A DIGITAL-CONTROLLED DC-POWER SUPPLY

BY

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ABSTRACT:

This paper presents a simple adjustable output-voltage DC-Power supply which can be controlled via a digital-analog converter by a digital computer. The performance of the designed DC-Power supply has been experimentally tested and showed satisfactory results.

I. INTRODUCTION:

The continuous need to implement direct real-time digital computation in engineering necessitates the existance of an intermediate link between the digital-analog converter and the engineering system which may be controlled in direct real-time. In electrical engineering adjustable DC-Power supplies are needed to design digital controllers for all aparatus and systems which use direct current. In general, adjustable DC-power supplies are designed using the principle of "PHASE CONTROL".

2. PRINCIPLE OF PHASE CONTROL:

Phase control is the process of rapid ON-OFF switching which connects an AC-supply to a load for a controlled fraction of each cycle. Then the basic function of an adjustable-voltage DC-power supply is to convert an alternatin input voltage to a controllable direct output voltage. Such arrangement is also known as phase-controlled converter.

Phase-controlled converters consist, basically, of a rectifier circuit arrangement in which some, or all, of the rectifier devices have gate-controlled forward-voltage blocking capability. The well-known silicon-controlled rectifier(SCR) or thyristor has become firmly established as the active power-control element of phase controlled converter.

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The basic principle of operation of a phase-controlled converter is to control the point in time at which conduction in each thyistor is allowed to commence during each AC-cycle. Control is then accomplished by governing the phase angle of the AC-wave at which the thyristor is triggered. The thyristor will then conduct for all the remainder of that half-cycle. By this means it is possible to choose the time segment of the AC-voltage waves which appear at the DC terminals, and there by, to continucusly control the mean value of the DC terminal voltage. In this way, the essentielly bistable switching characteristic of the thyristor itself is utilized to provide a linear control of the mean output quantity.

There are many forms of phase control possible with silicon-controlled rectifiers (REF. I), but a scheme in which the gate-triggering process of the thyristor is automatically actuated using a DC, milliwatt-level, analog control input signal is the object of this paper.

3. DESIGN FUNDAMENTALS OF A TRIGGER-PULSE-GENERATOR CIRCUIT:

The ability of the thyristor to switch from non-conducting to conducting state in response to a small control signal is the key factor in its widespread utility for control of power. Proper triggering or firing of the silicon controled rectifier requires that the source of the trigger signal should supply adequate gate current and voltage, in accordance with the characteristics of the thyristor and the nature of its load and supply. The trigger-source impedance, time of occurrence and duration of the trigger signal, and OFF-state conditions are also important design factors. Gate-trigger characteristics, ratings and methods are fully discussed in REF.(I).

In order to control the output voltage of a phasecontrolled circuit, it is necessary to control the phase of the thyristor-firing pulses. Thus the function of the triggerpulse generator is to deliver correctly timed, properly shaped firing pulses to the gates of the thyristors in the phasecontrolled circuit. Many alternative principles exist for achieving this object. The silicon unijunction transistor is an ideal device to be used as a source of the firing pulses. It has the advantages of a stable trigger voltage, a very low trigger current (which is most suitable for digital control) and operation over a wide temperature range. Thyristor-gate firing circuits using the unijunction transistor (UJT) are simple and compact with low power consumption and a high effective power gain in phase control circuits.

The basic UJT-trigger circuit used in applications with the thyristor is the simple relaxation oscillator shown in Fig. (1). In the circuit of Fig.(1), the capacitor C_1 is charged throungh R_1 until the emitter voltage reaches V_p, at which time the UJT turns on and discharges C_1 through R_{B1}. When the emitter voltage reaches a value of about 2 volts, the emitter ceases to conduct, the UJT turns off and the cycle is repeated. The period of ascillation T is fairly independent of the supply voltage and temperature. The value of period of oscilaation T is given by;

$$T = \frac{1}{f}$$

$$= R_1 \, C_1 \, \mathrm{Ln} \, \frac{1}{1-\eta}$$

Where, f is the frequency of oscilation

η is the intrinsic stansoff ratio of the UJT which lies between 0.51 and 0.82.

For an approximate nominal value of intrinsic standoff ratio of 0.63, the value of period of oscilaation is,

$$T = R_1 \, C_1$$

In practical applications of the basic firing circuit of Fig.1, a voltage regulator (normally, Zener diode) is used with the UJT to clip and regulate the peaks of the trigger circuit supply voltage.

