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TECHNOLOGY UTILIZATION

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ELECTRONIC SIGNAL GENERATORS

A COMPILATION



NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Foreword

The National Aeronautics and Space Administration and the Atomic Energy Commission have established a Technology Utilization Program for the dissemination of information on technological developments which have potential utility outside the aerospace and nuclear communities. By encouraging multiple application of the results of their research and development, NASA and AEC earn for the public an increased return on the investment in aerospace research and development programs.

The innovations in this compilation deal with electronic circuits and represent a carefully selected collection of items on electronic signal generators. Most of the items are based on well-known solid-state concepts that have been simplified or refined to meet NASA's demanding requirements for reliability, simplicity, fail-safe characteristics, and the capability of withstanding environmental extremes. The items included in the sections dealing with pulse generators and oscillators should be of particular interest to the electronic hobbyist, because of their simplicity and low cost.

Additional technical information on individual devices and techniques can be requested by circling the appropriate number on the Reader Service Card included in this compilation.

Unless otherwise stated, NASA and AEC contemplate no patent action on the technology described.

We appreciate comment by readers and welcome hearing about the relevance and utility of the information in this compilation.

Ronald J. Philips, *Director*
Technology Utilization Office
National Aeronautics and Space Administration

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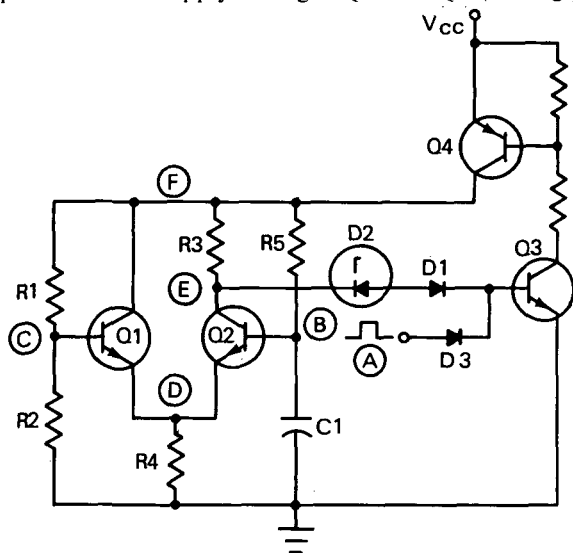
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Section 1. Pulse Generators

MONOSTABLE MULTIVIBRATOR HAS HIGH STABILITY OVER WIDE TEMPERATURE RANGE

A differential comparator is used to generate highly stable pulses over wide variations in temperature and supply voltage. Q1 and Q2 (see fig.)



operate as the differential comparator, with the supply voltage switched by Q4. In the quiescent state, Q3 and Q4 are cut off, thereby limiting power dissipation to the transistor leakage currents. Triggering is accomplished by applying a

short duration, positive pulse at point A. The trigger pulse turns on Q3 which then turns on Q4. The base current of Q3 flowing through Q4, R3, D2, and D1 keeps Q3 conducting.

When Q4 is conducting, point D is held at a voltage close to the voltage of point C. Until capacitor C1 is charged to approximately the voltage at point C, Q2 is cut off. Once Q2 starts to conduct, the voltage at E drops sufficiently to remove Q3 from a saturation condition. When Q3 is no longer saturated, Q4 is cut off and the entire circuit once again assumes the quiescent state.

Q1 and Q2 are closely matched transistors (ideally, a matched monolithic pair) to assure nearly identical base-emitter voltages over the usable temperature range. The circuit is capable of generating a pulse with periods varying from 5 μ sec to 100 msec over a 223 K to 373 K temperature range.

Source: W. C. Roehr, Jr., and R. C. Grimmer of IBM Electronics Systems Center under contract to Goddard Space Flight Center (GSC-10657)

No further documentation is available.

RESETTABLE MONOSTABLE PULSE GENERATOR

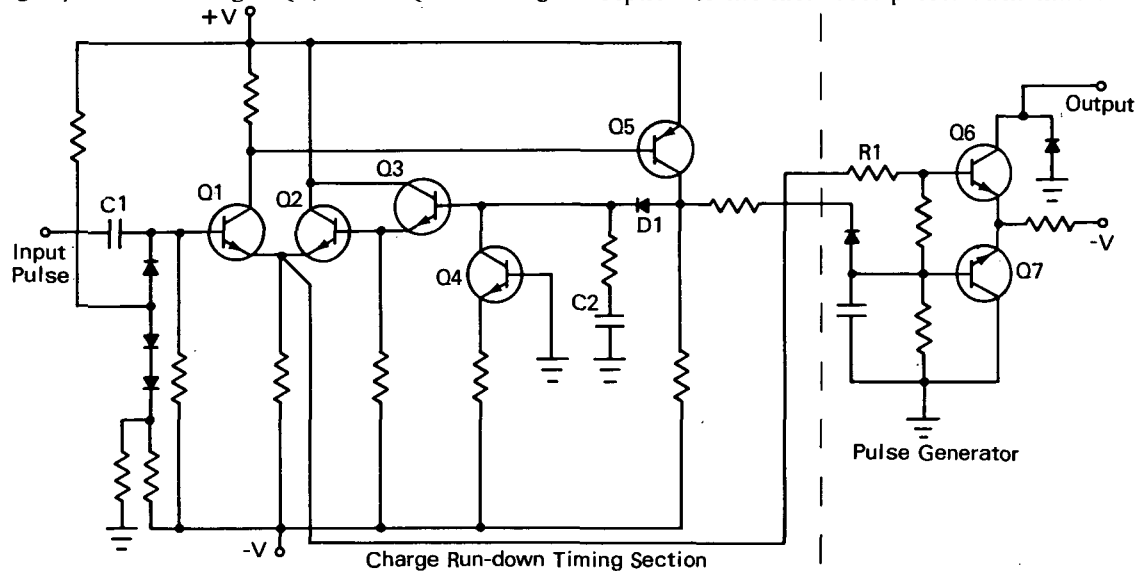
A new pulse generator is capable of producing an output pulse which begins upon receipt of a random input signal. The termination time of the output pulse can be preset to a specified pulse width from the beginning of the input pulse. The circuit continues to generate the specific output pulse width as long as a reset pulse occurs to recycle the pulse generator during a predetermined

time period. If no input pulse occurs during the predetermined time period, the output pulse returns to a quiescent state. The pulse generator is particularly suitable for use where small packing volume, low power consumption, and simplicity are needed.

The resettable monostable pulse generator (see fig.) includes a charge run-down timing circuit

with a capacitor that is charged to a peak value by a random pulse from a constant amplitude pulse source. After being charged, C2 immediately starts to discharge through Q3 and Q4. The primary discharge path is through Q4, with Q3 drawing

capacitor is again charged to its peak value. This reset pulse prevents terminating the output pulse and recycles the termination time of the output pulse (pulse width) to be measured from the inception of the last reset pulse. Each time a reset



enough current to maintain it in the "on" condition. Q3 turns Q2 on, and the emitter signal of Q2 is applied through R1 to the output pulse generator. The output pulse generator starts to generate a pulse as soon as C2 is charged to its peak value, and continues to generate the output pulse until the charge drops to a predetermined level. If a second pulse from the constant amplitude pulse source occurs during this run-down period, the

pulse occurs during a run-down period, the capacitor is recharged to its peak value; hence, the output pulse exists for a time period depending on the occurrence of the random reset pulses.

Source: N. M. Garrahan
Goddard Space Flight Center
(XGS-11139)

Circle 1 on Reader Service Card.

NANOSECOND PULSE GENERATOR

Short duration, fast rise-time pulses with zero dc components are generated by a new coaxial line pulser. The output pulses can be directly radiated by a broadband antenna instead of being used to modulate a carrier frequency.

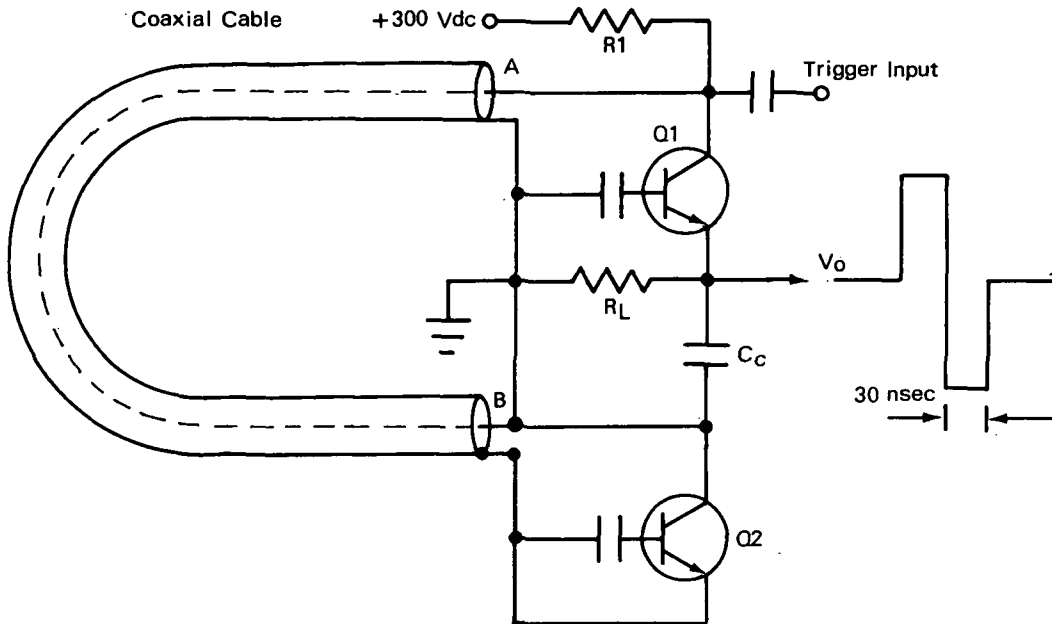
When the 300 Vdc supply is applied to the coaxial cable, the capacitance of the cable begins to charge through R1 (see fig.). The voltage on the center conductor of the cable also appears on the collectors of Q1 and Q2. Q1 is chosen to have a lower avalanche threshold than Q2. Therefore, as the voltage on the cable increases, Q1 fires and enters a low impedance conducting state. This

connects end A of the coaxial cable to the load R_L . The sharp increase of voltage across R_L is coupled through capacitor C_c to the collector of Q2, causing Q2 to fire also. The firing of Q2 short circuits end B of the coaxial cable.

In the charged condition, the cable generates two equal amplitude waves which travel in opposite directions and are reflected at the cable ends. When Q1 fires, the wave traveling in the direction from B to A is coupled into the matched load R_L and there is no further reflection at A. At B, however, the wave traveling from A to B is reflected with a polarity inversion because of the short cir-

cuit produced by Q2. The voltage across R_L is the voltage at end A of the cable. When the transistors fire, the voltage across R_L rises from zero to one-half of the initial voltage on the cable.

but less than the avalanche threshold of Q1 or Q2, the cable will become charged and no further action will occur. Avalanche may then be initiated by applying a trigger pulse to the collector of Q1.

