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TEMPERATURE-STABILIZED TRANSISTOR MULTIVIBRATOR

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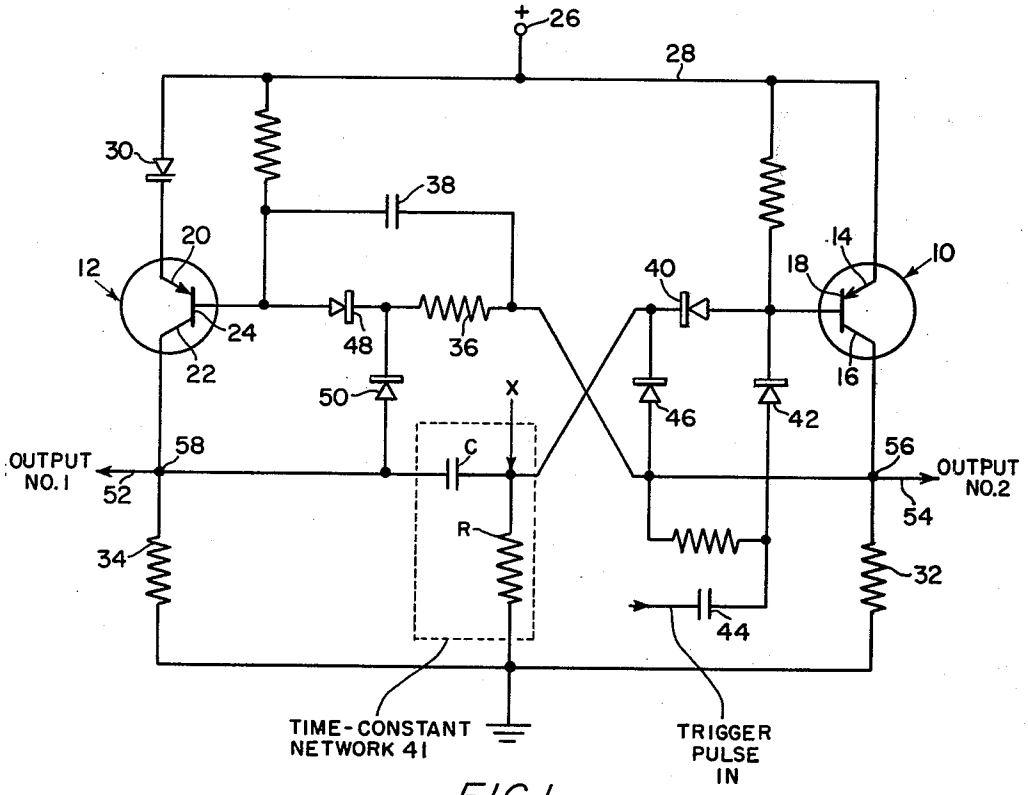

FIG. 1

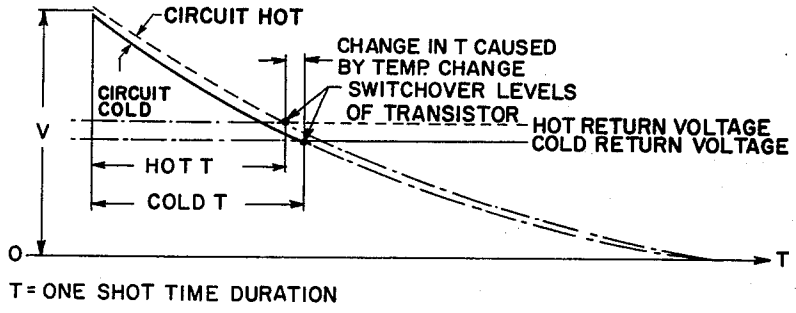

FIG. 2

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TEMPERATURE-STABILIZED TRANSISTOR MULTIVIBRATOR

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1 Claim. (Cl. 307—88.5)

The present invention relates in general to trigger circuits of the relaxation type, and more particularly to a monostable multivibrator incorporating means for precluding any drift in operating frequency when the ambient temperature of the network undergoes an appreciable variation.

A multivibrator circuit is essentially a relaxation oscillator which may be arranged to be "free-running" at a given frequency. It may also be "monostable," or triggered by the reception of regularly-recurring pulses, so that it undergoes a complete cycle of operation in response to the reception of a single such triggering pulse, and then remains in its original condition until triggered by the next succeeding pulse of the series. In its "bistable" form it requires a triggering pulse to effect each change from one of its stable conditions to the other.