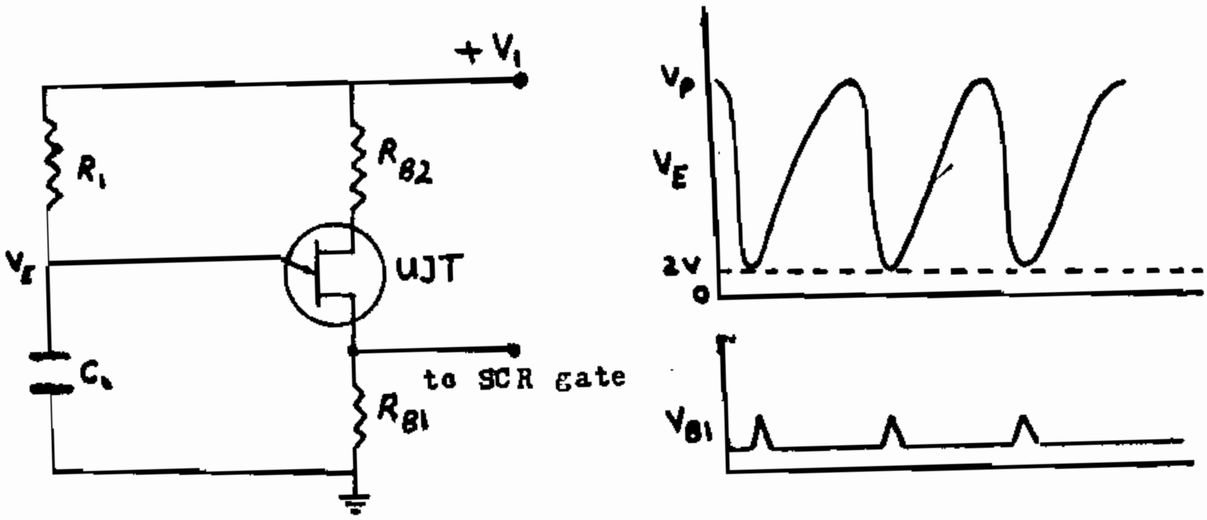

Fig. (1): Basic UJT Relaxation Oscillator-Trigger

with Typical Waveforms.