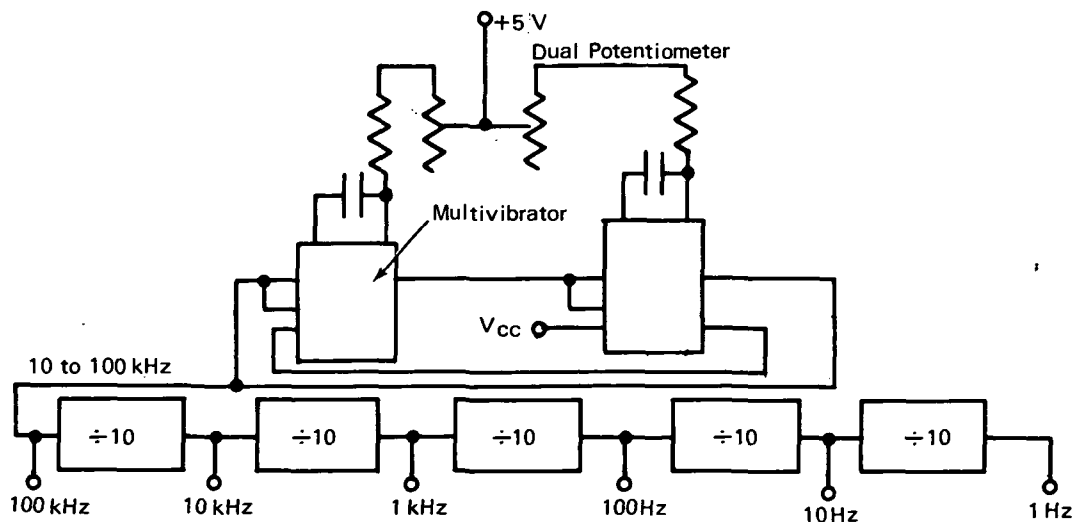


After the transistors have fired, the voltage across R_L undergoes an abrupt polarity reversal. After a short period of time, the cable is discharged, the transistors turn off, and the charging cycle begins again. If the input voltage is large

Source: R. A. Cliff
Goddard Space Flight Center
(GSC-10516)

No further documentation is available.

WIDE FREQUENCY RANGE PULSE GENERATOR



A range of pulses from one pulse every 10 seconds to 20,000 pulses per second is available with this well-designed pulse generator (see fig.). The pulse generator uses a circuit consisting of two one-shot multivibrators. The period of each multivibrator is linearly controlled over a frequency range of 10 kHz to 100 kHz by a ganged potentiometer. The output of the multivibrator is fed into a series of 5 decade counters which produce output pulses as low as one per second. The circuit has

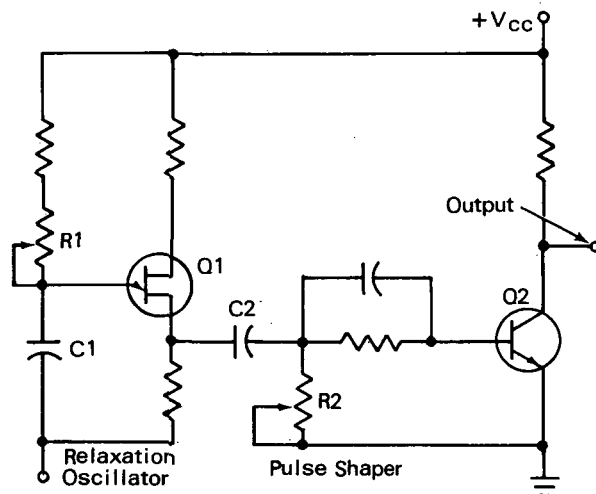
been designed with integrated circuit transistor logic using a 5 V power supply. Frequency stability is very good, and the frequency versus control resistance is linear.

Source: H. H. Holt of
Sperry Rand
under contract to
Marshall Space Flight Center
(MFS-21197)

No further documentation is available.

A VARIABLE PULSE GENERATOR

The variable pulse generator circuit (see fig.) produces a continuous train of pulses whose repetition rate and width are adjustable. The circuit



consists of a relaxation oscillator and the pulse shaping components. Potentiometer R1 varies the repetition rate by varying the charge time of capacitor C1. This controls the time between successive firings of the unijunction transistor Q1. Potentiometer R2 adjusts the pulse width by controlling the charge time of capacitor C2. The variation in charge time determines the time period over which the base of Q2 is provided with sufficient current for saturation. The pulse width can be adjusted from one to several hundred microseconds.

Source: A. T. Nasuta, Jr. of
Westinghouse Electric Corp.
under contract to
Goddard Space Flight Center
(GSC-90506)

No further documentation is available.

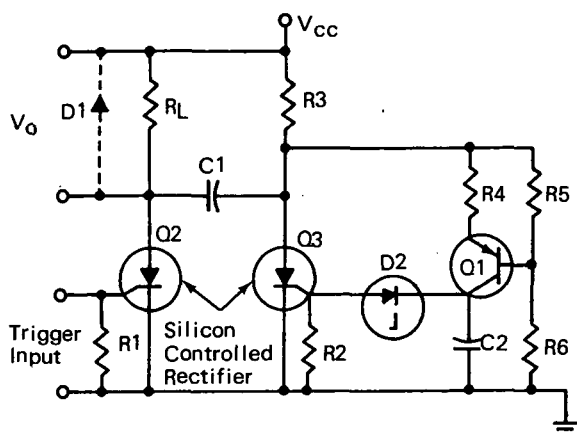
Section 2. High Voltage Pulse Generators

HIGH-POWER MONOSTABLE PULSE GENERATOR CONTROLS SOLENOID VALVE OPERATION

This circuit (see fig.) consists of a dc semiconductor switch and a timing circuit which gate a 100 msec burst of power (48 W) to a solenoid valve. It is particularly useful for controlling large amounts of power in applications requiring long

life, low maintenance, high reliability, low stand-by-power dissipation, small space, and rapid re-setting.

When the circuit is stabilized, Q3 is conducting and Q2 is turned off. When Q2 is triggered, it fires



and causes power to be applied to the load R_L . The negative load pulse is commutated through $C1$ to cut off $Q3$. $Q3$ is triggered "on" after a time-delay determined by the constant current source ($R4$, $R5$, $R6$, and $Q1$) which charges $C2$ to the zener breakdown voltage of $D2$. When $D2$ breaks down, current from $Q1$ flows into the gate of $Q3$. $D1$ is used when the load is inductive.

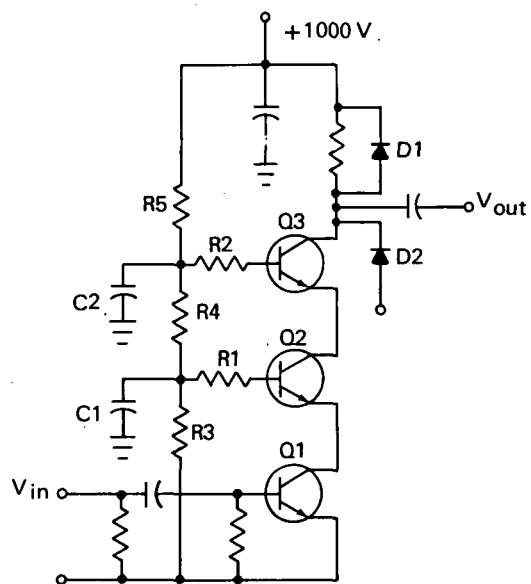
Source: J. D'Arcy of Radio Corp. of America under contract to Goddard Space Flight Center (GSC-90300)

No further documentation is available.

SOLID-STATE HIGH VOLTAGE PULSE GENERATOR

A solid-state pulse generator delivers a 20 kV pulse to a 100 pF load with a rise and fall time of less than 1 μ sec and a pulse width between 10 and 100 μ sec.

A positive input pulse of 2 or 3 V switches $Q1$ on (see fig.). When $Q1$ begins to conduct, the collector voltage decreases, turning on $Q2$. The same operation occurs when the collector of $Q2$ decreases, switching on $Q3$, with base current flowing through $R2$. The switching times of $Q2$ and $Q3$ are limited only by the response of $Q1$, $Q2$, and $Q3$, since they are switched with emitter drive voltage. Therefore, the switching speed of the complete circuit is limited almost entirely by the switching of $Q1$. The transistor string is protected from spurious high voltage spikes by high voltage rectifier diodes $D1$ and $D2$. The rise and fall times of the pulse can be decreased by using higher frequency transistors. The important features of the pulse generator are the availability of a positive or negative pulse at the output, without transformer coupling, and the protection of the circuit components against high voltage breakdown with the use of the diode biasing scheme.



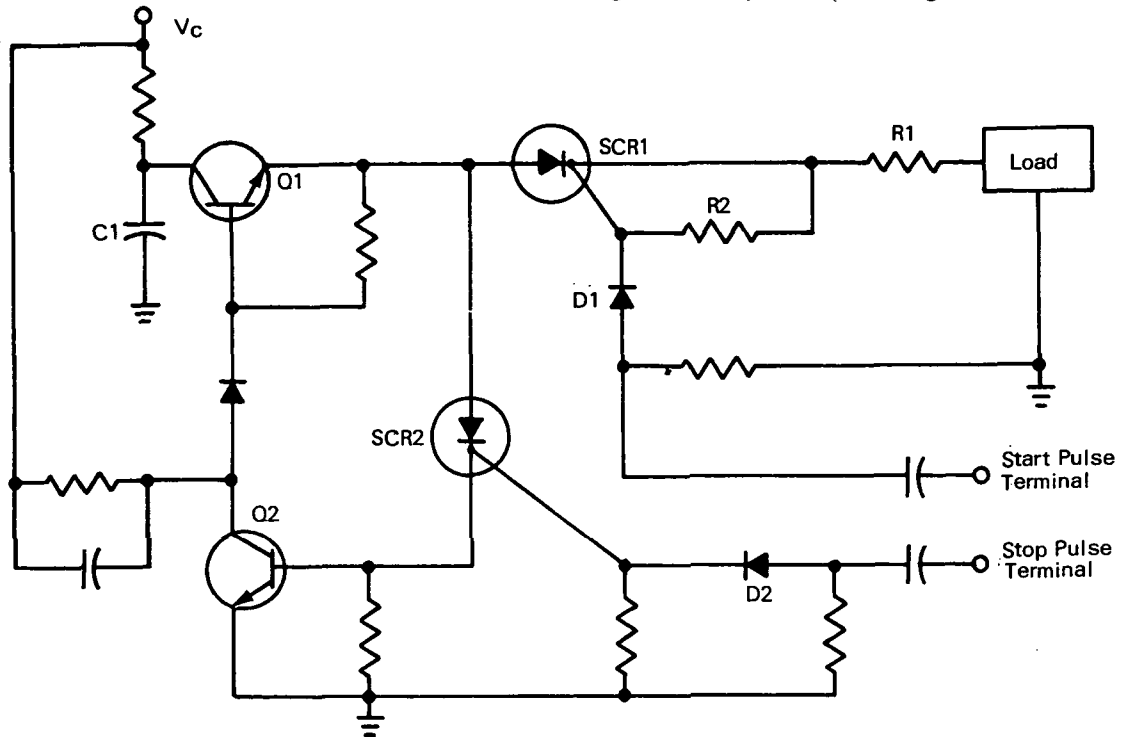
Source: D. O. Hansen of TRW Space Technology Laboratories under contract to NASA Headquarters (HQN-10050)

Circle 2 on Reader Service Card.