Multivibrator circuits may incorporate electron-discharge devices in the form of vacuum tubes. In one arrangement of this type, the grids and anodes of a pair of tubes are mutually interconnected, the circuit arrangement being such that a single output pulse is generated following the application of a trigger voltage variation to the circuit. The duration of the output pulse in such a system is predetermined in accordance with the constants of a timing network, usually of the R-C (resistance-capacitance) type, which is normally inserted between the anode of the first tube and the grid of the second tube. In this design, the first tube is normally cut off and the second tube is normally conducting. A trigger pulse reverses this condition, so that the second tube conducts for a period determined by the time constant of the R-C network.

It is also known to substitute for the vacuum tubes of prior arrangements semiconducting devices such as transistors. One form of multivibrator designed to include such devices incorporates a pair of transistors, of the same conductivity type, having their collector and base electrodes intercoupled. In a manner similar to the tube circuit above discussed, the transistor arrangement is such that an output pulse is generated following the application of a trigger voltage excursion to the system. The duration of this output pulse is again predetermined by a timing network which is inserted in the path which couples the collector electrode of the first transistor to the base electrode of the second transistor. It is a characteristic of such designs that the discharge period of the timing circuit is relatively short, and that the charge interval is maintained essentially constant. For multivibrator circuits employing vacuum tubes, these requirements are generally obtainable without difficulty, since vacuum tubes as a class possess a relatively high stability. Stable operation of a transistorized multivibrator, however, is not readily attained.

Briefly, this condition may be understood when the sequence of operation of a transistor multivibrator circuit

is analyzed. This action is characterized by a rapid cumulative swing from one extreme of current and potential conditions to another, being limited at one end of the swing by cutoff of the transistor and at the other end of swing by its saturation. In the intermediate portion of this swing, the transistor acts in a manner which may be compared to that of a linear amplifier, and hence can respond readily to control influences. However, at the saturation-limited extreme of each cycle, the transistor becomes "sluggish," or less readily responsive. In other words, once the transistor has reached a condition of saturation, a certain time period is required to recondition it for linear operation during the next succeeding swing interval. It will thus be apparent that this sluggishness of a saturated transistor becomes a limiting factor in determining the speed of operation of the trigger circuit as a whole. It is believed that this characteristic of a transistor is due to an excess of minority carriers in the body of the semiconductor. Expressed differently, it is theorized that when a transistor is driven to saturation, minority carrier storage delay is introduced, with consequent pulse widening and reduction in the maximum repetition rate at which the circuit may be driven.

It has previously been proposed to avoid these undesirable effects by including in the multivibrator circuit one or more threshold-responsive devices suitably connected and suitably adjusted to change the condition of the transistor at a potential which is short of its saturation level. The latter is thereby permitted to remain continually in a condition of linear operation, since its swing is now terminated not by alteration of the transistor conditions themselves, but instead by alteration of the response of this threshold device.

One particularly suitable form of threshold-responsive device is a junction diode. When a number of such diodes are employed in a transistorized multivibrator, it is possible to limit the transistor swing at both extremes so as to avoid operation both at its cutoff and at its saturation. This type of operation, utilizing "clamping," is usually accomplished by the insertion of a germanium diode with a low forward-voltage drop between the collector and the base electrode of each transistor, and a further silicon diode between the base and the transistor emitter electrode. The effect of this "clamping" arrangement is that each transistor operates only over an essentially linear portion of its transfer characteristic, and hence the fidelity of the output wave form is greatly enhanced by comparison with arrangements in which the transistors are driven both to saturation and to cutoff.

While circuits of the above type yield satisfactory results in a majority of situations, they possess one undesirable characteristic when extremely precise responses are necessary such, for example, as in certain forms of television systems and in devices for telemetering information to a central point from a moving object such as a guided missile. When so employed, distortion of the output wave form may occur when the ambient temperature of the multivibrator circuit undergoes any appreciable changes. This is a result of variations in the potential appearing on the transistor collector electrode when the temperature-dependent cutoff current changes. This change in collector potential not only increases (or decreases) the time period of each operating cycle, but furthermore causes erratic operation of any succeeding

multivibrator stages which may form part of the over-all system.