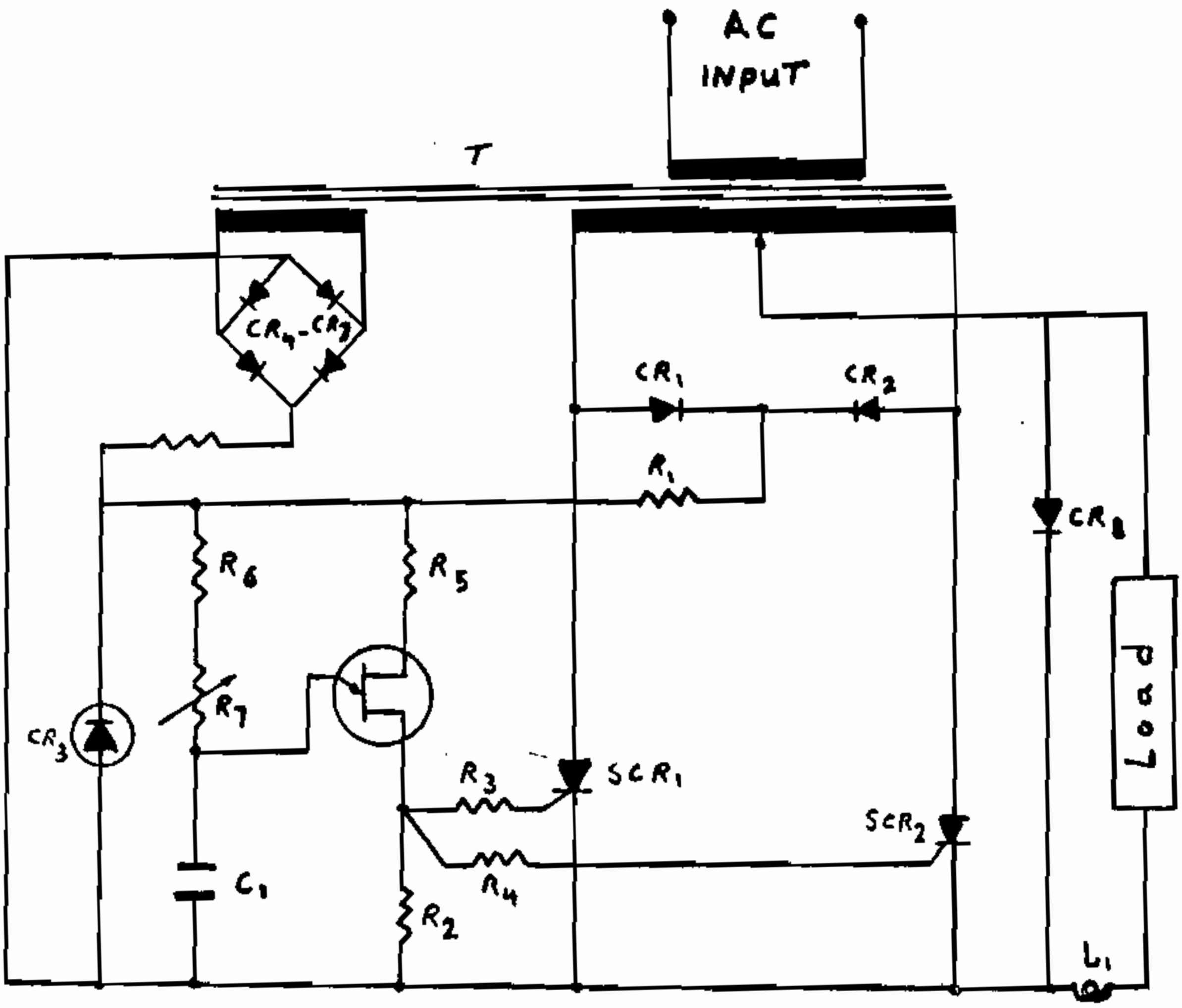

Fig. (2): Phase-Controlled DC-Power Supply

4. THE DIGITAL CONTROLLED DC-POWER SUPPLY:

A typical phase-controlled circuit for DC loads has been given in Ref, (1) (page 273) and is shown in Fig.(2) for convenience. Whichever of the two thyristors of Fig.(2) has positive anode voltage at the time the gate pulse occurs will fire, thus applying voltage to the load for the remainder of that half-cycle. The firing angle can be adjusted by means of R_7. By varying R_7, the DC voltage across the load can be steplessly adjusted from its maxium value down to zero. If the load requires filtering, inductance L_1 and free-wheeling diode CR_8 may be added as shown in Fig. (2).

Inductive DC loads often require the use of a free-wheeling diode to prevent feedback of power into the supply line during a portion of each half-cycle. If the circuit shown in Fig. (3) is operated without diode D and L is large enough that continuous current flows in the load, current flows through each thyristor until the other thyristor is triggered into conduction. With triggering of the thyristors delayed by an angle α, the load voltage is negative during the delay period and energy stired in L is returned through the thyristors to the AC-supply. with diode D across the load, the load voltage is clamped at essentially zero during the delay period, and the load current maintained by L flows through D during this period.

The development of the present digital-controlled DC-power supply has been derived from the previous theory and a practical experimentation on a ciroult built in the laboratory. The final scheme which may be reccmmended for direct reak-time digital control applications is given in Fig.(4).

The developed scheme of the digital controlled DC-power supply of Fig.(4) is more practical, much simple than that shown in Fig.(3). Furthermore the developed scheme is adaptable for digital control applications.

... (3): ... ing Diode (D).