HIGH-CURRENT PULSE GENERATOR

A high-current pulse generator (see fig.) contains a storage capacitor which discharges into the load through input transistor Q1, the first silicon controlled rectifier SCR1, and resistors R1 and

undergoes negligible discharge, permitting an average current-to-peak-current ratio that approaches the duty cycle ratio. In this manner, high-current pulses can be generated with high



R2. Upon application of a pulse to the stop pulse terminal, SCR2 is turned on, diverting the load current through it and turning on Q2. Shortly after, SCR1 and SCR2 are turned off, and finally Q2 is turned off. The cycle is repeated upon application of the next start pulse.

The pulse on-time and the circuit storage time represent a small fraction of the interpulse period. The storage capacitor, under these conditions,

undergoes negligible discharge, permitting an average current-to-peak-current ratio that approaches the duty cycle ratio. In this manner, high-current pulses can be generated with high circuit efficiency. The pulse on-time is determined by the turn-on characteristics of the circuit elements.

Source: M. G. Woolfson of Westinghouse Electric Corp. under contract to Manned Spacecraft Center (MSC-405)

Circle 3 on Reader Service Card.

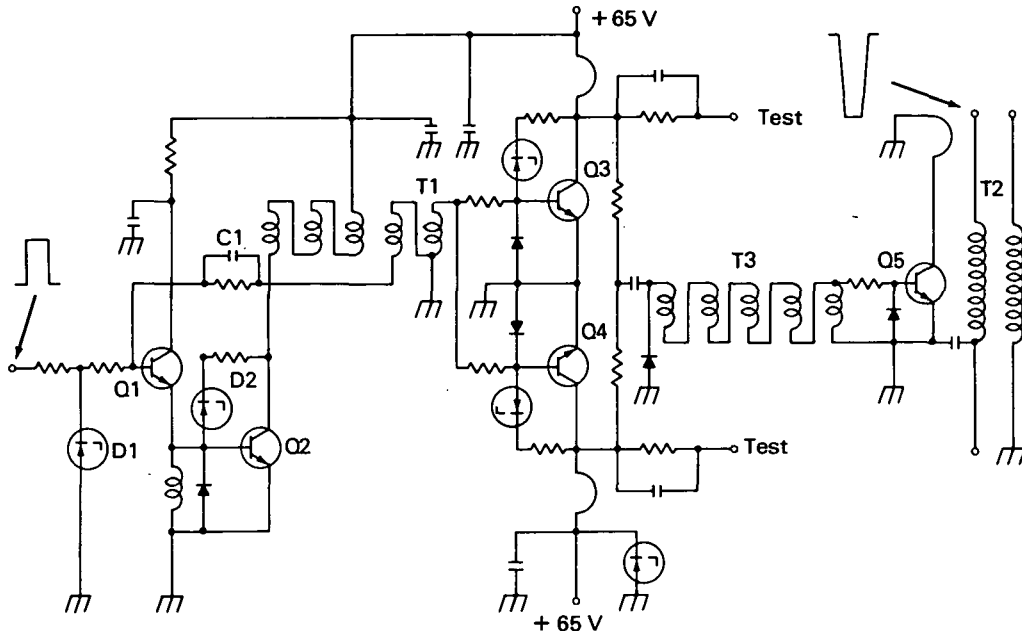
PULSE GENERATOR DELIVERS HIGH-SPEED PULSES AT MEGAWATT LEVELS

This solid state, high-speed circuit has been designed for application as a klystron cathode pulser. The circuit delivers 3 kW, 3 kV pulses from a bifilar filament transformer. Unlike most state-of-the-art pulsers, which require high supply

voltages to generate high-voltage pulses, only 65V are required to generate a 3 kV pulse. The circuit (see fig.) offers advantages in operational safety and reliability and in improved packaging. The special components which make low-voltage op-

eration possible are broadband video transformers wound in multifilar toroids and loop-coupling toroids.

safe, secondary breakdown region. Coupling and matching from the drive amplifier to the dual base input circuit of transistors Q3 and Q4 are made



Transistors Q1 and Q2 form a stabilized amplifier with a 15 dB power gain. Stabilization is achieved by negative feedback from one secondary of transformer T1 to the summation point of the base of Q1. Zener diode D1 is incorporated into the signal input network of Q1 to regulate the drive voltage. Zener diode D2, connected between the base and collector of Q2, is used to prevent the backswing of T1 from exceeding the supply voltage. When such transients occur, the zener avalanche causes Q2 to conduct, thus preventing collector-to-base avalanche. The transistor operates at its full voltage capabilities within the

via a transmission line toroidal transformer which minimizes capacitance and leakage reactance. Parallel transmission lines are used to approximate a true transmission line, providing a unity power factor (or VSWR) over many frequency decades.

Source: W. E. Milberger of
Westinghouse Electric Corp.
under contract to
Marshall Space Flight Center
(MFS-14034)

Circle 4 on Reader Service Card.

A SIMPLE, HIGH VOLTAGE PULSE GENERATOR FOR WIDE-GAP SPARK CHAMBERS

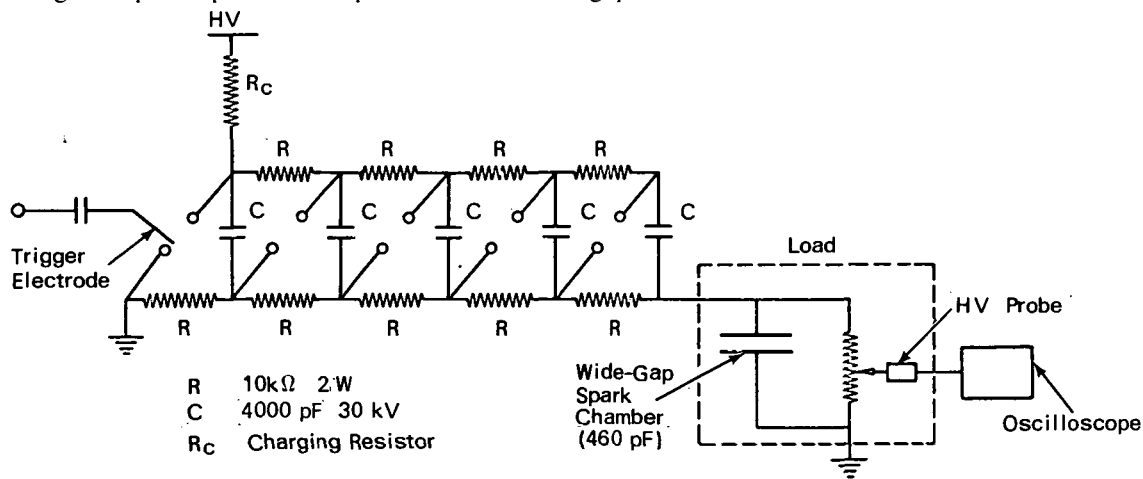
A low-inductance, high-capacitance, Marx pulse generator uses a coaxial configuration to produce a 100 kV pulse, with a 2.5 nsec rise time, across a resistive load. The generator design and coaxial configuration, which minimize internal inductance and suppress external electromagnetic radiation, can be used for electromagnetic pulse simulation and flash X-ray generation.

The Marx pulser (see fig.) employs a capacitor parallel-charging and series-discharging technique to obtain the high voltage multiplication. A spark gap chamber provides a series capacitor discharge path upon triggering of the first spark gap breakdown.

The spark gaps of the generator are enclosed in a pressurized nitrogen atmosphere which allows

the charging voltage to be varied by changing the nitrogen pressure. The inner wall of the pressure vessel is painted with a white reflective coating, providing an optical path which permits the un-

set near the spontaneous breakdown threshold of the first gap, the gap is adjusted so that it breaks down at a slightly lower voltage than the other gaps.

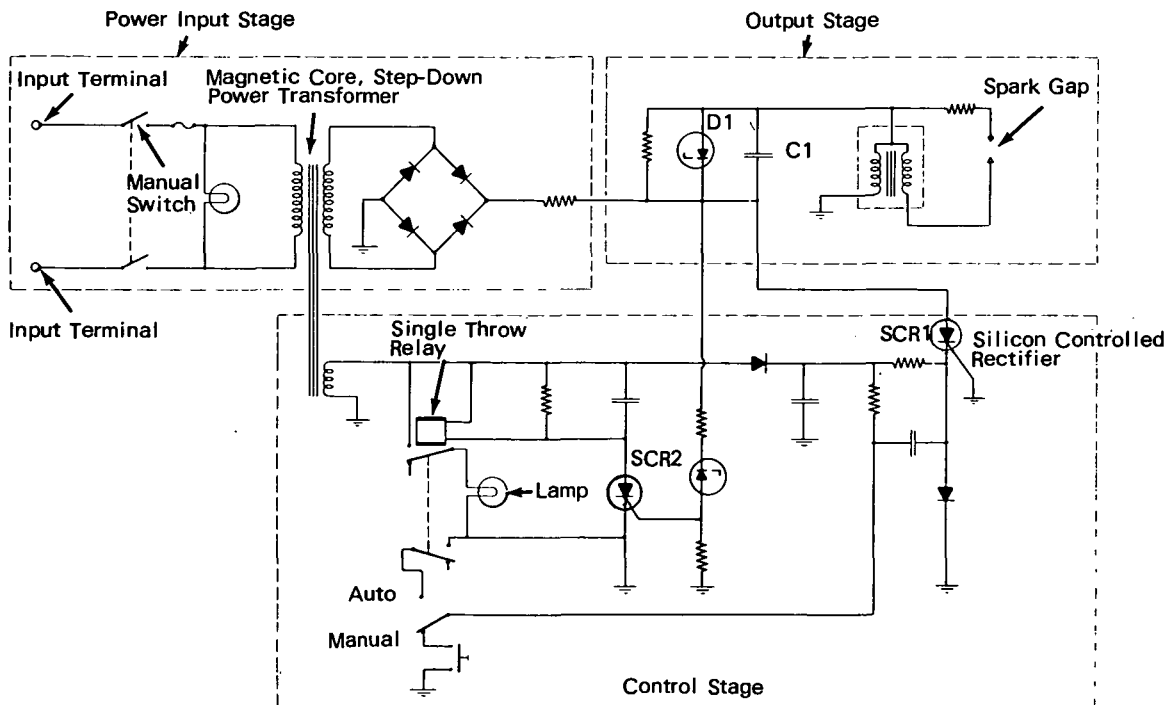


fired gaps to be irradiated with ultraviolet light from the fired gaps. The capacitors are barium titanate cylinders with silver plated ends, and the electrodes are brass hemispheres 11 mm in diameter. To ensure that the operating voltage can be

Source: L. P. Keller and E. G. Walschon
 Argonne National Laboratory
 (ARG-10136)

Circle 5 on Reader Service Card.

HIGH VOLTAGE PULSE GENERATOR PRODUCES FIXED ENERGY PULSE



A unique feature of a new high voltage pulser is an automatic discharge control circuit which operates only when the proper spark-producing voltage is present.