At the present time, such circuit instability is compensated for by the use of rather complex and costly pulse-shaping networks and/or delay lines. It is a principal feature of the present invention to eliminate the need for such additional equipment by introducing into the basic transistor multivibrator circuit means which compensates for ambient temperature variations over a wide range and thus prevents any output frequency variations which would otherwise develop as a function of these temperature changes. In a preferred embodiment, the present concept makes use of a threshold-responsive device, such as a silicon diode, connected in the emitter circuit of one of the transistors of the multivibrator. A second silicon diode is connected to the emitter-base junction of the other transistor of the multivibrator. The arrangement is such that, when the ambient temperature varies, a change in voltage is developed across one of these diodes, while a corresponding change in voltage is developed across the remaining diode. However, due to their mode of interconnection in the multivibrator circuit, these voltage changes have an opposite effect upon the operating frequency of the system, in effect balancing out or compensating for one another. The result is that the period of each operating cycle remains unchanged, with both the frequency of operation of the multivibrator as well as the shape of its output wave form being held constant.

One objection of the present invention, therefore, is to provide an improved form of transistorized multivibrator which is relatively insensitive to changes in ambient temperature.

Another object of the present invention is to provide an improved form of transistorized multivibrator particularly suitable for use where output pulse fidelity is of importance, such, for example, as in both color and monochrome television networks and for multichannel telemetering systems.

A still further object of the invention is to provide a monostable transistorized multivibrator of the "nonsaturating" type, which is temperature-stabilized in the sense that the time period of the multivibrator is caused to remain unchanged over a wide range of ambient temperature variations.

Other objects and many of the attendant advantages of this invention will be readily appreciated as the same become better understood by reference to the following detailed description when considered in connection with the accompanying drawing, in which FIG. 1 is a schematic illustration of a preferred form of temperature-stabilized transistor multivibrator constructed in accordance with the principles of the present invention, and FIG. 2 is a graft useful in explaining the operation of the multivibrator of FIG. 1.

Referring now to FIG. 1 of the drawing, there is shown a transistorized multivibrator of the monostable type. As shown, this multivibrator includes a pair of transistors generally identified by the reference numerals 10 and 12. Both of these transistors are of the P-N-P type, the transistor **10** including an emitter **14**, a collector **16** and a base electrode **18**. In similar fashion, the transistor **12** incorporates an emitter **20**, a collector **22** and a base electrode **24**. Operating energy for the transistors **10** and **12** is supplied from a source (not shown) connected to the terminal **26**. The latter is connected to the emitter electrode **14** of transistor **10** by a conductor **28**, and to the emitter **20** of transistor **12** through a diode **30** the function of which will be later described. The collector electrodes of transistors **10** and **12** are grounded as shown through resistors **32** and **34**, respectively.

As is conventional in multivibrators, the arrangement of the drawing circuit is such that the output of the transistor **10**, as derived from the collector electrode **16**, is coupled to the base electrode **24** of transistor **12** through a resistor **36** connected in parallel relationship with a capacitor **38**. The collector electrode **22** of transistor **12** is coupled to the base electrode **18** of transistor **10** through a capacitor C and a unilateral conducting device such as the diode **40**. The capacitor C, together with a resistor R, constitutes a time-constant network **41** (as indicated by the broken lines in the drawing) one end of resistor R being grounded so as to dissipate any electrical charge appearing on capacitor C within a period of time determined by the electrical values of these two components.

In order to ensure that the transistors **10** and **12** do not go into saturation (there is no need to limit the cutoff excursion as no minority carriers occur then), each transistor is provided with a pair of semi-conducting devices arranged to limit transistor operation in the direction of saturation. To achieve this result, one such pair of semi-conducting devices, as, for example, the diodes identified by the reference numerals **46** and **40**, and associated with transistor **10**, is interposed in series opposition between the collector electrode **16** of the transistor **10** and its base electrode **18**. Diode **46** should be composed of germanium and diode **40** should be of the silicon type to enhance the non-saturating capability of the circuit. The input trigger pulses should be of positive polarity, as transistor **10** is normally conducting. Further, these trigger pulses need not be of short duration as long as the rise time and amplitude of a step input is sufficient to provide the energy required to trigger the multivibrator. The transistor **12** has associated therewith a pair of current-limiting diodes **48** and **50** interposed in series opposition between the collector electrode **22** of the transistor and its base electrode **24**.

