF connector. When an external reference is used, the AMPLITUDE control is disabled.
ATTEN (Attenuation):	These four toggle switches provide attenuation of the pulse generator output in the following amounts: X2, X5, X10, X10. • Various combinations may be used to provide attenuation in a 1-2-5 sequence from X1 (no attenuation) to X1000.
PULSE OUT:	The pulse generator output appears at this connector. For best results, the output cable should have a characteristic impedance of 50 a and should be terminated with a 50 a non-inductive resistor.
TRIG OUT:	This connector provides a synchronizing pulse which precedes the output pulse. The output impedance is 50 a, but operation of the pulse generator is not affected if this output is not properly terminated.
EXT TRIG:	This connector is provided to connect an external trigger to control the output rate. **NOTE** Signals present at this connector will interfere with operation of the internal clock circuits unless the FREQUENCY switch is set to EXT. Also, when an external trigger is used, the MODE switch should be set to REP. However, if the MODE switch is set to RANDOM, the pulse generator will provide randomly spaced pulses at an average rate approximating the external trigger rate.
EXT REF:	This connector allows the use of an external voltage to control the magnitude of the voltage transitions produced by the pulse generator.

OPERATING INFORMATION

The Model DB-2 is a precision instrument and certain care must be taken to obtain optimum performance. The following paragraphs discuss various factors which contribute to this performance.

TERMINATION

The output of the DB-2 should be terminated in 50 n whenever long (greater than ten feet) 50 n cables are being used. Cables of other impedances may be used if they are properly terminated; however, the reverse termination impedance is designed for 50 n. Termination of cables shorter than ten feet is usually not required.

Termination with R ohms will reduce the DB-2 amplitude by a factor N defined by:
N = R/(R+50) {1}
For example, if R = 50 n, N = o. 5 and the amplitude is half of the unterminated value.

Termination of the trigger output is unnecessary for proper DB-2 operation, but it is recommended if the trigger signal is used with high-speed logic such as electronic counters.

OUTPUT COUPLING

The Model DB-2 is capacitively coupled at its output by a long time constant (0. 1 s). Therefore, the output will exhibit base line shift as the frequency is increased. This will have no effect on the output amplitude as each pulse produces a controlled amplitude step regardless of the initial location of the base line. 1 1Base Line Wander. The base line will

wander (hunt-and-seek) in a millisecond time range with an amplitude excursion proportional to the decay time·. It will be a maximum of 200 m V with a 1 ms tail time as viewed at 10 ms/cm on a scope. This is normal servo operation of the instrument and does not affect the amplitude of the step transition,

PULSE PILEUP IN THE RANDOM MODE

Certain combinations of AMPLITUDE, FALL TIME, and FREQUENCY settings in the .RANDOM MODE will produce unwanted side effects, a situation analogous to duty factor limitation in ordinary pulse generators. The side effect is saturation of one or more of the internal amplifiers, and occurs for a combination of maximum amplitude pulses, highest average rates and longest fall times. Because the intervals between pulses obey the interval distribution, combinations of these parameters may be calculated which yield certain percentages of distorted or missing pulses. Figure 2-1 is a graph showing the maximum frequency that yields fewer than 1 % distorted or missing pulses for combinations of AMPLITUDE and FALL TIME settings. As can be seen from the graph, reducing the AMPLITUDE by a factor of two allows operation at a frequency four times higher.

FIG. 2-1. Duty Factor Limitation of the Model DB-2. Amplitude, Rate and Fall Time Settings for less than 1 % distorted pulses.
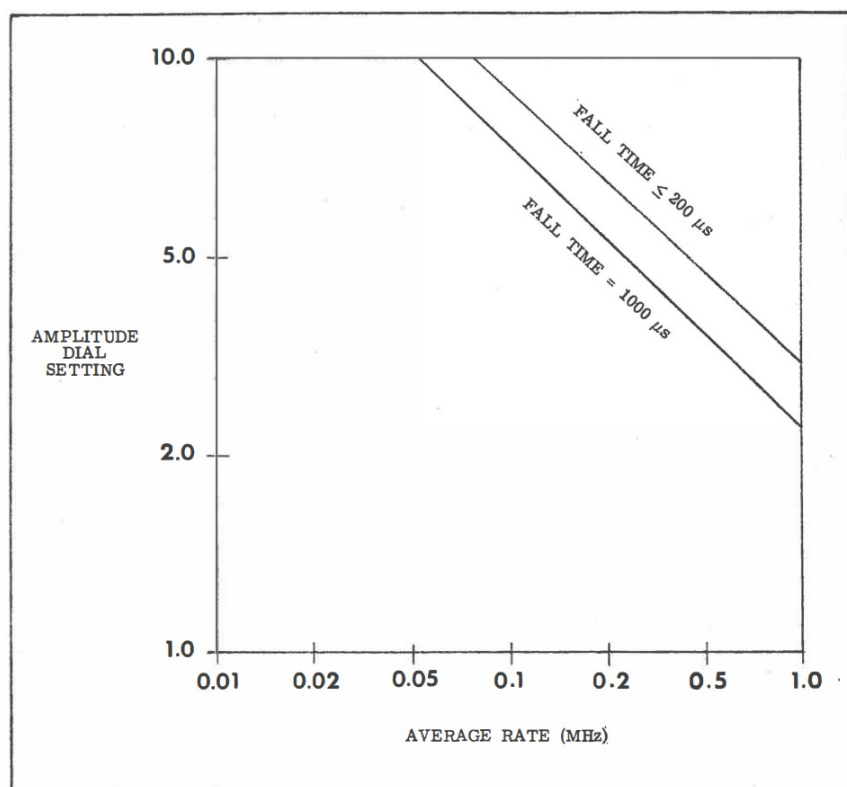
The graph is intended as a guide to· indicate those combinations of A MPLITUDE, FALL TIME, and FREQUENCY settings that warrant close monitoring of the DB-2 output by an oscilloscope. Flattened or saturated traces at the top and bottom of the screen indicate that the DB-2 duty factor is being exceeded.

EXTERNAL TRIGGERING

When placed in the repetitive (REP) MODE, the Model DB-2 will produce one output pulse for· each exl'ernal trigger pulse applied to the EXT TRIG connector. Trigger pulses closer together than 120 ns will not produce multiple pulses. If the MODE switch is set to RANDOM, the average rate of the output pulses will be within 20% of the external trigger rate.

EXTERNAL REFERENCE

The amplitude of the output pulses may be controlled by an external reference voltage· applied to the EXT REF connector by switching the REF switch to EXT. The range of control at the EXT REF connector is O – 10 V, but no damage will result from voltages less than ± 25 v.

When used as a sliding pulsar (by connecting a Berkeley Nucleonics Model LG-1 Ramp Generator to the EXT REF input), the Model DB-2 exhibits differential nonlinearity 1 e s s than ±0.25% over the top 85% of the amplitude range. The lower portion of the amplitude range and the ramp turnaround points should be excluded from any differential linearity tests. Computer control · of the amplitude may be accomplished by use of a digital-to-analog converter such as the Berkeley Nucleonics Model 9060 DC Reference Programmer.

TRANSIENTS

During the time that pulses are being formed, switching transients will unavoidably be produced. By careful design, 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 dominate the waveform. Consequently, it is recommended that the AMPLITUDE control be operated near maximum and the attenuators (ATTEN) be used to obtain the cleanest small pulses.

NIM POWER SUPPLY

The Model DB-2 is a NIM module and depends upon power from an external source. It is important that the power supply is in good condition and meets all regulation, stability, and ripple specifications of U. S. AEC Report TID20893 (Rev. 3). If a NIM power supply is inadvertently overloaded, the DB-2 may cease to operate, but will not sustain damage

APPUC.ATIONS

DETECTOR SIMULATION

The Model DB-2, used in conjunction with the normal charge conversion capacitor at the test input of a preamplifier, simulates the output of a wide range of detector types.