The high voltage pulse generator illustrated in the schematic produces a controlled, high voltage, fixed energy spark. A fixed voltage for the spark discharge is provided by a storage capacitor C1 connected in parallel with a zener diode D1. Discharge of the capacitor through the primary of an output transformer is controlled by a separately powered control circuit which uses a silicon controlled rectifier, SCR1, as a switching device. When the desired capacitor voltage is reached, the zener diode in the control circuit is driven into

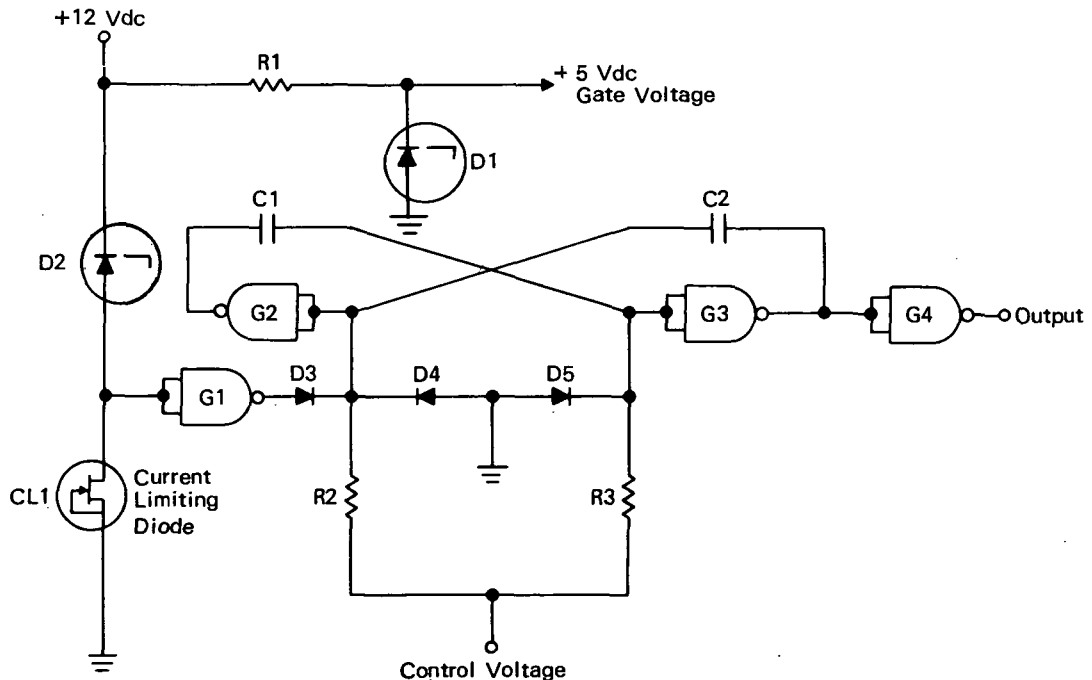
conduction to fire SCR2; this operation activates a relay that energizes a "ready" lamp, indicating the circuit is prepared to deliver a fixed energy spark. The charge circuit is manually fired by closing a switch, or automatically fired by linking the switching mechanism to the relay. After each discharge, SCR1 is automatically commutated by the back EMF of the output transformer, and SCR2 is commutated by the ac input to the control circuit.

Source: D. L. Phippen
Manned Spacecraft Center
(MSC-12178)

Circle 6 on Reader Service Card.

Section 3. Oscillators

LOW POWER, COMPACT, VOLTAGE-CONTROLLED OSCILLATOR



A low power, compact, voltage-controlled oscillator (VCO) has a wide control range, a linear control response, and an output which is compatible with integrated circuitry.

The VCO (see fig.) is designed with an integrated circuit containing NAND gates G1, G2, G3, and

G4. The oscillator has a linear response over the frequency range of 1 to 4 MHz for a control voltage of -1 to -6 V, respectively. The highest frequency design limit with a linear response is approximately 5 MHz. The limiting factor is the propagation delay of the low power logic.

The oscillator section is a bistable multivibrator consisting of G2, G3, D4, D5, R2, R3, C1 and C2. The output is buffered by G4 for fanout purposes to additional circuits. The input network, consisting of G1, D2, D3, and C1, assures that the oscillator will start when power is initially applied, and prevents severe power supply transients from causing the oscillator to "latch up." CL1 is a current-limiting diode used to conserve power.

Voltage regulation for the gates, provided by R1 and zener diode D1, prevents undesirable frequency deviations which would otherwise occur from ripple on the 5 V power supply. Circuit power consumption is 65 mW at 4 MHz, when the control voltage power is a maximum of 11 mW.

Assuming that a 5 V supply would have sufficient regulation to prevent undesirable frequency deviation, R1 and D1 could be eliminated and D2 changed to a 3 V zener. Subsequent power consumption could be reduced to approximately 25 mW, with no change in the control characteristics.

Source: J. A. Exley of
IBM

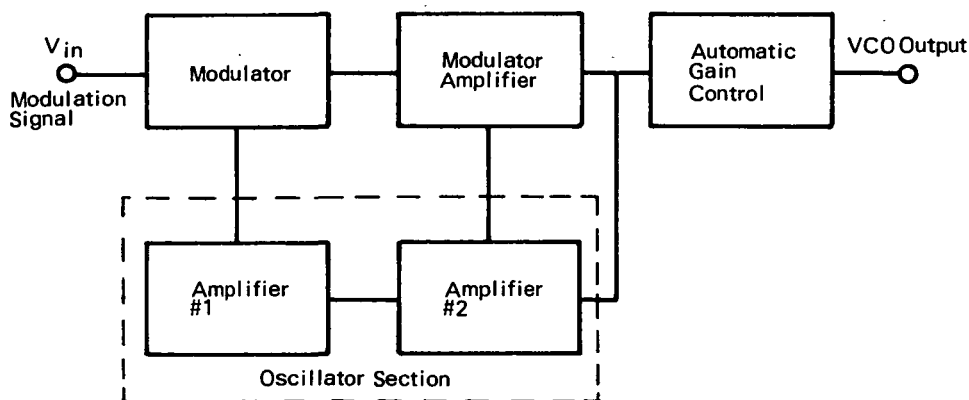
under contract to
Marshall Space Flight Center
(MFS-20136)

Circle 7 on Reader Service Card.

VOLTAGE-CONTROLLED OSCILLATOR

The voltage-controlled oscillator outlined in the block diagram represents a unique approach to the generation of FM subcarriers and FM modulation. The VCO consists of an RC oscillator, a modulator, and an automatic gain-control

constant if the phase shift in the amplifiers is small. The design of the oscillator requires a balanced, high input impedance, differential amplifier with matched transistors that have minimal drift characteristics.



circuit. The basic oscillator is a phase shifter whose output amplitude is always constant regardless of the amount of phase shift. Two of these phase shifters (amplifiers) are connected in series, and the output of the second phase shifter is inverted and fed back to the input to produce the oscillations. The feedback loop-gain is controlled by an AGC circuit so that the amplifiers operate in their linear regions with a low-distortion sine-wave output. The frequency of the oscillator is primarily determined by the value of the RC time

The modulator section generates a current at the oscillator frequency, the magnitude of which is proportional to the modulating signal. The modulator can be considered as an analog multiplier, since its output is the product of an input signal at the oscillator frequency and the magnitude of the modulating signal. The modulator exhibits nonlinear characteristics which serve to negate the opposite nonlinear modulating characteristics of the phase-shift oscillator.

Automatic gain control is accomplished by vary-

ing the resistance in the feedback loop of the oscillator second stage. This resistance is varied by changing the gate potential of a field effect transistor. The AGC amplifier compares the output signal amplitude with a reference voltage and supplies a current pulse.

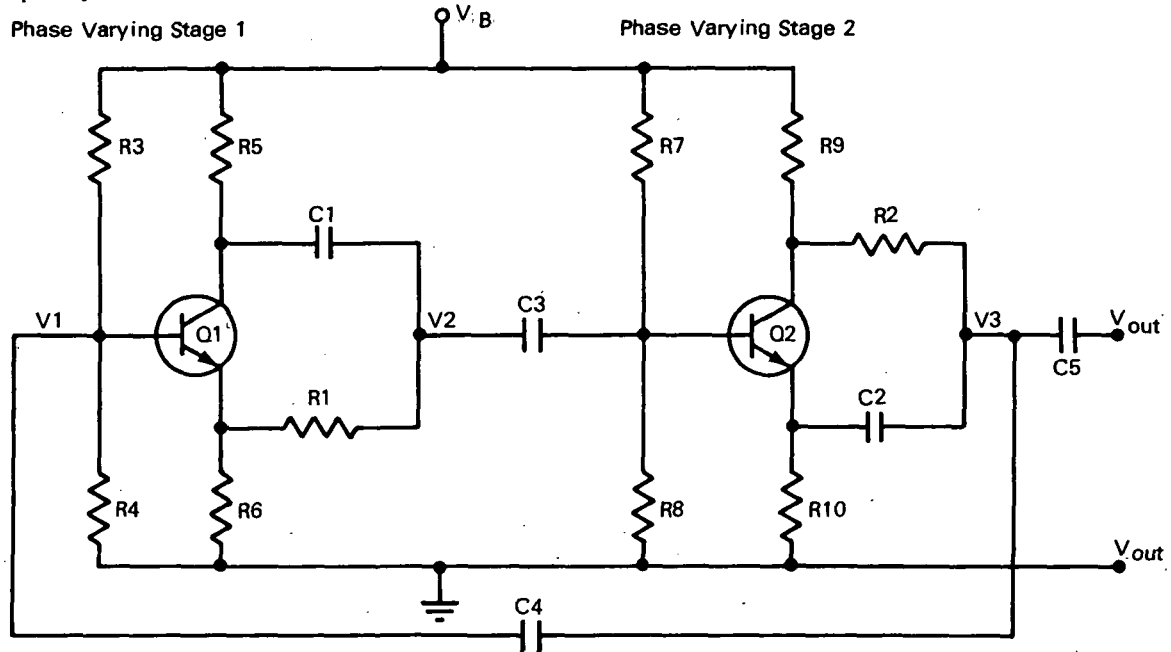
Source: Spacelabs, Inc.
under contract to
Manned Spacecraft Center
(MSC-11707)

Circle 8 on Reader Service Card.

CONSTANT-AMPLITUDE RC OSCILLATOR

A sinusoidal oscillator has a frequency determined by the RC values of two charge control devices, and a constant-amplitude voltage independent of frequency and RC values. RC elements can be selected to provide either voltage control, resistance control, or capacitance control of the frequency.

A variation of the input frequency changes the phase angle but not the amplitude of V2. The first stage provides a positive phase shift from 0 to π radians, depending on the frequency and the values of R1 and C1. The second stage has a phase shift of opposite polarity. Therefore, if the base-to-collector and the base-to-emitter transistor



The basic oscillator circuit has two cascaded phase-varying all-pass stages. As shown in the figure, bias resistors R3, R4, R7 and R8 are chosen in conjunction with load resistors R5, R6, R9 and R10 to operate transistors Q1 and Q2 with input-to-collector and input-to-emitter voltage gains of unity. Resistor R1 and capacitor C1 form one all-pass network, and resistor R2 and capacitor C2 form the second all-pass network. The two stages are shown ac-coupled by capacitors C3 and C4.

voltage gains are unity for each stage, and if coupling capacitors C3 and C4 have negligible reactance compared to capacitors C1 and C2, the circuit will oscillate at a frequency such that the sum of the two phase shifts is equal to zero.