In operation, it may be assumed that the multivibrator of the drawing is in its quiescent condition, that is, it has completed a full cycle of operation and is awaiting the reception of a trigger pulse so that another operating cycle may be initiated. In this state, transistor **12** is cut off and transistor **10** is conductive, so that a negative voltage appears in a conductor **52** (designated in the drawing as output No. 1) while a positive voltage appears in a conductor **54**, the latter being designated in the drawing as output No. **2**. This condition is brought about by the fact that with transistor **12** cut off its impedance is extremely high, and hence the junction point **58** is essentially at ground potential. On the other hand, with transistor **10** conducting, junction point **56** assumes essentially the positive value of the potential source connected to terminal **26**. It is this situation that prevails when a positive trigger pulse, or step, is applied through the capacitor **44** and diode **42** to the base electrode **18** of transistor **10**. When this occurs, transistor **10** is rendered cutoff, and current stops flowing from the collector electrode **16** to ground through the resistor **32**. This cause the potential at junction point **56** to become negative, and this negative voltage is applied through the resistor **36** and diode **48** to the base electrode **24** of transistor **12** to lower the potential thereof. The latter then starts to conduct, thus causing the junction point **58** to rise to a positive potential. In other words, the multivibrator has now entered into the other of its two steady-state conditions.

During the time that transistor **10** was conductive (that is, the condition which existed prior to the reception by the circuit of an incoming trigger pulse) the junction point **56** was essentially at the positive voltage of the source terminal **26**, and a corresponding charge was developed on the capacitor C of the time-constant network **41**. However, upon cutoff of transistor **10** in the manner above described, the positive voltage on the right-hand plate (in the drawing) of capacitor C bleeds off through resistor R until the charge on this capacitor is no longer sufficient to maintain the base electrode **18** of transistor **10** at a potential sufficiently positive to ensure continued nonconduction of this transistor. At the latter

point the voltage conditions again reverse, transistor 12 becoming nonconductive while current flows through transistor 10, and a complete cycle of operation has taken place.

A circuit arrangement such as above described operates satisfactorily as long as the ambient temperature conditions do not vary to any appreciable extent. However, should temperature changes be encountered, the impedance of the transistors 10 and 12 and especially diode 40, will correspondingly change, and this variation may be to such a degree that the desired operating period of the multivibrator (as determined by the values of the components of the R-C network 41) will no longer remain constant.

To overcome this condition, the present invention incorporates means for canceling out these temperature effects in such a manner that the resulting wave form undergoes no appreciable distortion throughout extended periods of system operation. Briefly, this is accomplished by inclusion of the diode 30 in the components normally associated with transistor 12. It is known in the art that the resistance of a diode semiconductor (whether of the germanium or the silicon type) varies inversely as a function of temperature. Consequently, the presence of diode 40 between the base electrode 18 of transistor 10 and the capacitor C of the time-constant network 41 means that the voltage drop across this diode 40 and the base-emitter diode of transistor 10 (when the temperature rises, for example) will decrease to correspondingly increase the actual "switch-over" voltage of the one-shot multivibrator. This has the effect of decreasing the switch-over time instant of the transistor 10 insofar as its regulation by the voltage on capacitor C is concerned.

However, this effect is balanced out by the action of the diode 30 connected to the emitter electrode 20 of transistor 12. It will be noted that this diode 30 is in series with the potential source connected to terminal 26, and hence the assumed temperature increase, by reducing the voltage drop across diode 30, has the effect of increasing the potential on the emitter electrode 20 by an amount equal to that by which the voltage across diode 30 changes thereby increasing the voltage swing available to time constant network 41 which in turn increases the switch-over time instant of transistor 10. These effects oppose one another to create a balanced condition, so that any tendency for the instant of change-over of transistor 10 to be decreased by diode 40, for example, is accompanied by a tendency for the instant of change-over of such transistor 10 to be increased by diode 30. The over-all operating cycle, or output pulse width, of the network is thus maintained essentially constant regardless of the assumed temperature variation.