Each detector has a characteristic time or time constant associated with it. For solid state detectors, this time is the charge collection time; for scintillators it is the primary light decay constant. In general, the detector type is simulated by adjusting the DB-2 RISE TIME to be 2. 2 times the detector's characteristic time constant (the time required to collect 63% of the detector's charge output).

SOLID STATE DETECTORS, PROPORTIONAL COUNTERS, SPARK CffM1BERS, GEIGER-MULLER TUBES and PLASTIC (ORGANIC) SCINTILLATORS

For these detector types, the DB-2 RISE TIME should be set to O. 1 µs (or to other settings if the charge collection time for individual detector configurations is known to be greater than 0.1 µs). When the DB-2 is used to simulate detectors with very small (less than 0.1 µs) charge collection (or light decay) times, the system preamplifier will still collect all of the charge produced by the DB-2; however, the collection time will be longer than if the charge were produced by such a detector. For most applications, the difference will not be noticeable, but systems with ultra – small shaping time constants (<0. 5 µs) in the main amplifier will experience a slight amplitude reduction

2ruse time (10%- 90%) is equal to 2, 2 time constants when compared to systems with normal time constants (1 – 3 µs). The amplitude reduction is termed ballistic deficit3 and also exists when ultra-small shaping time constants are used with detectors having long charge collection times. This effect does not cause problems in most system testing, but does interfere with preamplifier rise time measurements. 4

NORGANIC SCINTILLA TORS

In order to simulate the charge pulse generated by a photomultiplier tube viewing an inorganic scintillator such as CSci(Tl), CSci(Na) , or NaIl(Tl), the DB-2 RISE TIME control is adjusted to the nearest value equal to 2. 2 light decay constants. Table 3-1 lists the primary light decay constants for some popular inorganic scintillation materials.

Primary Light Decay Constants for Some Inorganic Scintillators.

Material: Primary Decay Constant
CsI(Tl): 1.1 µs
CsI(Na): 1.0 µs
NaI(Tl): 0.25 µs

Intermediate settings of the RISE TIME control may be obtained by replacing one or more of the rise time capacitors (C81 – C87) with different valued capacitors. Consult the Berkeley Nucleonics Engineering Department for details.

3Roddick, R. G., Semiconductor Nuclear Particle Detectors and Circuits, National Academy of Sciences, 1969, p. 705.

For a further discussion, refer to IEEE Standard No. 301 "Test Procedures for Amplifiers and Preamplifiers", IEEE, 1969.

PREAMPLIFIER SIMULATION

The Model DB-2 can be used to simulate the output waveform of a system preamplifier in order to test the rest of a system. The output of the DB-2 is connected directly to the main (shaping) amplifier and the FALL TIME is set to approximate the decay constant of the preamplifier being simulated. The RISE TIME is set according to the following formula:

$$\text{RISE TIME} = \left[T_1^2 + 4.84\, T_2^2 \right]^{1/2}$$

where Tl = Preamp rise time
T2 = Detector Time Constant

The detector time constant is either the light decay constant (for scintillators) or charge collection time constant (time to collect 63% of the charge). The polarity (POL) should be set, and the FREQUENCY controls adjusted to the desired average rate.

If the main amplifier is equipped with pole zero compensation, it should be adjusted to compensate for the DB-2 pole simulating the preamplifier decay constant.

SYSTEM POLE-ZEROCANCELLATION

The Model DB-2 can be used to adjust system pole-zero cancellation for optimum counting at high rates. The DB-2 is connected to the test input of the system preamplifier. The FALL TIME control should be set to 1000 µs, which is long compared to the normal 50 µs – 100 µs decay constant of most system preamplifiers. This insures that the preamplifier output wave shape is dominated by the preamplifier pole. The RISE TIME control should be set according to the guidelines given in paragraph 3. 1 above. The remaining controls are adjusted to the expected system operating parameters.

The system pole – zero compensation is now adjusted while monitoring the data collected on a multi-channel analyzer until the DB-2 peak is as narrow as possible.

It should be noted that the DB-2 introduces non-cancellable poles into the system, but they are sufficiently larger than the preamplifier pole as to not interfere with most systems.

CHECKING BASE LINERETORERS

Operation of a base line restorer may be checked using the Model DB-2 to provide randomly spaced events at the same rate normally experienced by system. The DB-2 is connected to the preamplifier test input, and the system pole-zero cancellation is checked (see paragraph 3. 3).

An oscilloscope is used to monitor the DB-2 output to detect pile-up limitation (see paragraph 2. 3. 3). A multichannel analyzer is used to monitor the system output with the base line restorer off, then on. A sharp reduction in the DB-2 peak width should be noticed with the restorer on. If the restorer has a choice of time constants, each time constant may be tested to discover which yields the narrowest peak at the counting rate of interest.

CHECKING RATEMETERS

Ratemeters can be checked for accuracy using the Model DB-2 to provide randomly spaced events at a variety of average rates, The DB-2 is connected to the system preamplifier test input as before (see paragraph 3. 3).

An oscilloscope is used to monitor the DB-2 output to detect pile-up limitation (see paragraph 2. 3. 3). A digital counter is connected to 5Nowlin and Blankenship, Review of Scientific Instruments, 36, 1830, 1965. the DB-2 TRIG OUT connector. The trigger cable should be properly terminated at the cowriter for best results. The readings of the ratemeter and the digital counter will agree for low repetition rates. As higher rates are measured, the ratemeter will begin to miss pulses due to system resolving time, thus indicating less than true rate.

Operation with periodic and random inputs is easily compared by changing the MODE switch on the DB-2 from RANDOM to REP (repetitive)

The rejection interval may be measured by using the DB-2 in conjunction with a conventional pulse generator. The conventional pulse generator is operated in the double pulse mode to trigger the DB-2 twice in succession. The DB-2 MODE switch should be set to REP, the FREQUENCY switch to EXT, and the RANGE switch to 1 V. The time between the two pulses is increased until the second pulse is being rejected 50% of the time. The time between the pulses is measured on an oscilloscope and is the rejection interval.

CHECKING PILE-UP Ejectors

The Model DB-2 allows the operation of pile-up rejecters to be optimized and the rejection interval to be measured. The DB-2 is connected to the system preamplifier as before (see paragraph 3. 3). An oscilloscope is used to monitor the DB-2 output to detect pile-up limitation (see paragraph 2. 3. 3).

Optimization of rejecter operation may be performed by monitoring the system output with a multi-channel analyzer as the rejection interval is adjusted to just eliminate the sum peak. If the rejection interval is too short, part of the sum peak will remain; if the interval is too,. long, events that would have been correctly analyzed will be lost.

CHECK I NG PULSE SHAPE ANALYZERS

Operation of a pulse shape analyzer may be checked by using the Model DB-2 to simulate events with various pulse shapes. A typical use of a pulse shape analyzer is to discriminate between Cal and Nil events detected by a phasic. The general techniques given in paragraph 3.1 are used to simulate first C events, then Nil events, and the pulse shape analyzer output is monitored with a multi-channel analyzer. Mixtures of events may be simulated by intermediate values of rise time using a singleDB-2, or two DB-2's may be slaved to allow any mixture ratio to be simulated. One DB-2 is set for Csl events; the other DB-2 is set for Nil events; and their amplitude ratio varied to simulate different mixture ratios.

THEORY OF OPERAT

INTRODUCTION

Section 4 deals with the theory of operation of the Model DB-2 in four parts: Paragraph 4. 2 gives an overall view of the instrument· and its major block diagram. Paragraphs 4. 3 and 4. 4go into greater detail but still deal with block diagrams. Paragraph 4. 5 refers to the schematics and discusses the circuit paths through the instrument. (Diagrams are located at the end of this se

BLOCK DIAGRAM

An overall block diagram of the Model DB-2 appears in Figure 4-1. The Clock Generator provides either periodic

or random trigger pulses to the Timing Control and to the TRIG OUT connector. The Precision Current Source provides an adjustable precise current to the Timing Control. The Preciion Current Source may be controlled by an external reference voltage applied to the EXT REF connector. The Timing Control switches the current (from the Precision Current Source) to the Charge Sensitive Amplifier for 80 ns each time a trigger pulse arrives from the Clock Generator. This current pulse contains an amount of charge that is directly proportional to the magnitude of the current provided by the Precision Current Source.