Source: W. J. Kerwin and R. M. Westbrook
Ames Research Center
(ARC-10262)

Circle 9 on Reader Service Card.

A 225 MHz FM OSCILLATOR WITH RESPONSE TO 10 MHz

A frequency-modulated transistor oscillator is designed for use in wideband television transmitters. The oscillator circuit, represented in the schematic, is an LC Colpitts tank-circuit configuration which provides sinusoidal output waveforms, even when excited by a nonsinusoidal input. The circuit also provides a high rate of phase change at the resonant frequency, which has the effect of producing good frequency stability.

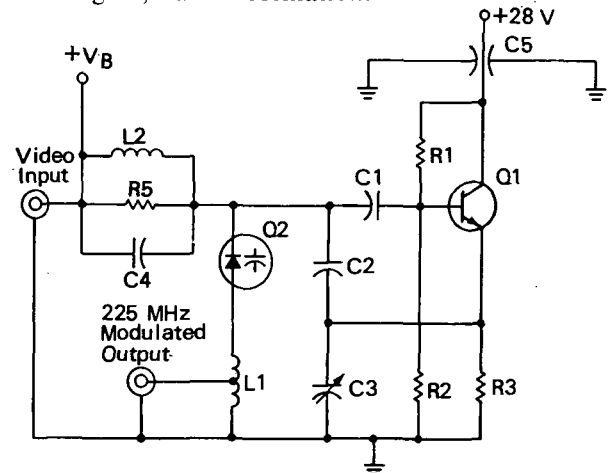
A common-collector configuration for transistor Q1 is used primarily because the collector is internally connected to the case. The combined effects of case capacitance to ground and heat-sink capacitance to ground provide an effective RF ground for the collector.

The varactor Q2 is placed in series with the coil to eliminate the modulation effects that occurred when it was originally placed in a parallel configuration. At high frequencies, there is sufficient internal inductance and lead inductance to cause the varactor to enter the series-resonant mode. If this condition were allowed to exist, a drastic reduction in Q would occur, producing unpredictable modulation response.

The problem of applying the modulation signal and the bias voltage to the varactor is solved by the use of a blocking capacitor C1 and a series-trap tuned to a 225 MHz signal. The trap was de-

signed with a low value Q to avoid undue attenuation of the sidebands through the trap and the video amplifier to ground.

The dc biasing network is conventional, with Q1 biased at 40 mA collector current and V_B at approximately 15 V. This biasing level enables the transistor to operate at a point which produces small-signal, class-A oscillation.

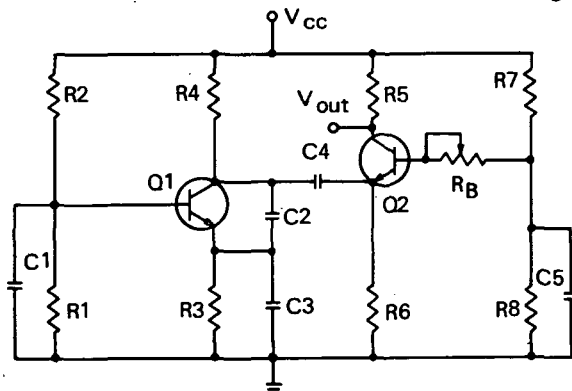


Source: Auburn University under contract to Marshall Space Flight Center (MFS-14977)

Circle 10 on Reader Service Card.

OSCILLATOR USES TRANSISTOR AS INDUCTIVE ELEMENT

An inability to fabricate suitable inductors with present day microminiature component technology places a serious limitation on the design



engineer. A new circuit uses a bipolar transistor Q2, operated in a grounded-base configuration, in place of an inductor. The circuit can be fabricated with either thin-film hybrid or monolithic technology.

The basic oscillator shown in the schematic is a modified Colpitts circuit. Resistors R1, R2, R7, R8, R3, and R6 comprise the biasing networks for transistors Q1 and Q2, while C4, C1, and C5 are bypass capacitors. R4 and R5 are the load resistors for Q1 and Q2. C2 and C3 form the tuning capacitances, and, in conjunction with Q2 (the inductive transistor), form the feedback network. Resistor R_B , a tuning resistor, varies the frequency by changing the equivalent induct-

ance. For crystal control, C1 is replaced by a crystal, and operation takes place at the series-resonant frequency of the crystal. The value of inductive reactance jX_L obtained with this circuit arrangement is

$$jX_L = \frac{jR_B F_T}{F} \left[\frac{1}{1 + \left(\frac{F_T}{F}\right)^2} \right]$$

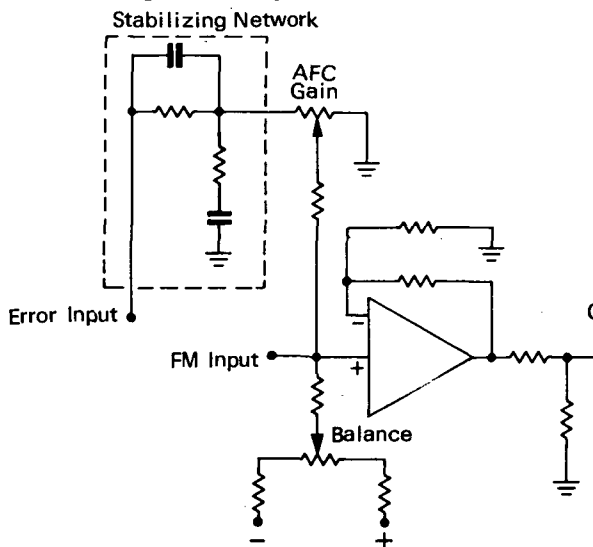
where R_B is the base resistance, F_T is the transitional frequency, and F is the operating frequency.

Source: L. L. Kleinberg
Goddard Space Flight Center
(GSC-10375)

No further documentation is available.

AUTOMATIC FREQUENCY CONTROL OF VOLTAGE-CONTROLLED OSCILLATORS

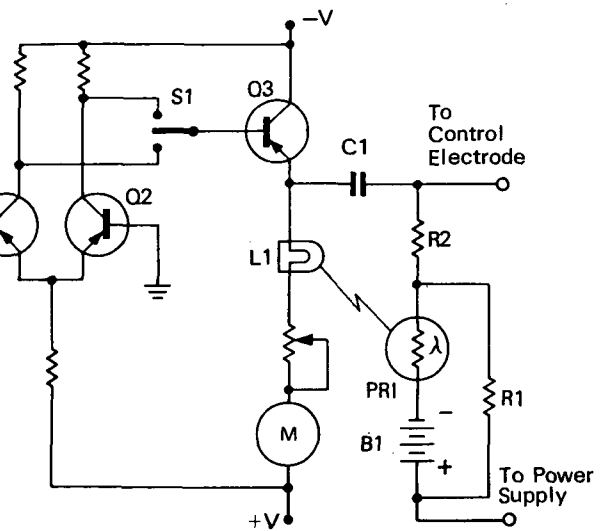
A unique feature of this frequency-control oscillator circuit is the use of optical-capacitive coupling for isolation of the klystron control electrode. The electrode voltage is controlled by a voltage-divider photoresistor whose value



approximates the potential of the control electrode. This circuit can be used for controlling the frequency of laboratory oscillators and for stabilizing the pump frequencies of parametric amplifiers.

The circuit shown in the figure is designed to stabilize the frequency of an S-band reflex klystron. The error input, derived from a discriminator which compares the klystron frequency with a harmonic of a stable crystal oscillator, is applied to a stabilizing, lead-lag network and then amplified with an operational amplifier. Transistors Q1 and Q2 form an emitter-coupled differen-

tial pair for phase inversion of the amplified signal, without shifting the base operating point of Q3. Q3 drives the lamp L1 and the coupling capacitor C1. The meter indicates the lamp current and acts as an error indicator. The increase in the current through the lamp decreases the resistance of the photoresistor PR1 and changes the voltage of the control electrode. Because the lamp has a relatively long time constant, the coupling capaci-



tor is used to transfer the high frequency components of the error signal.

Source: R. B. Kolbly of
Caltech/JPL
under contract to
NASA Pasadena Office
(NPO-11064)

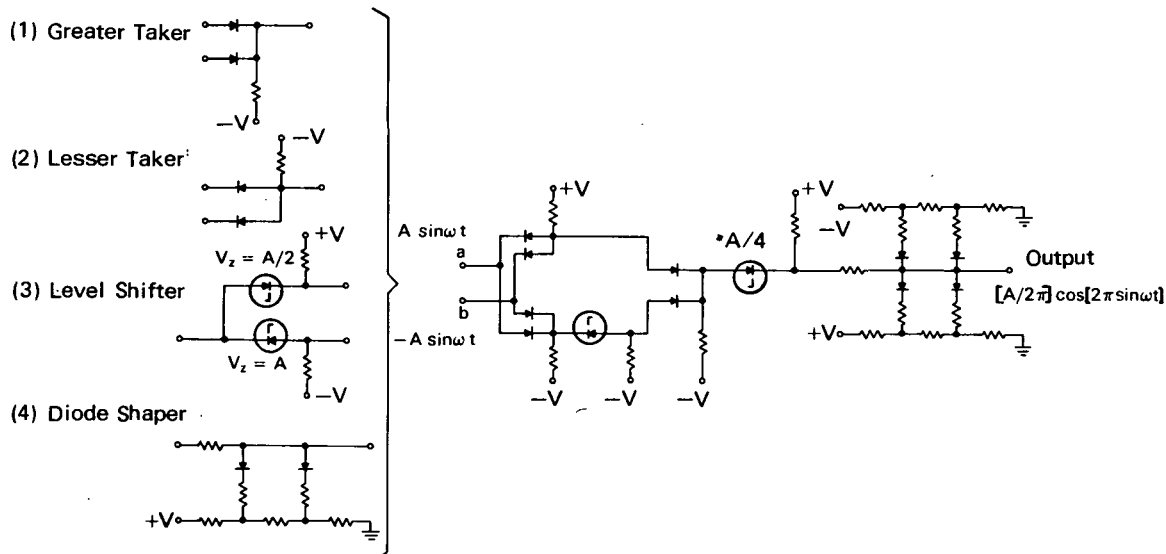
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Section 4. Analog Signal Generators

CIRCUIT GENERATES COMPLEX WAVEFORMS

A diode generator electronically produces the complex waveforms of $\sin(2\pi \sin \omega t)$ and $\cos(2\pi \sin \omega t)$ without using series summation. Four circuits alter the input signals in the

The four basic circuits can be connected in a variety of ways to produce the same waveform. They have sufficient flexibility to permit eliminating several resistors, replacing diodes



following manner: #1 takes the greater part of both input signals; #2 takes the lesser part of both signals; #3 splits the positive input into a positive and negative signal of the same wave-shape (level shifter); and #4 rounds off the positive input (diode shaper). For example, the circuit diagram shows the development of $\cos(2\pi \sin \omega t)$. The circuits are so connected that the characteristic input waveshapes of $A \sin \omega t$ at point "a" and $-A \sin \omega t$ at point "b" are modified sequentially by each circuit, resulting in an output waveform that very closely approximates the desired function.

by emitter-follower transistor configurations, and varying the number of components in the diode-shaper, depending on the particular application of the generator.

Many functions other than those indicated here can be implemented by an empirical synthesis of the same building-block circuits.