The above operation is made clear by the graph of FIG. 2, this graph illustrating why the period of a one-shot multivibrator varies with changes in temperature when no compensating means are employed. The variation in time duration (T) of the circuit output pulse is due principally to the increase in "switch-over" voltage (V). The addition of diode 30 of FIG. 1 compensates for the decrease in T with rising temperature because the voltage across diode 30 decreases with rising temperature, thereby allowing a greater voltage to be impressed upon the time-duration-determining elements (C and R of network 41). This results in an increasing (with rising temperature) pulse duration T to compensate for the decreasing effect on T of the increasing switch-over voltage which, in turn, is caused by the decreasing (with rising temperature) voltages across diode 40 and the base-emitter diode of transistor 10. It will be noted in FIG. 2 that the "switch-over voltage" is equal to the "return voltage" to which point X in FIG. 1 returns, and from which it starts when the multivibrator is triggered.

It has been ascertained in practice that the inclusion of the compensating diode 30 has a marked effect upon circuit stability. For example, in one situation in which the diodes 30, 48, and 40 were of the silicon type, the network was initially adjusted for a delay period of 20 microseconds at room temperature. When the temperature was raised to 75° centigrade, it was found that a more or less conventional circuit, which did not include the diode 30, exhibited a change in this delay interval of 3.5 microseconds. However, as soon as the diode 30 was included in the circuit arrangement, there was no detectable change in this predetermined delay period under similar circumstances.

The above test was conducted with transistors of the germanium type. When silicon transistors were substituted therefor, a change in delay time of 1.8 microseconds occurred without the diode 30, while this change in delay, with the diode 30 present, was only 0.2 microsecond.

Although the values of the various circuit components may be chosen in accordance with the particular operating results desired and in view of the conditions to be encountered, it has been found that the following values are especially suitable for optimum operation in one set of circumstances.

Transistors 10 and 12	Germanium GT–153 or Silicon 2N335.
Resistor 32	680 ohms.
Resistor 34	680 ohms.
Resistor 36	5,600 ohms.
Capacitor 38	160 mmfd.
Potential source at terminal 26	+6 volts.
Diodes 30, 40 and 48	1N457.
Diodes 50 and 42	1N695.
Resistor R	6,800 ohms.
Capacitor C	4,700 mmfd.

Obviously many modifications and variations of the present invention are possible in the light of the above teachings. It is therefore to be understood that within the scope of the appended claim the invention may be practiced otherwise than as specifically described.

We claim:

In a transistorized multivibrator of the monostable type, wherein each of the two P-N-P transistors of the multivibrator have emitter, base and collector electrodes, with the collector electrode of each transistor being electrically coupled to the base electrode of the other transistor, and wherein a time-constant network is incorporated in said multivibrator to establish the interval during which the multivibrator remains in one of its steady-state conditions, the improvement which comprises stabilizing means for precluding an appreciable change in the interval during which the said multivibrator remains in its said one steady-state condition in the face of variations in the ambient temperature of the multivibrator, said stabilizing means including a first semiconducting device one terminal of which is connected directly to the emitter electrode of one of said transistors and the other terminal of which is connected to a point of positive potential, and a second semiconducting device, having operating characteristics similar to those of said first semiconducting device, one terminal of said second semiconducting device being connected to the base electrode of said second transistor and the other terminal of said second semiconducting device being connected to said time-constant network, and with the output of said time-constant network being applied to the base electrode of said other transistor through said second semiconducting device, the electrical resistance of each of said semiconducting devices being chosen to change in essentially identical fashion in response to similar variations in the operating temperature thereof so that the voltage drop thereacross also changes by the same amount, the connection of said two semiconducting devices to their respective transistors thus producing opposite effects on the

operating period of the multivibrator, the voltage drop across one of said semiconducting devices tending to increase the interval during which said multivibrator remains in its said one steady-state condition, while the voltage drop across the other of said two semiconducting devices tends to decrease the interval during which the said multivibrator remains in its said one steady-state condition, the over-all effect being that said interval remains essentially constant and the operation of said multivibrator is stabilized.

References Cited by the Examiner

UNITED STATES PATENTS

2,770,732	11/56	Chong	307—88.5
2,892,165	6/59	Lindsay	307—88.5 X
3,017,524	1/62	Koletsky	307—88.5
3,060,331	10/62	Habisohn	307—88.5

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