The Charge Sensitive Amplifier accepts the charge pulse from the Timing Control, and produces an abrupt voltage transition at its output. An Average Value Subtractor removes the DC component of the Charge Sensitive Amplifier output, thereby increasing its dynamic range.

The Pulse Shape Controls introduce RC pulse shaping allowing the pulse rise time and fall time to be varied. The Output Buffer Amplifier isolates the Pulse Shaping Controls from the output connector, provides polarity selection, and contains passive attenuators. The Output Buffer Amplifier has a 50 n output impedance to allow the use of terminated coaxial cables to transmit the pulse.

CLOCK CIRCUITRY (See Fig. 4-2.) _

The Periodic Generator utilizes an Emitter ·Coupled Multi vibrator as the basic timing el emend. Coarse frequency adjustment in decade steps is realized by switching the emitter capacitor, C_T , while fine adjustment within Y decade is accomplished by varying the charging rate via a potentiometer, RT One coarse switch position di s ab 1 e s the multi vibrator, allowing an external trigger to be used. A Comparator detects external trigger signals exceeding O. 7 V and provides a logic signal to the OR gate. The 80 ns One Shot standardizes the pulses from either the multi vibrator or the external trigger.

The random portion of the Clock Generator consists of a noise generator, buffer amplifier, variable threshold comparator and cascade one shot. A Differential Ratemeter compares the average frequencies from the Random and Periodic Generators, and adjusts the discrimination threshold level until the two frequencies are the same.

Examining the Random Generator in Figure 4-2,a base-emitter junction operating in the avalanche mode provides a broad band gaussian noise. The high impedance Noise Source is buffered with an amplifier using a Field Effect Transistor (FET Input Buffer). The noise signal is then differentiated, creating _ a signal with

THEORY OF OPERATION

sharp spikes of varying amplitude. The Comparator detects those spikes exceeding a certain threshold. If the threshold is set to zero, the Comparator will fire on nearly every spike, yielding an average output rate greater than 2 MHz. If the threshold is increased to twice the rms noise voltage, only 2. 3% of the spikes will trigger the Comparator, and a lower average rate (~46 kHz) will result. Thus, the average rate of the Random Generator is controlled by the Comparator threshold voltage.

The Comparator output triggers the Cascade One Shot. The first one shot produces a pulse whenever its threshold is exceeded, but its output pulse width varies due to the amplitude and duty cycle variations of the input signal. The second one shot provides output pulses that have little variation in amplitude or pulse width.

The Differential Ratemeter uses two equal diode pumps feeding the same capacitor. The Periodic Generator adds 200 pC (200 x 10-12coulomb) of charge for each periodic pulse, and the Random Generator subtracts 200 pC for each random pulse. A high input impedance operational amplifier decides whether the Random Generator is subtracting too little or too much charge from the common capacitor. If the voltage on this capacitor is positive, insufficient charge is being   therefore, the random frequency is lower than the periodic frequency. The Differential Ratemeter then adjusts the Comparator threshold lower, more noise spikes are counted, and the average random frequency increases. Conversely, a negative voltage on the common capacitor will cause an increase in the Comparator threshold and a decrease in the average random frequency.

The output pulses from the Random Generator and the Periodic Generator are presented to NAND gates, where one pulse source (Random Generator or Periodic Generator) is selected

by the MODE SWITCH, and the other pulse source is blocked. The selected pulses activate the Trigger One Shot, which standardizes the trigger waveform. One signal path delivers the trigger pulses to the pulse forming circuit, and another path goes to a buffer and then the TRIG OUT connector. The buffering drives 50 n loads and isolates the pulse generator from even short circuits at the TRIG OUT connector.

CHARGE LOOP AND OUTPUT (See Figure 4-3.)

The basic output pulse is created by allowing a Charge Sensitive Amplifier to sample a carefully controlled current for a precise time interval. The units of current multiplied by time yield charge, thus the magnitude of the voltage transition at the output of the Charge Sensitive Amplifier is proportional to both the controlled current and the precision time interval. The time interval is fixed at 80 ns, with a temperature coefficient that compensates for the thermal coefficient of the Charge Sensitive Amplifier feedback capacitor.

Referring to Figure 4-3, the Precision Current Source utilizes a reference diode and a constant current source to generate a reference voltage that is independent of power supply variations. A portion of this voltage, selected by a ten-turn potentiometer (the DB-2 AMPLITUDE control) is compared to the voltage drop across a series resistor in a FET current generator circuit. The FET gate voltage is adjusted by the Comparator -to reduce any difference voltage discovered. Virtually all the current passing through the sense resistor comes through the FET from the Current Switch. An external input (not sho"{n) may provide the reference voltage to accommodate programming of the amplitude by external means.

The Current Switch, operated by the Timing Control One Shot, uses Schottky (or ho tcarrier) diodes to insure rapid switching and minimum charge storage. Normally D17 is conducting and D18 is reverse-biased. The current required by the Precision Current Source is provided by the Timing Control One Shot. When this one shot is triggered, D17 is reverse-biased and D18 conducts, diverting the current path from the one shot to the Charge Sensitive Amplifier for the duration of the one shot timing interval (80 ns).

The Charge Sensitive Amplifier integrates the rectangular current pulse from the Current Switch to produce a voltage transition proportional to its charge content. A discrete component operational amplifier with a FET input and a slew rate in excess of 350 V / μs is used in this section. The feedback capacitor and resistor is switched to implement the different output voltage ranges. The decay time constant of the Charge Sensitive Amplifier output pulse is 10 ms, and the leading edge is- a linear ramp lasting 80 ns.

The Average Value Subtractor restores the average value of the Charge Sensitive Amplifier output to zero volts in order to reduce the dynamic range requirements for the Charge Sensitive Amplifier. The time constant of the Average Value Subtractor is sufficiently long that the 10 ms tail pulse remains undistorted.

Control of the pul,se Rise Time and Fall Time is obtained by passive RC shaping circuits (Pulse Shape Controls) between the Charge Sensitive Amplifier and the Buffer Amplifier.

The Fall Time adjustment controls the time constant of the exponential decay. If a periodic rate is selected such that rate > 10 / fall time constant, then the output waveform will approximate a linear discharge between pulses because less than the first 10% of the exponential decay is shown. However, the time constant does not change from that originally selected.

Polarity selection and signal buffering occurs in the Buffer Amplifier. The circuit is arranged to amplify the pulse by +4 or -4, depending upon the selected output polarity. A series 50 U balanced 1r attenuator (not shown) allows the output pulse to be attenuated by as much as 1000, yet maintains the 50 n output impedance.

CIRCUIT DESCRIPTION

Before studying the following paragraphs, it is recommended that paragraphs 4. 1 through 4. 4 be read to obtain the general concepts.

PERIODIC CLOCK

(Refer to Schematic DB-2-31 in Section 6.) A free – running multi vibrator, Ql – Q2, · generates the Periodic Clock frequency when S1 is in one of the continuous frequency positions. The frequency range is selected by C2 – C6 on Sl, and continuous adjustment is provided by R5. The signal at the collector of Q2 is differentiated by C7 – R14 and passes through diode D4 to the input (pins 3, 4) of the periodic one shot, Zl.

External trigger signals exceeding O. 7 V are amplified by Q3 – Q4 and presented to the input (pins 3, 4) of the one shot, Zl. ' Protection against- excessive voltages is provided by D2 – D3.

Zl provides a standard-width, negative-going pulse at pin 6 and a positive pulse at pin 8.

RANDOM CLOCK

(Refer to Schematic DB-2-31 in Section 6.) The base-emitter junction of Q9 is reversebiased to provide a source of noise. The noise signal is amplified by QlO, then differentiated by C18 – R34. Q12 and Q13, in conjunction with the input circuit of the random one shot, Z5, form a comparator circuit. This comparator fires Z5 every time the noise signal exceeds the comparator threshold voltage. The output of Z5 is a negative-going pulse and appears at pin 6 of Z5 and is also connected to the input (pin 13) of Z3. Flip-flop Z3 is connected as a one shot.