Source: D. Mead, A. J. McCall, and
J. D. Callan of
Hughes Aircraft Co.
under contract to
Goddard Space Flight Center
(GSC-214)

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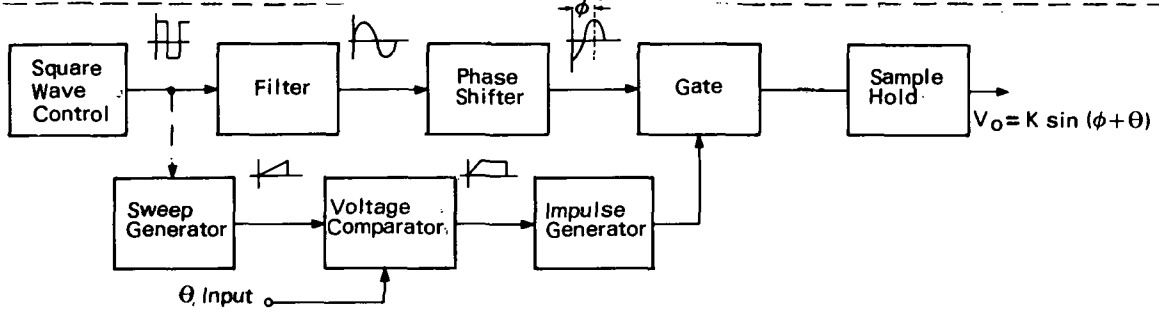
SINE FUNCTION GENERATOR

A new sine function generator (see fig.) produces an output signal whose magnitude is proportional to the trigonometric sine of a

given angle, plus or minus a fixed-phase angle. A novel circuit samples the magnitude of a sine wave at a point in its period determined by

the magnitude of the input signal. The output of a square-wave generator is filtered in order to generate a sine wave of the same frequency as the square wave. Simultaneously, the square

until the next sample is taken. The synchronism control determines the frequency of sampling, which is designed for the anticipated maximum rate of change of the input θ , and may be as



wave is used to synchronize a sawtooth sweep generator. The synchronized sweep signal is applied to a voltage comparator which compares this input with a voltage that is linearly proportional to a second input, θ .

When the value of θ is equal to the magnitude of the sweep voltage, the output of the voltage comparator drives the impulse generator, which in turn opens an electronic gate for a short interval. The sine wave obtained from the filter is phase shifted through a predetermined angle ϕ by the phase shifter and is passed through the gate when the impulse generator signal is applied. Thus, an impulse whose magnitude is proportional to $\sin(\theta + \phi)$ is applied to the sample hold. This sample is the output voltage, $V_o = K \sin(\theta + \phi)$, which is maintained

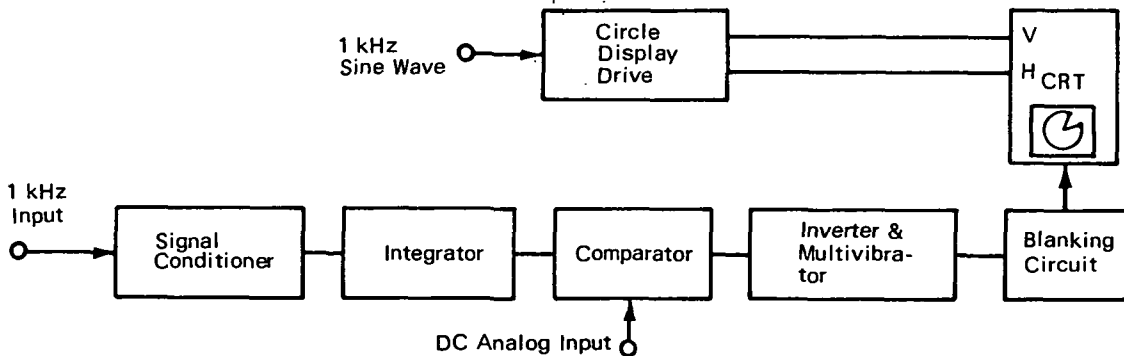
great as the fundamental frequency of the square wave. The greater the sampling rate, the more accurately the output will represent $K \sin(\theta + \phi)$ as θ varies with time.

The static accuracy is not limited by the resolution (number of turns) of a nonlinear potentiometer, such as those used in mechanical systems, nor does the overall accuracy depend on the length of the interval over which it is generated.

Source: T. Bogart, Jr. of North American Rockwell Corp. under contract to Manned Spacecraft Center (MSC-00255)

Circle 13 on Reader Service Card.

CIRCLE-NOTCH GENERATOR CIRCUIT



A novel circuit generates a blanking signal which discontinues a small segment of the circle line on a cathode ray tube (CRT) display. In

order to accomplish this, a clock pulse is conditioned and fed into an integrator that produces a negative ramp output. A positive dc analog

input is compared with the ramp output by a comparator whose output pulse is a function of time. The comparator output is inverted and conditioned through a one-shot multivibrator for an adjustable pulse output.

A circle is displayed on the CRT by applying a clock-controlled sinusoidal signal on the vertical and horizontal deflection circuits. Since the periods of the ramp and the sine wave are the same, each ramp is equal to 2π rad of a circle and the ramp amplitude becomes a function of radians. Calibrating the ramp amplitude and the dc analog input in volt/radian enables

the comparator to establish the point of the period for a corresponding radian. The one-shot multivibrator accepts this varying signal and generates an adjustable pulse width equal to the number of radians that are blanked out on the circle.

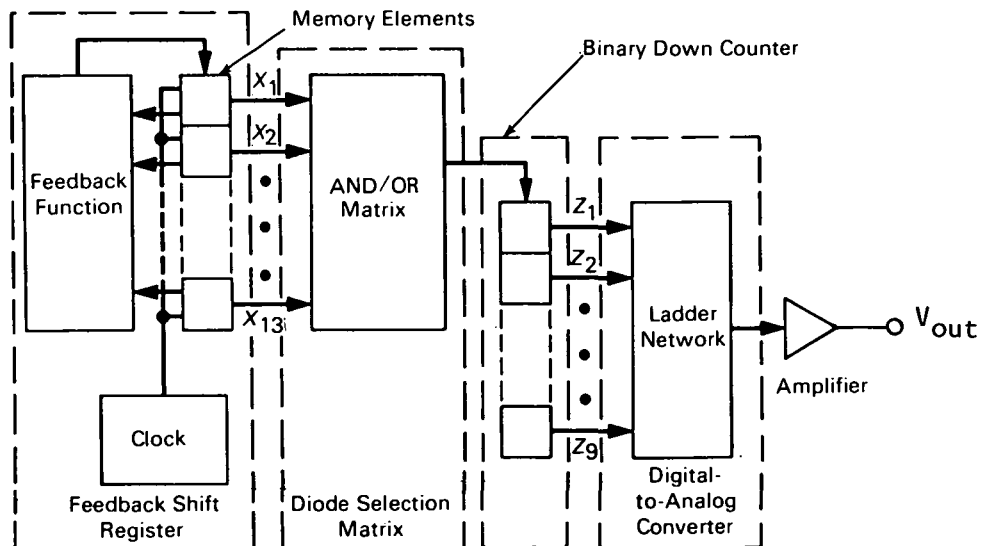
Source: O. Hayakawa of
North American Rockwell Corp.
under contract to
Manned Spacecraft Center
(MSC-15846)

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DIGITAL-VOLTAGE CURVE GENERATOR

A curve generator produces an easily controlled, precisely repeatable curve for any single-valued function of voltage versus time. The curve generator (see fig.) consists of a clocked, feedback shift-register; a large-scale, integrated-circuit diode matrix; a counter; and a digital-to-analog converter.

ates designated output states in accordance with a feedback function. Entries in this matrix are the selected states of the shift register which decrease the output of the counter. Successive states appear for a fixed duration of time, whereas selected states are separated in time in accordance with the desired curve.



Equal changes of voltage, sufficiently small in value and number to reflect small changes in the curve, are held for varying time durations in accordance with the desired shape of the curve.

Time is quantized by the feedback shift register and the diode selection matrix, which gener-

ates designated output states in accordance with a feedback function. The purpose of this matrix is to convert the non-weighted code of the feedback shift register to a series of nonuniformly spaced time pulses. The output of the matrix decreases the output of the binary down counter, for example, to

produce a monotonically decreasing function. The output of the binary counter is applied to a digital-to-analog converter in order to derive an analog equivalent of the binary signals. An analog output amplifier is used to set the operating levels over which the curve will vary.

Source: M. Perlman of Caltech/JPL under contract to NASA Pasadena Office (NPO-11104)

Circle 15 on Reader Service Card.

Section 5. Square Wave Signal Generators

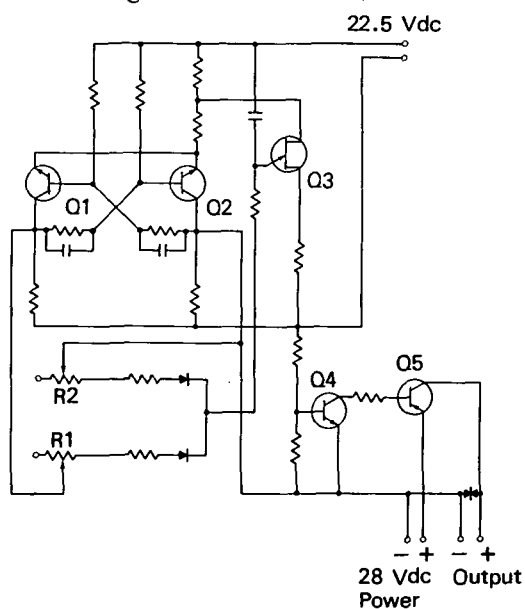
VARIABLE PULSE GENERATOR SWITCH

The variable pulse generator delivers square wave pulses of 28 Vdc to operate conventional solenoid valves. The pulse width is adjustable over the range of 10 to 40 msec, and the interval

between pulses is adjustable from 8 to 350 msec. The complete circuit consists of a solid state flip-flop (Q1 and Q2), a triggering unijunction transistor Q3, and output amplifiers Q4 and Q5. The pulse-forming circuit is powered by an independent 22.5 V battery, and is assembled from readily available components. Pulse width is controlled by adjusting a 100 k Ω potentiometer R1 ("On Time"); the interval between pulses ("Off Time") is similarly controlled by a 500 k Ω potentiometer R2.

This circuit can be used in hydraulic and pneumatic flow-control systems where critical flow timing is required. It can be used for single-flow operations or, with a suitable arrangement of relays, as a closely sequenced, multiple-flow control.

Source: J. D. Gillett of North American Rockwell Corp. under contract to Marshall Space Flight Center (MFS-91895)



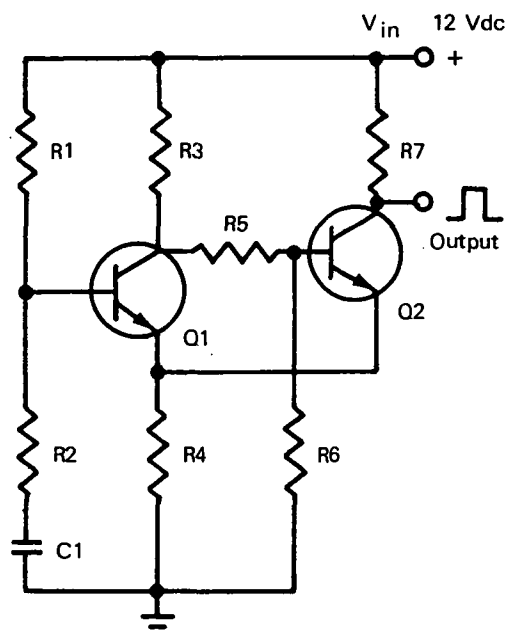
Circle 16 on Reader Service Card.