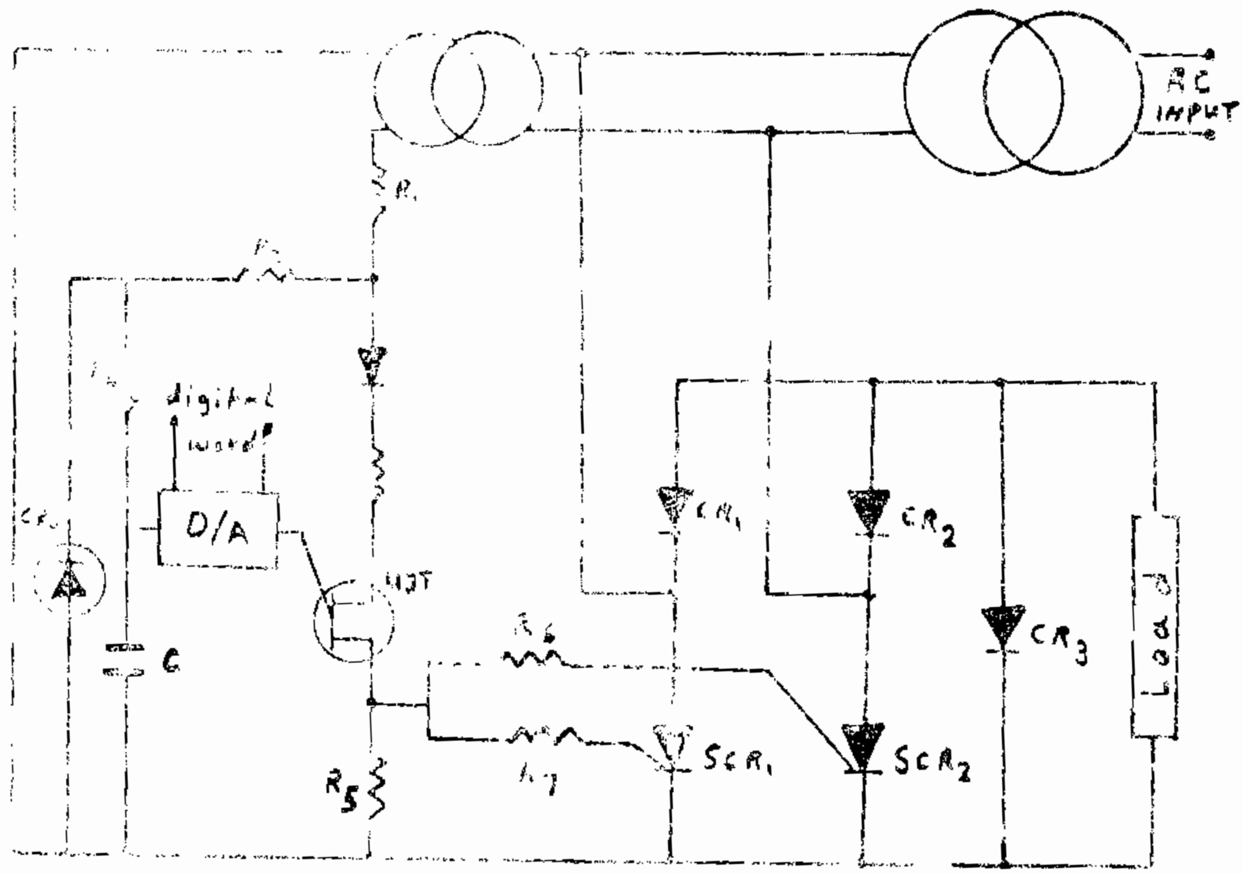

FIG. (4): Digital-Controlled DC-Power Supply

In the circuit of the developed scheme of Fig.(4) combined phase-control and DC-bias control through through the UJT is used. A variable DC-bias or control signal is combined with a shifted-phase AC-voltage. If the DC-bias is increased or decreased, the zero axis of the AC-componenet is raised or lowered and the intersection of the resultant voltage and the emitter-base one voltage or the firing angle is varied. The zener diode is placed in the circuit to protect the UJT from high reverse bias and to achieve synchronization with the AC-supply voltage. To generalize the use of the digital-controlled DC-power supply, a reverse connected or free-wheeling diode is connected across the load to carry the load current during the decay period and to prevent feedback of power into the supply line.

The developed scheme has been successfully used in a major direct digital-computer control project (Ref. 5). The values of the inner elements of the scheme complement each other and therefore, the final values for any particular operating condition should be experimentally determined.

5. CONCLUSION:

An adjustable voltage DC-power supply has been developed and presented. The circuital configuration of the developed scheme of the adjustable power supply is practical, economical and simple. It uses combined phase-shift and DC-bias control to enable its use in real-time digital control applications. The developed scheme has been used in a major direct digital-computer control project in the laboratory of the Electrical and Electronic Engineering Department of the Herict-Watt University, Edinburgh.

6. REFERENCES:

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