A negative-going edge at input pin 13 causes a "0" to be shifted into the flip-flop, The Q output, pin 9, goes low and C23 begins to discharge through R40. A short time later, C23 is discharged sufficiently to activate the direct set input. and the flip-flop is set to the "1" state. Pin 9 goes high and C23 is rapidly charged through Dll. The negative-going pulse at pin 9 is inverted by gate Z2 and a positive-going pulse appears at pin 3 of Z2. The Q output of the flip-flop (pin 8) produces a positive-going pulse.

DIFFERENTIAL RATEMETER

(Refer to Schematic DB-2-31 in Section 6.) The negative pulse from Zl pin 6 discharges ClO through D8 to ground. After the pulse is over, ClO is charged in series with C16 through D7. This adds 200 pC (or 0, 2 x 10-9 coulomb) to C16 for each periodic pulse. Positive pulses from Z2 pin 3 charge Cl4 and C15 through Dl0 to ground. After each pulse,. Cl4 and C15 are discharged in series with C16, thus subtracting 200 pC from C16 for each random pulse.

The voltage of C16 is compared to ground by Q7 – Q8 and Z4. The output of Z4 (pin 10) swings more negative if the voltage of Cl6 is negative. C12 and R24 integrate the Z4 output so that rapid variations in the voltage of C16 are ignored. The output signal (Z4 pin 10) drives current source Q6 and offsets the base voltage of Q12 from that of Q13. This action effectively varies the threshold vol.{age of comparator Q12 – Q13. thereby controlling the average rate of pulses that fire Z5.

Because the voltage of Cl6 can only equal zero if the periodic rate (Zl pin 6) is equal to the average random rate (Z2 pin 3), the Differential Ratemeter varies the random rate until it matches the periodic rate. C15 adjusts the amount of charge subtracted from C16 by each random pulse, and R25 adjusts the QJ – Q8 offset voltage.

MODE SWITCH ANDTRIGGER ONE SHOT

(Refer to Schematic DB-2-31 in Section 6.) The Mode switch, S2, provides a low level to Z2 pin 13 when in the REP position, Pin 9 of Z2 is high, allowing the positive pulses from Zl pin 8 to pass through (and be inverted by) Z2. The positive pulses from Z3 pin 8 are blocked by Z2 because of the low signal on pin 13. Z2 pin 11 is high, keeping D12 reverse biased, and the negative pulses appearing at Z2 pin 8 pass through D5 to pin 1 of Z3, In a

similar manner, when the Mode switch is ·in the RANDOM position, pulses from Zl are blocked, and pulses from Z3 pin 8 are passed through Z2, D12 and hence to pin 1 of Z3. When Range switch, S3, is in the 10 V position, the Mode switch is overridden and only periodic pulses from Zl reach pin 1 of Z3.

Flip-flop Z3 is connected as a one shot as described above (see 4. 5. 2, Random Clock). The negative-going pulse at pin 5 is inverted by Z2, and the positive pulse at Z2 pin 6 passes through R20 and is routed to the EXT TRIG connector. The positive pulse at Z3 pin 6 passes through R19 to the one shot in the Timing Control.

TIMING CONTROL

(Refer to Schematic DB-2.-32 in Section 6.) The trailing edge of the positive pulse from Z 3 pin 6 triggers the Timing Control one shot, Z7. C22 is charged by current from temperature dependent current source Q15 – Ql6. R46 adjusts the temperature coefficient, while the one shot interval is set by R45. The Timing Control output is a negative-going pulse at Z7pin 6.

PRECISION CURRENT SOURCE

(Refer to Schematic DB-2-32 in Section 6.) Q32 – Q33 form a constant current source for reference diode Dl6. The fixed voltage across Dl6 is divided down to a 0V – 2V range (referenced to -12 V) by R54 and R56. R60 provides an adjustment of the minimum voltage.

External reference voltages produce a reference current through R48 – R49 to the virtual ground at Z8 pin 4. Essentially, all of that current passes through Q14 to R52, where a fixed fraction (1/5) of the original reference voltage is now referenced to the same -12 V as the internal reference. voltage. Dl5 and D25 pro- vide protection against excessive external voltages, and R51 provides an adjustable bias current to set the minimum voltage across R52.

The Reference Select switch, S4, may be set to allow either the internal reference or the external reference to control the output pulse amplitude.

The current flowing through Q l 7 produces a voltage across R59 and R61. Z9 compares this voltage to the selected {by S4) reference voltage and varies the Ql 7 current until both voltages {Z9 pins 4, 5) match. For a given voltage at Z9 pin 4, the Q l 7 current may be adjusted by means of R61 (N formalize Control).

CURRENT SWITCH

(Refer to Schematic DB-2-32 in Section 6.) The current for Ql 7 is normally supplied by R105 through Dl 7. Current also flows through D27 and D26. When Z7 fires, pin 6 is forced to ground, and all of the current flowing in R105 is diverted to Z7. The drain voltage of Ql 7 rapidly drops from 5, 5 V to 2 V, forward biasing Dl8. The current required by Ql 7 is now supplied by C37 {10 V range) or C37, C36 (1 V range). At the end of the time interval for Z7 {80 ns), the voltage at Z7 pin 6 rises to 5. 5 V {clamped by D26) and D17 is forward-biased again. D18 becomes reverse-biased, and current from C37 or C37 and C36 ceases to flow through D18.

CHARGE SENSITIVE AMPLIFIER

(Refer to Schematic DB-2-32 in Section 6.) When current flows through Dl8, the voltage at the gate of Q22 drops slightly, thereby unbalancing the Q22 – Q23 differential pair, and the Q20 – Q21 differential pair. The collector voltage of Q21 rises slightly, reducing the ·emitter current of Q25. This causes a rise in Q25 collector voltage, and Q26 – Q27 base voltages. The output of the Charge Sensitive Amplifier increases, causing the required current to flow through C36 (or C37 and C36) through D18, and on to Ql 7. Bias current for Q22 – Q23 is provided by constant current source Q24, while input voltage offset is adjusted by R89. Q18 supplies bias current to Q20 – Q21, and Q19 provides bias current for the output stage, Q26 – Q27. D20 and D21 provide thermal compensation for Q26 – Q27 quiescent current as determined by R94 and R95. High – frequency compensation is provided by C28 and R88, C57.

Each output pulse is 2. 5 V in amplitude (10 V range) or O. 25 V (1 V range). Range selection is provided by changing the size of the feedback capacitor with S3.

AVERAGE VALUE SUBTRACTOR

(Refer to Schematic DB-2-32 in Section 6.) The Charge Sensitive Amplifier output signal is compared to ground by ZlO. If the average signal voltage is positive, the voltage on C38 is slowly reduced until the signal averages zero volts. Simultaneously, the voltage on C55 decreases, causing an increase at the collector of Q31, and an increase in emitter current of Q30. The increased current flows through R68 into the feedback capacitor of the Charge Sensitive Amplifier, causing a reduction of the voltage at the output. The long time constant of R78 – C38 insures that this process happens so slowly that individual pulses in the Charge Sensitive Amplifier are not distorted. R75 corrects for Zola offset current.

If the output of the Charge Sensitive Amplifier exceeds +_7. 5 V or -7. 5 V, either Q28 or Q29 temporarily conducts, changing the voltage on C38 more rapidly than normal. This provides quick return to the null condition (Charge Sensitive Amplifier output = zero average) for sudden changes in rate or amplitude.

PULSE SHAPE CONTROLS

(Refer to Schematic DB-2-33 in Section 6.) The Charge Sensitive Amplifier output signal (at Q26 emitter) has an 80 ns linear rise time (0% – 100%) and a 10 ms exponential fall time (100% – 37%). The signal is integrated by R152 and a capacitor selected by S6, the Rise Time switch. (Some additional integration is provided by C65 in the Buffer Amplifier and C71at the output connector.)