SQUARE WAVE GENERATOR FOR HIGH FREQUENCY APPLICATIONS

A new pulse generator provides high frequency operation and good stability. Only two components govern the frequency, and only one component determines the pulse width control.

Ease in changing the frequency and pulse width makes this pulse generator (see fig.) well suited for remote electronic control operations.

The circuit operation begins with Q2 in con-



duction and Q1 out of conduction. (Q1 is held out of conduction by the voltage drop across R4). When the charge on capacitor C1 reaches a sufficient voltage to turn on Q1, Q2 is turned off by the reduced current through R5. The voltage drop across R4, resulting from current flow through Q1, further biases Q2 out of conduction. Under these conditions, the input impedance of Q1 drops sufficiently to discharge C1 through R2, Q1, and R4. Q1 then goes out of conduction, Q2 goes into conduction, and the cycle is repeated.

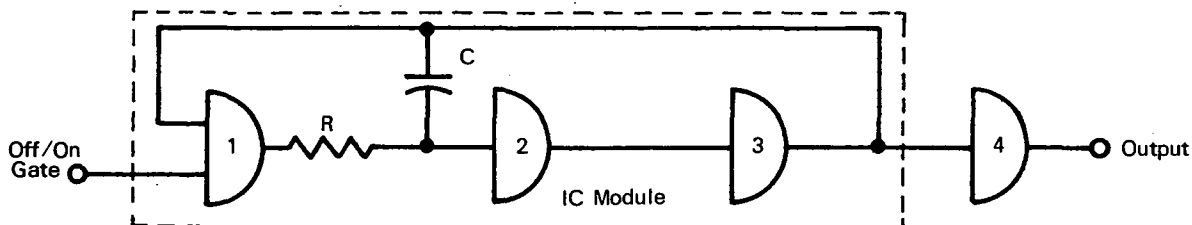
Source: E. R. Quinn, F. E. Downs, and R. D. Lynch of Lockheed Electronics Co. under contract to Manned Spacecraft Center (MSC-91061)

Circle 17 on Reader Service Card.

SQUARE WAVE GENERATOR HAS VARIABLE DUTY CYCLE

A square wave oscillator circuit, constructed with an integrated circuit "AND" gate module, a resistor, and a capacitor, provides an output with a frequency range from 1 Hz to greater

while module 4 is a pulse-shaping circuit. Module 1 provides a π rad phase shift and is used to gate the oscillator on and off. Modules 2 and 3 are operated as high-gain amplifiers,



than 1 MHz. The oscillator can be used to generate clock pulses for any electric circuit requiring a square wave pulse with stability of $5 \times 10^{-4}/K$. The oscillating pulses can be synchronously gated on and off without any additional circuitry.

The components of the oscillator, shown in the block diagram, can be integrated onto a single chip. This form of circuit fabrication improves temperature stability, since the RC combination is an integral part of the circuit module.

Modules 1, 2, and 3 are part of the IC module,

with R as the input resistance and C in the feedback loop.

The frequency of the "AND" gate oscillator is easily adjusted throughout the wide frequency range by selecting the proper RC combinations. In addition, the gated oscillator can be gated on and off with a control pulse. The oscillator's waveform is synchronous with the starting edge of the control pulse.

Source: W. H. Miller
Goddard Space Flight Center
(GSC-10836)

Circle 18 on Reader Service Card.

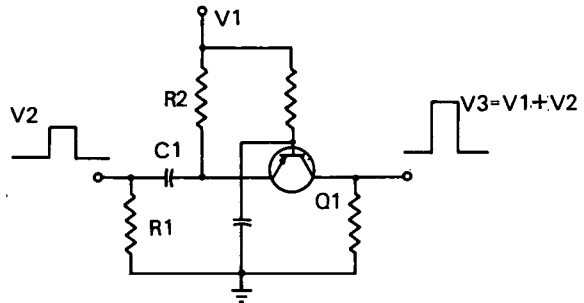
SINGLE TRANSISTOR CIRCUIT BOOSTS PULSE AMPLITUDE

A simple circuit provides a voltage pulse greater than that normally available from emitter-follower circuits to drive a 100 W transmitter. Capacitor storage, followed by common-base switching, is accomplished with only one transistor.

During circuit operation, capacitor C1 (see fig.) is charged through R1 and R2 to the supply line voltage V1. With no input pulse, both the emitter and base of the transistor are at the same potential and the collector is cut off. With an input pulse V2 present, the potential of C1 with respect to ground is increased by V2. The emitter becomes more positive than the base, and the transistor is switched on. This action produces an output pulse, V3, equal to V1 + V2 (minus small losses in C1 and the transistor.)

In order for C1 to reach approximate full charge between pulses, the ratio of charging interval to charging time-constant must be much

greater than the ratio of discharge interval to discharge time-constant. The circuit produces an output waveform at about twice the amplitude of the supply line voltage V1.



Source: M. W. Matchett and T. Keon of Cutler Hammer under contract to Goddard Space Flight Center (GSC-501)

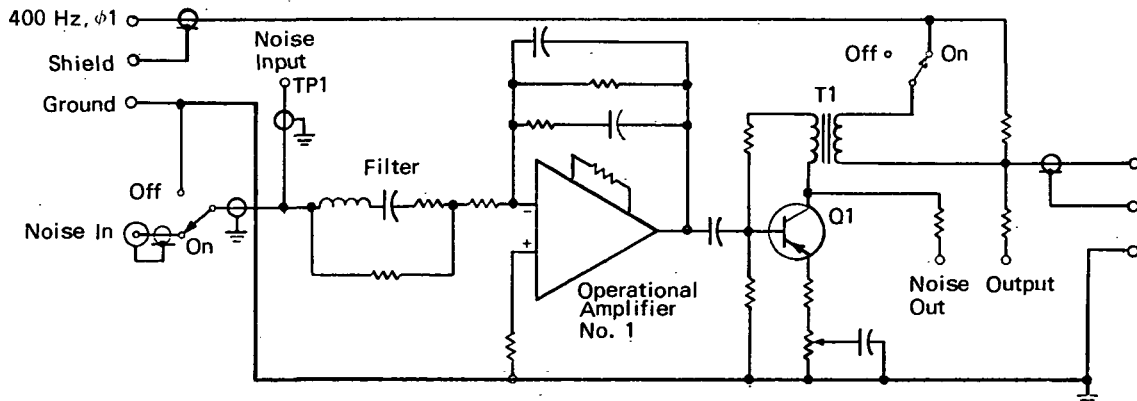
Circle 19 on Reader Service Card.

Section 6. Special Function Signal Generators

400 Hz NOISE GENERATOR

The noise-adder circuit shown in the schematic conditions and amplifies noise from a random noise generator and adds it, in series, to two

applied to two operational amplifiers through separate input filters (one section is shown in the figure). The combination of the input filters and



phases of a power source that supplies a magnetic tape recorder.

Noise from a random noise generator is

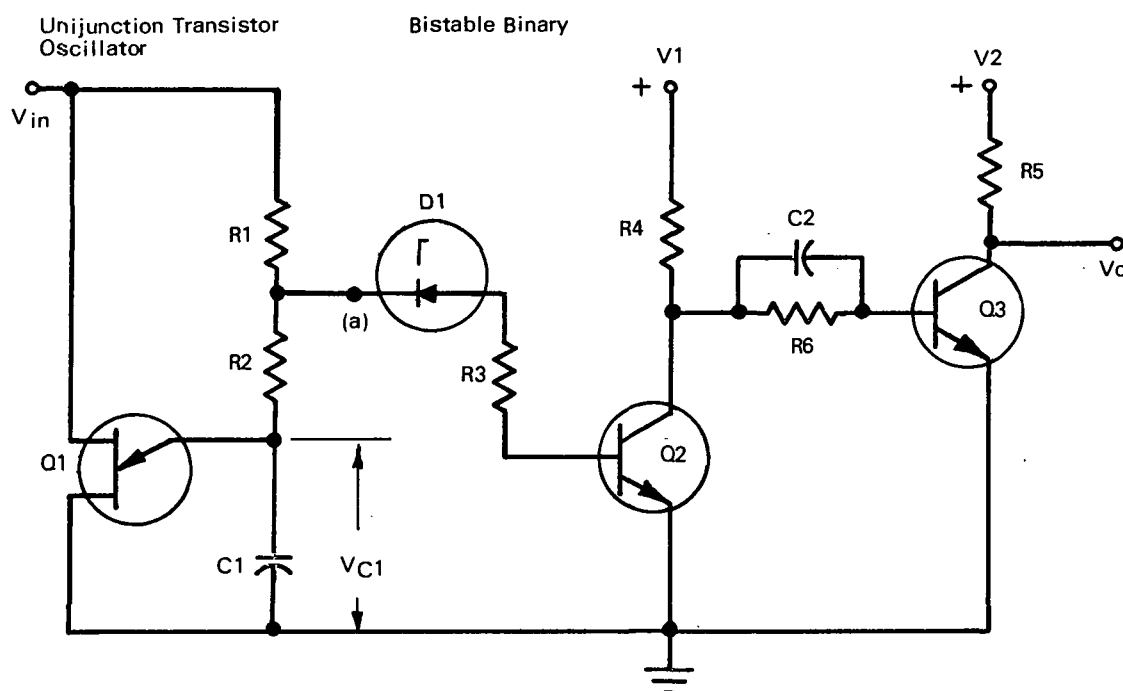
the operational amplifier circuits increases the low-frequency response of the adder circuits, providing an overall pass band (flat within 3 dB)

of 2.3 kHz to 1.3 MHz for the noise. The noise is amplified to a level of 20 dBm and added in series with both phases of the 2-phase, 400 Hz power source across load resistors; these resistors provide the required 250 Ω output impedance of the power source. This circuit can be used whenever controlled noise must be introduced into a low impedance power source.

Source: O. Hergenhan, G. A. Cutsogeorge, and E. W. Dusio of Radio Corp. of America under contract to Goddard Space Flight Center (GSC-10944)

No further documentation is available.

CONSTANT FREQUENCY, VOLTAGE-TO-DUTY-CYCLE GENERATOR



The characteristics of a unijunction transistor oscillator and those of a bistable binary have been combined in a very simple circuit to produce a constant-frequency voltage-to-duty-cycle generator. With its capability of producing duty cycles from zero to unity, this generator should be very useful in applications involving efficient regulation of dc converters supplied by widely varying voltages. Important advantages of this generator are its simple structure and its very low power consumption, especially if a unijunction transistor with very low leakage current is used.

When the unijunction transistor Q1 (see fig.)

is fired, capacitor C1 discharges to zero volts. The base current required to turn Q2 on is negligible compared to the current in R1, and the voltage drops across R3 as well as the base-emitter junction of Q2 are negligible compared to the breakdown voltage of the zener diode D1.

Whenever the level of the voltage at point "a" is below that of V_{ZD} , Q2 is cut off, since no current is supplied to its base. Simultaneously, base current for Q3 is provided via R4 and R6, Q3 is turned on, and V_o becomes zero. However, when the level of the voltage at "a" equals or exceeds V_{ZD} , base current is provided for Q2, causing it to turn on. Q3, which is re-

verse biased by the voltage across speed-up capacitor C2, is turned off, and the voltage level rises to V2. If the input voltage is not too low, the frequency of oscillation, which is mainly a function of the product $(R1 + R2) \times C1$, is relatively constant.

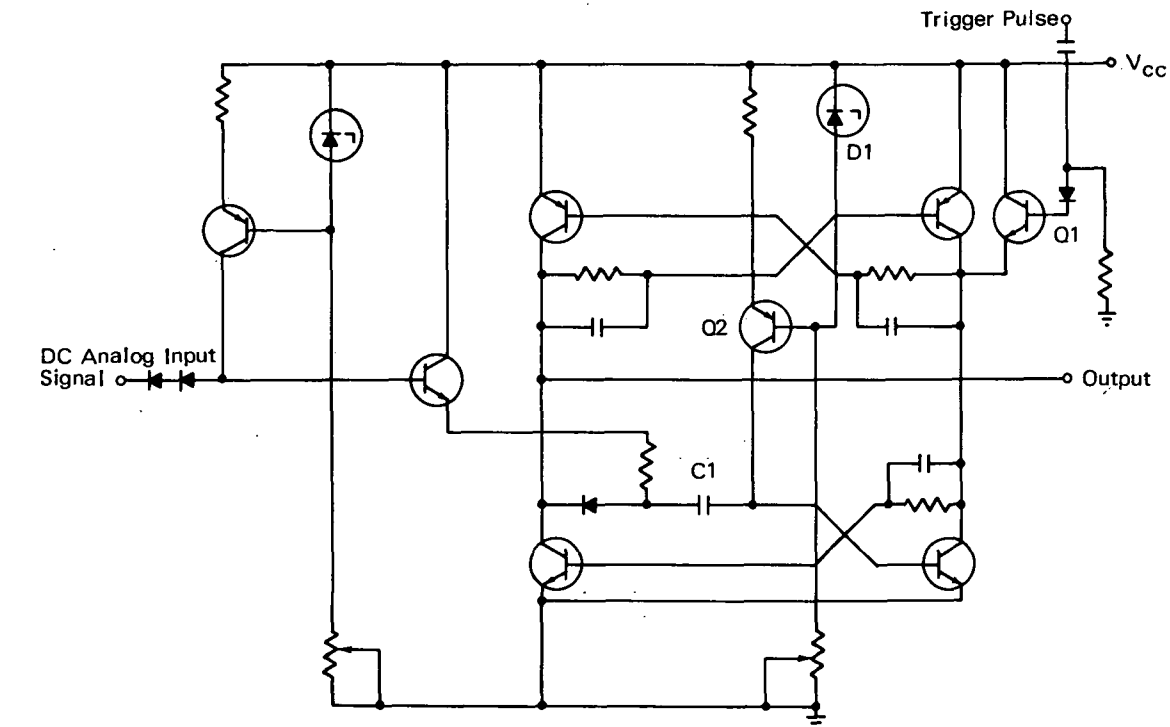
Source: I.M.H. Babaa of
Duke University
under contract to
NASA Headquarters
(HQN-10070)

Circle 20 on Reader Service Card.

LINEAR DC ANALOG VOLTAGE-TO-PULSE WIDTH CONVERTER

This circuit converts a dc analog input signal to an output pulse whose width is proportional to the input signal voltage. The circuit represents an improvement over previous pulse-

width converters with regard to design simplicity, efficiency, linearity, accuracy, and temperature stability. It would be particularly useful as an analog-to-digital converter where low power, ruggedness, reliability, and good linearity are prime requirements.



width converters with regard to design simplicity, efficiency, linearity, accuracy, and temperature stability. It would be particularly useful as an analog-to-digital converter where low power, ruggedness, reliability, and good linearity are prime requirements.

The converter (see fig.) consists of a complementary, monostable flip-flop controlled by the constant-current discharge of the temperature compensated capacitor C1. This capacitor

is charged by the analog input signal and discharged through the constant-current generator Q2 and D1 when a pulse is applied to Q1. The complementary flip-flop operates for one complete cycle with a period (pulse width) proportional to the dc analog input voltage. The linearity of this circuit is relatively independent of temperature variations over a range from 253 to 343 K (-20° to 70° C). Its power drain is less than 100 mW.

Source: W. R. Crockett
Goddard Space Flight Center
(GSC-556)

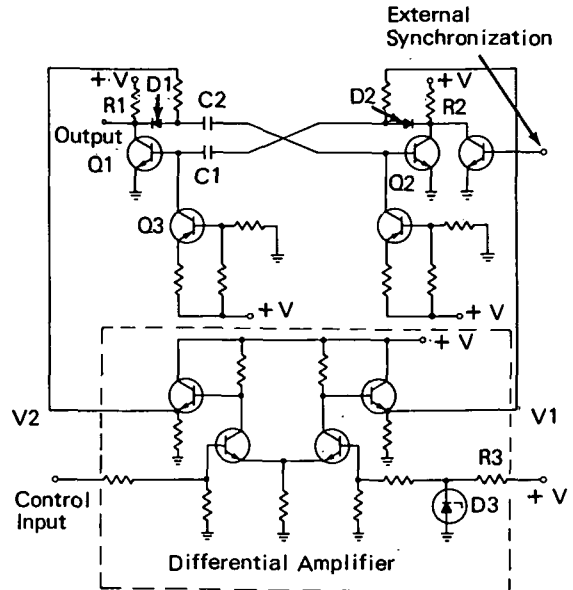
Circle 21 on Reader Service Card.

CONSTANT-FREQUENCY, VARIABLE DUTY CYCLE MULTIVIBRATOR

A constant-frequency pulse source has a duty cycle that can be adjusted by an external input signal. Applications of this pulse source include a switching-mode voltage regulator and a switching source for control systems. The circuit can also be used as a pulse-duration modulator.

In normal circuit operation, transistor Q2 is on and capacitor C1 is charged to potential V1. With Q2 on, V1 is applied to the base of Q1, turning it off. The current source, formed by Q3 and its bias resistors, causes this potential to increase linearly with time.

Since V1 and V2 are derived from the differential amplifier, the sum, $V1 + V2$, is constant. Thus, the frequency of operation is constant, but the duty cycle (or equivalently, the off-time of Q1) is a linear function of V1. V1 is a linear function of the control input signal. The duty cycle can be controlled at a constant frequency. Diodes D1 and D2 serve to decouple the charging of C1 and C2 from the positive supply. R3 and D3 provide a reference input so that the duty cycle is a function of the difference between the control input and the reference voltage of D3.



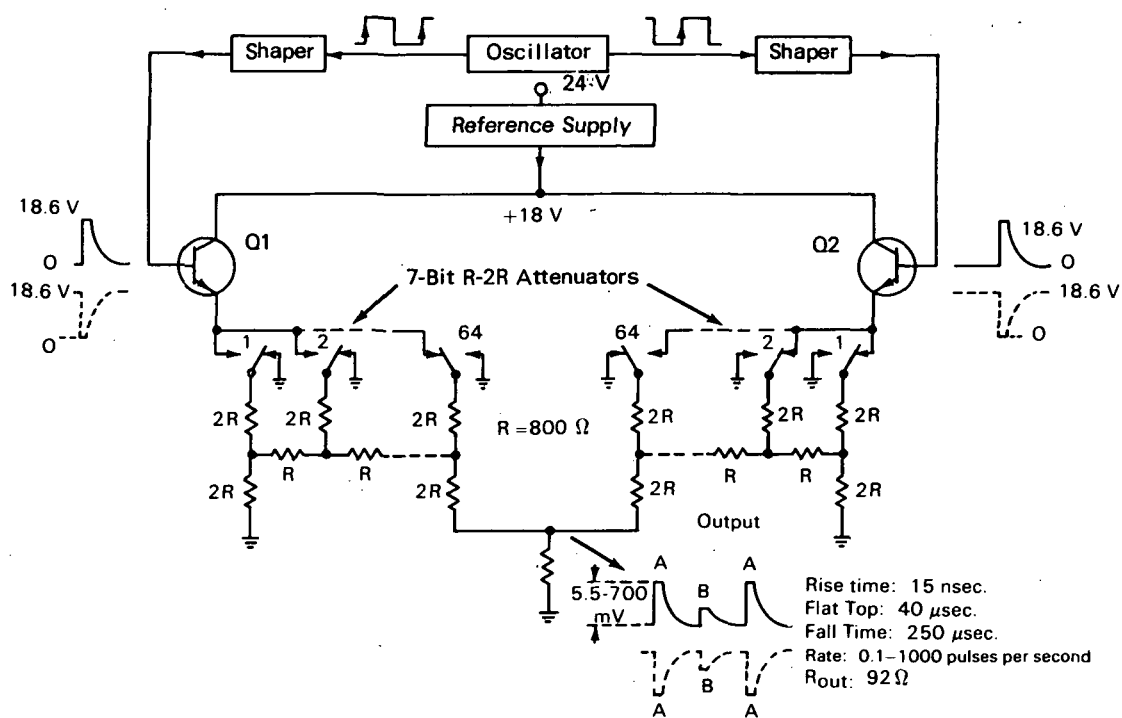
Source: J. E. Johnson of
University of Michigan
under contract to
Goddard Space Flight Center
(XGS-10033)

No further documentation is available.

ULTRASTABLE REFERENCE PULSE GENERATOR FOR HIGH-RESOLUTION SPECTROMETERS

A solid-state, double-pulse generator has a pulse amplitude-temperature coefficient of 0 to 8 ppm/K. The pulser generates signals that rise in 15 nsec, remain flat-topped for 40 μ sec, and then fall exponentially to the baseline in 250 μ sec. The pulse rate can be varied from 0.1 to 1000 pulses per second in nine steps; and the amplitude of the two pulses can be set independently, from 5.5 to 700 mV, by use of a seven-bit, precision, R-2R attenuator. The circuit of the pulse generator includes an oscillator, followed by a flip-flop that generates two square waves π rad out of phase. After the signal is applied to pulse shapers, the outputs of the shapers are applied to emitter followers that are normally "off." (For negative

outputs, they are normally "on.") The emitter followers alternately saturate and then return exponentially to their initial condition. The 18 V emitter signals are attenuated by a 7-bit ladder and mixed at the output across a 100 Ω resistor to produce the proper waveform. Since the temperature coefficient is only 2 ppm/K, the power has no appreciable effect on the stability of the output pulses. The attenuator also has only a second-order effect on the stability of the output pulses. The variations in saturation voltage due to fluctuations of temperature and base drive are quite small compared with 18 V. Thus, instead of producing the low-level signals directly, the 18 V pulses are generated and subsequently attenuated to



the desired millivolt level, thereby reducing the instability of the output signals by a factor which ranges from 25 to 3300. This reduction is the basic concept underlying the stability of the pulser.

Source: M. G. Strauss, L. L. Sifter,
 F. R. Lenkszus, and R. Brenner
 Argonne National Laboratory
 (ARG-10364)

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