The signal, after the integration for rise time, is differentiated by Rl52, a capacitor selected by S5, and the input impedance of the Buffer Amplifier. This differentiation allows control of the fall time decay constant. The pulse is fully shaped at this point.

BUFFER AMPLIFIER

(Refer to Schematic DB-2-33 in Section 6.)

The Buffer Amplifier is an operational amplifier providing a gain of either +4 or -4 depending upon the Polarity switch (S7) setting. The operational amplifier is nearly identical to that used in the ,Charge Sensitive Amplifier. Input offset adjustment is provided by R118, and output quiescent current is set by R131. When the Polarity switch is set to "+", the signal from S5 is routed to the positive input of the amplifier, Q36 – gate, and the negative input is connected to -2. 5 V through R155 and R153.

The signal from S5 is divided by R152 and R154, then multiplied by the follower-with-gain connection of the amplifier. The net effect is a gain of ·+4 from the Charge Sensitive Amplifier output to the Buffer Amplifier output. In this configuration, both Buffer Amplifier inputs are referenced to -2. 5 V, thus the output average voltage (at R126, R127) is -2. 5 V. The output signal is coupled through C69 – C70 and referenced to ground by R135. R133 and R134 increase the output impedance to 50 n.

When the Polarity switch is set to "-", the signal from S5 is routed through R155 to the negative input of the amplifier. The positive input is connected through R154 to -2. 5 V. Q34 is turned on by connecting Rill through R153 to -2. 5 V. In this configuration, the Buffer Amplifier is converted to an inverting amplifier with a gain of -4. The steady current through R113 changes the output average voltage (at R126, R127) from -2. 5 V to +2. 5 V. Again, the output signal is coupled through C69 – C70 Model DB-2 and referenced to ground by R135. R133 and Rl34 increase the output impedance to 50 n.

ATTENUATOR

The output signal passes through four Attenuators, controlled by switches S8 – S11. Each Attenuator is a 50 n balanced 1r type providing either 2, 5, or 10 times attenuation. A noise filter, consisting of two ferrite beads and C71, reduces switching splices down to the millivolt level.

+5 VOLT POWER
Power for the digital logic (Zl, Z2, Z3, Z5, and Z7) is supplied by Z6 from the +12 V input. The nominal current through Z6 is 100 mA.

MAINTENANCE

INTRODUCTION

The Model DB-2 Random Pulse Generator has been designed to provide trouble-free service with minimal preventive maintenance required • However, an occasional operational check using the calibration procedure (paragraph 5, 3) can be useful in discovering and localizing minor problems which may not be apparent in normal use. In some cases, recalibration will cure the problem.

TEST EQUIPMENT
The following test equipment is required to calibrate the Model D B – 2. Recommended equipment models are given in parentheses.

1. 50 MHz Oscilloscope with a Differential Comma? aerator Plug-In (Tektronix 7504, 7A13, 7B50),
2. Regulated NIM Power Supply (BNC AP-2),
3. Shaping Amplifier wit h Bipolar Output (Tunneled TC211).
4. Adjustable Regulated DC Power Supply, 0 – 10 V (Hewlett Packard 721A).
5. VOM (Triplett 630-NA).
6. 50 n cables and termination.
7. Extender cable for NIM Power Supply.
8. Laboratory Oven.

CALIBRATION PROCEDURE

The calibration procedure should be performed in the sequence given to minimize interaction of adjustments, Any defective components should be replaced prior to calibration. The Model DB-2 and all test instrumentation should be allowed to operate for thirty minutes prior to making adjustments (the initial performance check may be performed during this time).

NOTE
Location of the calibration trimmers is shown in Figure 5-1.

VISUAL INSPECTION

The exterior of the Model DB-2 should be examined for bent or broken controls or connectors. Remove both side covers and inspect the interior for damage to the circuit board, wires, or components. The remedy for most visible defects will be obvious; however, care must be used if heat-damaged components are encountered, Usually overheating is only a symptom of trouble. For this reason, it is essential to determine the actual cause of the overheating, or the damage may be repeated.

SETUP

Connect the Model DB-2 to the NIM power supply via the extender cable. Monitor the output pulse (PULSE OUT) with the oscilloscope using a 50 n terminated line.

Set the controls as follows:

- RANGE = 10 V
- MODE = REP (Repetitive)
- AMPLITUDE = 10.0
- NORMALIZE = 10,0
- FREQUENCY = 1 kHz (fine control fully clockwise)
- RISE TIME = 0.1 µs
- FALL TIME = 200 µs
- POL (polarity) = +
- REF = INT
- No attenuation = (All ATTEN switches set to left)

MAINTENANCE

NITIAL PERFORMANCE CHECK

1. Apply power to the NIM supply and check for 5 V (approximately) output pulses over all frequency settings (except EXT).
2. Return the FREQUENCY controls to the nominal 1 kHz setting· (see setup above) and note that the leading edge of the tail pulse is positive in slope.
3. Change the polarity (POL) switch and notethat the leading edge is now negative in slope.
4. Set the RANGE to 1 V and the MODE to RANDOM. Note that the pulses are approximately 0. 5 V in amplitude, and are randomly spaced in time.

NOTE
Allow the Model DB-2 to operate for thirty minutes before continuing the procedure.

I}TEMETER OFFSET (R25}
Monitor. the cathode of D7 with the oscilloscope using the O. 2 V /div St; ale. Adjust R25 for zero average volts.

LOOP INPUT DC OFFSET

1. Set the FREQUENCY to EXT and the RANGE switch to 10 V.
2. Set the MODE to REP.
3. Using the differential comparator, monitor the cliffenmtial voltage from the anode ofD28 to the cathode of D29.
4. Adjust R89 until the voltage is zero ± 0.1 V.

LOOP OUTPUT DC OFFSET (R75)

1. Set the RANGE to 1 V and monitor the jW1ction of C72 – C79 (on the FALL TIME switch).
2. Adjust R75 for a DC voltage of -0.5 ±0.5 V.

Since there are long time constants in the circuit, 30 or more seconds should be allowed for circuit settling. The adjustment range of R75 is 10 V, thus the output offset would only change by 2. 5 V for a quarter turn of the pot.

RA TEMETER CHARGE EQUALIZATION (C15)

1. Set the FREQUENCY controls to approximately 1 MHz.
2. Monitor Zl0 pin 10 with the differential comparator.
3. Measure the DC voltage with the MODE set to REP.
4. Change the MODE to RANDOM and adjust C15 (using a non-metallic tool) until the DC voltage is within ..t 0. 01 V of the REP val

BUFFER AMPLIFIER DC OFFSET (R118)

1. Set the FREQUENCY control to EXT and monitor the heat sink of Q45 with the oscilloscope.
2. Set the RANGE lo 1 V and set POL to '+'.
3. Measure the DC voltage to the nearest 0. 1 V. It should be negative.
4. Set the POL switch to '-' and again measure the voltage which should now be positive.
5. Adjust Rl18 until the magnitudes of the two voltages are the same within ± O. 1 V.
6. Repeat both measurements each time R118 is adjusted. The final value should be 2. 5 ± 0. 5 V.

BUFFER AMPLIFIER BIAS (R131)

1. Set the FREQUENCY control to 10 kHz (fine control fully clockwise), RANGE to 1 V, MODE to REP, and POL to '-'.
2. Meritor the output (PULSE OUT) using the 50 n termination at the oscilloscope.
3. Adjust R131 for minimum peaking. Use a non-metallic tool for this adjustment.

OUTPUT AMPLITUDE (R45)

1. Set the RANGE to love, and verify that both AMPLITUDE and NORMALIZE are set to 10. 0.
2. Set the RISE TIME to 0. 2 μs and the FALL TIME to 100 μs.
3. Monitor the output pulse (PULSE OUT) with the differential comparator (terminate with 50 0) and measure the magnitude of the amplitude step.
4. Switch POL to '+' and repeat the measurement.
5. Adjust R45 until both amplitudes fall between 5. 0 V and 5. 1 V (10. 0 – 10. 2 V unterminated).

NTERNAL ZERO INTERCEPT (R60)

1. Set the AMPLITUDE to 2. 00, RANGE to 1. 0 V, and POL to '+'.
2. Connect the output pulse (PULSE OUT) to the input of the shaping amplifier and terminate with 50 n.
3. Set the amplifier for time constants between O. 5 μs and 3 μs.
4. Set the gain to a value between 20 and 40, yielding a signal between 2 V and 4 V.
5. Measure the signal with the differential comparator.
6. Set the AMPLITUDE to 1. 00 and repeat the measurement.

7. Subtract the readings to obtain the calculated 1. 00 value.

8. Adjust R60 until the measurement at 1. 00 equals the calculated 1. 00 value.

FIG. 5-1. Location of Calibration Trimmers.
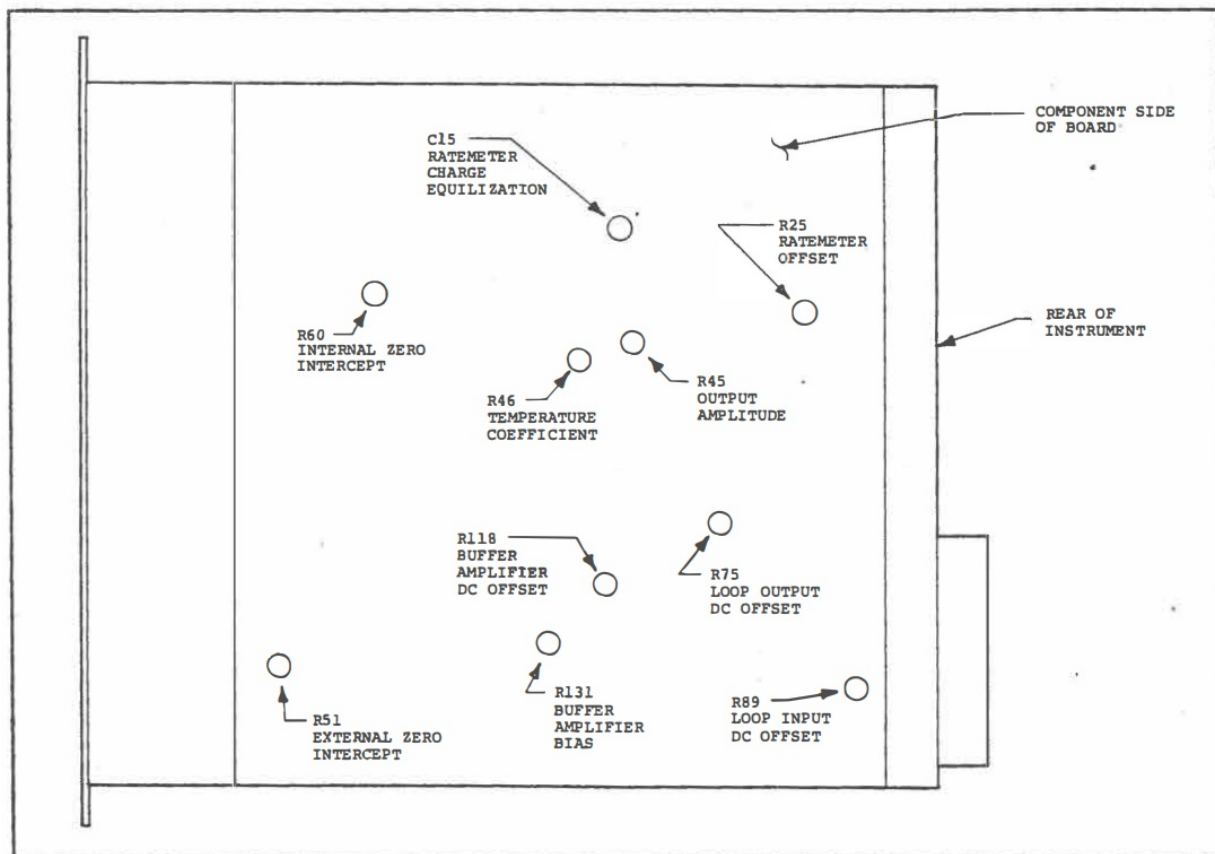
EXTERNAL ZERO INTERCEPT (R51)

1. Properly adjust R60 (see above) before
   adjusting R51.

2. Set REF to EXT.

3. Connect the DC power supply to the EXT
   REF connector.

4. Adjust the power supply until it is set to
   2. 000 ± O. 001 V.

5. Measure the output of the shaping amplifier as before.

6. Set the supply to 1. 000 ± O. 001 V.

7. Subtract the readings to obtain the calculated 1. 000 V .

8. Adjust R51 until the 1. 000 measurement matches the 1. 000 value.

TEMPERATURE COEFFICIENT (R46)

The two amplitude ranges have slightly differing temperature coefficients (TC). If either
range is adjusted for zero TC, the other range
will fall within the stated s p e c if i cation
(0. 02%/ °C).

1. Place the DB-2 in the laboratory oven and set the temperature controller to slightly above room ambient

temperature. Page 5-4

2. Set the AMPLITUDE to 9. 00, the MODE to REP, the RANGE to 10 V.

3. Set the RISE TIME to 0. 2 µs and the FALL TIME to 100 µs.

4. After thermal . equilibrium is obtained, measure the wiper arm voltage of R46 using the differential comparator.

   NOTE: Be sure that all probes and cables are removed from R46 after each measurement.

5. Record the output voltage, the temperature, and the wiper arm voltage of R46.

6. Repeat these measurements at an elevated (room + 15°C) temperature.

7. **Calculate the thermal coefficient:**

   (a) If the TC is negative, adjust R46 so that a higher wiper voltage is obtained.

   (b) If the TC is positive, adjust R46 so that a lower wiper voltage results.

8. Record the new wiper voltage.

9. While monitoring the DB-2 output, adjust R45 until the output voltage returns to the earlier recorded value (room temperature).

10. Repeat the temperature test until the TC is set to zero.

Contents

PARTS LIST AND SCHEMATICS

cer	ceramic	µ.H	microhenry
comp	composition carbon	µF	microfarad
elec	electrolytic, metal case	pF	picofarad
mic	mica	pos	positions
My1	Mylar	tan	tantalum
k	kiloohm	v	working volts DC
M	megaohm	var	Variable
M	mill	w	Watts
MF	metal film	WW	wire wound

NOT E
The last number after each part description is the BERKELEY NUCLEONICS part number for reordering.

CAPACITOR

Ref	Value	Type	Voltage	Tol.	Part No.
C1	0.05 µF	cer	500 V		110-015
C2	470 pF	mic	100 V	5%	112-013
C3	0.0047 µF	myl	400 V	10%	114-008
C4	0.047 µF	myl	200 V	10%	114-018
C5	0.47 µF	myl	100 V	10%	114-023
C6	4.7 µF	tan	35 V	10%	122-004
C7	220 pF	cer			110-020
C8	22 pF	mic	500 V	5%	112-001
C9	25 µF	elec	25 V		120-005
C10	56 pF	mic	500 V	5%	112-022
C11	330 pF	mic	500 V	5%	112-010
C12	25 µF	elec	25 V		120-005
C13	100 pF	mic	500 V	5%	112-004
C14	68 pF	mic	500 V	5%	112-018
C15	4.5-50 pF	var			130-003
C16	0.05 µF	cer	500 V		110-015
C17	0.05 µF	cer	500 V		110-015
C18	100 pF	mic	500 V	5%	112-004
C19	0.05 µF	cer	500 V		110-015
C20	0.05 µF	cer	500 V		110-015
C21	22 pF	mic	500 V	5%	112-001
C22	0.05 µF	cer	500 V		110-015
C23	390 pF	mic	500 V	5%	112-011
C24	0.05 µF	cer	500 V		110-015
C25	25 µF	elec	25 V		120-005
C26	100 pF	mic	500 V	5%	112-004
C27	220 pF	cer			110-020
C28	20 pF	mic	500 V	5%	112-025
C29	0.05 µF	cer	500 V		110-015
C30	0.05 µF	cer	500 V		110-015
C31	0.05 µF	cer	500 V		110-015
C32	100 µF	elec	25 V		120-008
C33	100 µF	elec	25 V		120-008
C34	0.05 µF	cer	500 V		110-015
C35	0.05 µF	cer	500 V		110-015
C36	910 pF	myl		10%	114-032
C37	100 pF	poly	50 V	10%	115-001
C38	100 µF	elec	16 V		120-007
C39	0.33 µF	myl	600 V	10%	114-016
C40	0.47 µF	cer	10 V		110-016
C41	25 µF	elec	25 V		120-005
C42	0.05 µF	cer	500 V		110-015
C43	25 µF	elec	25 V		120-005
C44	22 pF	mic	500 V	5%	112-001
C45	0.05 µF	cer	500 V	.	110-015
C46	25 µF	elec	25 V		120-005
C47	0.47 µF	cer	10 V		110-016
C48	0.05 µF	cer	500 V		110-015
C49	0.05 µF	cer	500 V		110-015
C50	100 µF	elec	16 V		120-007
C51	25 µF	elec	25 V		120-005
C52	0.05 µF	cer	500 V		110-015
C53	0.05 µF	cer	500 V		110-015
C54	68 pF	mic	500 V	5%	112-018
C55	100 µF	elec	16 V		120-007
C56	25 µF	elec	25 V		120-005
C57	62 pF	mic	500 V	5%	112-023
C58	0.05 µF	cer	500 V		110-015
C59	0.05 µF	cer	500 V		110-015
C60	100 µF	elec	16 V		120-007
C61	100 µF	elec	25 V		120-008
C62	100 µF	elec	25 V		120-008
C63	5 pF	mic	500 V	5%	112-021
C64	0.05 µF	cer	500 V		110-015
C65	4 pF	mic	500 V	5%	112-027
C66	0.05 µF	cer	500 V		110-015
C67	1000 µF	elec	15 V		120-018
C68	1000 µF	elec	15 V		120-018
C69	1000 µF	elec	15 V		120-018
C70	1000 µF	elec	15 V		120-018

CAPACITORS (continued)

C71	1200 pF	myl		10%	114-031
C72	0.0022 μF	myl	600 V	10%	114-003
C73	0.0047 μF	myl	400 V	10%	114-008
C74	0.01 μF	myl	200 V	10%	114-025
C75	0.022 μF	myl	100 V	10%	114-014
C76	0.047 μF	myl	200 V	10%	114-018
C77	0.1 μF	myl	100 V	10%	114-020
C78	0.27 μF	myl	100 V	10%	114-030
C79	0.68 μF	myl	100 V	10%	114-028
C80	0.05 μF	cer	500 V		110-015
C81	150 pF	mic	500 V	5%	112-005
C82	430 pF	mic	100 V	5%	112-012
C83	0.001 μF	myl	600 V	10%	114-001
C84	0.002 μF	myl	600 V	10%	114-002
C85	0.0047 μF	myl	400 V	10%	114-008
C86	0.01 μF	myl	200 V	10%	114-025
C87	0.02 μF	myl	200 V	10%	114-013
C88	25 μF	elec	25 V		120-005
C89	33 pF	cer	1 KV	10%	110-004
C90	10 pF	mic	500 V	5%	112-016
C91	0.05 pF	cer	25 V	20%	110-019

DIODES

D1	1N4154	411-003
D2	1N4154	411-003
D3	1N4154	411-003
D4	1N4154	411-003
D5	1N270	411-002
D6	1N4154	411-003
D7	1N4154	411-003
D8	1N4154	411-003
D9	1N4154	411-003
D10	1N4154	411-003
D11	1N4154	411-003
D12	1N270	411-002
D13	1N4739	413-004
D14	1N4739	413-004
D15	1N4154	411-003
D16	1N821	412-001
D17	1N5713	415-003
D18	1N5713	415-003
D19	1N4154	411-003
D20	1N270	411-002
D21	1N270	411-002
D22	1N4154	411-003
D23	1N4154	411-003
D24	1N4737	413-003
D25	1N4154	411-003
D26	1N5713	415-003
D27	1N5713	415-003
D30	1N4100	410-001
D31	1N4742	413-005
D32	1N4154	411-003
D33	1N4742	413-005
D34	1N270	411-002
D35	1N270	411-002
D36	1N4154	411-003
D37	1N4154	411-003

INDUCTOR

L1	39 μH	310-009

INTEGRATED CIRCUITS

Z1	74122 N			440–145
Z2	MC3000P			440–024
Z3	74S113			440–094
Z4	741C			440–021
Z5	74122 N			440–145
Z6	7805			440–023
Z7	74122 N			440–145
Z8	741C			440–021
Z9	741C			440–021
Z10	741C			440–021

RESISTOR

R1	430 Ω	1/4 W	comp	5%	213–431
R2	100 Ω	1/4 W	comp	5%	213–101
R3	2.2 K	1/4 W	comp	5%	213–222
R4	2.7 K	1/2 W	comp	5%	212–272
R5	75 K		var		610–012
R6	15 K	1/4 W	comp	5%	213–153
R7	2 K	1/2 W	comp	5%	212–202
R8	2.2 K	1/4 W	comp	5%	213–222
R9	1 K	1/4 W	comp	5%	213–102
R10	1 K	1/4 W	comp	5%	213–102
R11	2.2 K	1/4 W	comp	5%	213–222
R12	2.2 K	1/4 W	comp	5%	213–222
R13	470 Ω	1/4 W	comp	5%	213–471
R14	1 K	1/4 W	comp	5%	213–102
R15	4.7 K	1/4 W	comp	5%	213–472
R16	10 K	1/4 W	comp	5%	213–103
R17	1 K	1/4 W	comp	5%	213–102
R18	150 Ω	1/4 W	comp	5%	213–151
R19	100 Ω	1/4 W	comp	5%	213–101
R20	39 Ω	1/4 W	comp	5%	213–390

RESISTORS (continued)

Ref	Value	Power	Type	Tol	Part No.
R21	10 K	1/4 W	comp	5%	213-103
R22	27 K	1/4 W	comp	5%	213-273
R23	270 K	1/4 W	comp	5%	213-274
R24	1 K	1/4 W	comp	5%	213-102
R25	1 K		var		244-025
R26	27 K	1/4 W	comp	5%	213-273
R27	1 K	1/4 W	comp	5%	213-102
R28	27 K	1/4 W	comp	5%	213-273
R29	2.2 K	1/4 W	comp	5%	213-222
R30	1 M	1/4 W	comp	5%	213-105
R31	2.2 K	1/4 W	comp	5%	213-222
R32	10 K	1/4 W	comp	5%	213-103
R33	10 K	1/4 W	comp	5%	213-103
R34	1 K	1/4 W	comp	5%	213-102
R35	1 K	1/4 W	comp	5%	213-102
R36	1 K	1/4 W	comp	5%	213-102
R37	470 Ω	1/4 W	comp	5%	213-471
R38	470 Ω	1/4 W	comp	5%	213-471
R39	4.7 K	1/4 W	comp	5%	213-472
R40	150 Ω	1/4 W	comp	5%	213-151
R41	10 K	1/4 W	comp	5%	213-102
R42	100 Ω	1/4 W	comp	5%	213-101
R43	(not used)				
R44	620 Ω	1/2 W	comp	5%	212-621
R45	10 K		var		244-025
R46	10 K		var		244-025
R47	1 M	1/4 W	comp	5%	213-105
R48	1.54 K	1/4 W	MF	1%	222-043
R49	8.45 K	1/4 W	MF	1%	222-040
R50	102 K	1/4 W	MF	1%	222-046
R51	10 K		var		244-025
R52	2.00 K	1/4 W	MF	1%	222-042
R53	604 Ω	1/4 W	MF	1%	222-048
R54	4.22 K	1/4 W	MF	1%	222-041
R55	1.5 K	1/4 W	comp	5%	213-152
R56	2 K		var		242-007
R57	5.1 K	1/4 W	comp	5%	213-512
R58	100 Ω	1/4 W	MF	1%	222-051
R59	649 Ω	1/4 W	MF	1%	222-047
R60	10 K		var		244-025
R61	1 K		var		242-006
R62	10 K	1/4 W	comp	5%	213-103
R63	10 K	1/4 W	comp	5%	213-103
R64	3.3 K	1/4 W	comp	5%	213-332
R65	10 K	1/4 W	comp	5%	213-103
R66	750 Ω	1/4 W	comp	5%	213-751
R67	5.6 K	1/4 W	comp	5%	213-562
R68	5.6 K	1/4 W	comp	5%	213-562
R69	1 M	1/4 W	comp	5%	213-105
R70	4.7 K	1/4 W	comp	5%	213-472
R71	2.2 K	1/4 W	comp	5%	213-222
R72	2.2 K	1/4 W	comp	5%	213-222
R73	4.7 M	1/4 W	comp	5%	213-475
R74	2.4 M	1/4 W	comp	5%	213-245
R75	10 K		var		244-025
R76	10 K	1/4 W	comp	5%	213-103
R77	4.7 K	1/4 W	comp	5%	213-472
R78	10 M	1/4 W	comp	5%	213-106
R79	10 K	1/4 W	comp	5%	213-103
R80	2.2 K	1/4 W	comp	5%	213-222
R81	22 M	1/4 W	comp	5%	213-226
R82	10 M	1/4 W	comp	5%	213-106
R83	10 Ω	1/4 W	comp	5%	213-100
R84	30 K	1/4 W	comp	5%	213-303
R85	1 K	1/4 W	comp	5%	213-102
R86	30 K	1/4 W	comp	5%	213-303
R87	2.2 K	1/4 W	comp	5%	213-222
R88	100 Ω	1/4 W	comp	5%	213-101
R89	10 K		var		244-025
R90	2.2 K	1/4 W	comp	5%	213-222
R91	10 K	1/4 W	comp	5%	213-103
R92	1 K	1/4 W	comp	5%	213-102
R93	10 K	1/4 W	comp	5%	213-103
R94	150 Ω	1/4 W	comp	5%	213-151
R95	15 Ω	1/4 W	comp	5%	213-150
R96	220 Ω	1/4 W	comp	5%	213-221
R97	10 K	1/4 W	comp	5%	213-103
R98	10 K	1/4 W	comp	5%	213-103
R99	10 K	1/4 W	comp	5%	213-103
R100	10 K	1/4 W	comp	5%	213-103
R101	1 K	1/4 W	comp	5%	213-102
R102	10 M	1/4 W	comp	5%	213-106
R103	2.2 K	1/4 W	comp	5%	213-222
R104	(not used)				
R105	4.7 K	1/4 W	comp	5%	213-472
R106	2.2 K	1/4 W	comp	5%	213-222
R107	10 Ω	1/4 W	comp	5%	213-100
R108	2.2 K	1/4 W	comp	5%	213-222
R109	10 K	1/4 W	comp	5%	213-103
R110	39 K	1/4 W	comp	5%	213-393
R111	100 K	1/4 W	comp	5%	213-104
R112	270 K	1/4 W	comp	5%	213-274
R113	12 K	1/4 W	comp	5%	213-123
R114	30 K	1/4 W	comp	5%	213-303
R115	1 K	1/4 W	comp	5%	213-102
R116	30 K	1/4 W	comp	5%	213-303
R117	2.2 K	1/4 W	comp	5%	213-222
R118	10 K		var		244-025
R119	2.2 K	1/4 W	comp	5%	213-222
R120	10 K	1/4 W	comp	5%	213-103
R121	1 K	1/4 W	comp	5%	213-102
R122	2.2 K	1/4 W	comp	5%	213-222
R123	100 Ω	1/4 W	comp	5%	213-101
R124	2.7 Ω	1/2 W	comp	5%	212-027
R125	15 Ω	1/4 W	comp	5%	213-150

RESISTORS (continued)

R126	1 Ω	1/2 W	comp	5%	212-010
R127	1 Ω	1/2 W	comp	5%	212-010
R128	15 Ω	1/4 W	comp	5%	213-150
R129	100 Ω	1/4 W	comp	5%	213-101
R130	2.7 Ω	1/2 W	comp	5%	212-027
R131	200 Ω		var		244-024
R132	8.06 K	1/4 W	MF	1%	222-045
R133	100 Ω	1/4 W	MF	1%	222-051
R134	100 Ω	1/4 W	MF	1%	222-051
R135	10 K	1/4 W	comp	5%	213-103
R136	10 Ω	1/4 W	comp	5%	213-100
R137	10 Ω	1/4 W	comp	5%	213-100
R138	150 Ω	1/4 W	MF	1%	222-049
R139	37.4 Ω	1/4 W	MF	1%	222-053
R140	150 Ω	1/4 W	MF	1%	222-049
R141	75 Ω	1/4 W	MF	1%	222-052
R142	121 Ω	1/4 W	MF	1%	222-009
R143	75 Ω	1/4 W	MF	1%	222-052
R144	61.9 Ω	1/4 W	MF	1%	222-005
R145	249 Ω	1/4 W	MF	1%	222-011
R146	61.9 Ω	1/4 W	MF	1%	222-005
R147	61.9 Ω	1/4 W	MF	1%	222-005
R148	249 Ω	1/4 W	MF	1%	222-011
R149	61.9 Ω	1/4 W	MF	1%	222-005
R150	10 Ω	1/4 W	comp	5%	213-100
R151	10 Ω	1/4 W	comp	5%	213-100
R152	1 K	1/4 W	MF	1%	222-044
R153	143 Ω	1/4 W	MF	1%	222-050
R154	1 K	1/4 W	MF	1%	222-044
R155	1 K	1/4 W	MF	1%	222-044
R156	2.2 K	1/4 W	comp	5%	213-222

TRANSISTORS

Q1	MPS5172	430-031
Q2	MPS5172	430-031
Q3	MPS5172	430-031
Q4	MPSA70	430-032
Q5	MPSA70	430-032

Q6	MPS5172	430-031
Q7	2N4360	430-035
Q8	2N4360	430-035
Q9	MPS5172	430-031
Q10	2N5485	431-005
Q11	MPS5172	430-031
Q12	MPSA70	430-032
Q13	MPSA70	430-032
Q14	2N4360	430-035
Q15	MPSA70	430-032
Q16	MPS5172	430-031
Q17	2N5485	431-005
Q18	MPSA70	430-032
Q19	MPSA70	430-032
Q20	MPS6522	430-034
Q21	MPS6522	430-034
Q22	2N5485	431-005
Q23	2N5485	431-005
Q24	MPS5172	430-031
Q25	MPS5172	430-031
Q26	MPS6522	430-034
Q27	MPS6520	430-033
Q28	MPSA70	430-032
Q29	MPS5172	430-031
Q30	MPSA70	430-032
Q31	MPS6520	430-033
Q32	MPSA70	430-032
Q33	MPSA70	430-032
Q34	MPS5172	430-031
Q35	2N5485	431-005
Q36	2N5485	431-005
Q37	MPSA70	430-032
Q38	MPSA70	430-032
Q39	MPSA70	430-032
Q40	MPS5172	430-031
Q41	MPSA70	430-032
Q42	MPS5172	430-031
Q43	MPS6520	430-033
Q44	MPS6522	430-034
Q45	MPSU52	430-037
Q46	MPSU02	430-036

Contact Us
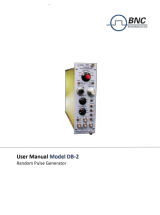
Model Type User Manual

Documents / Resources

BNC Model DB2 Benefits, Random Pulse Generator [pdf] User Manual
DB2 Benefits Random Pulse Generator, DB2, Benefits Random Pulse Generator, Random Pulse Generator, Pulse Generator, Generator