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AN INTEGRATED 3-PHASE GATE-DRIVER
FOR THYRISTOR-OPERATED CONTROL-SYSTEMS

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ABSTRACT:

For thyristors engaged in 3-phase static electrical power conversions (such as 3-phase cycloconverters, constant-frequency power supplies, etc.) where 3-phase controllable output is needed, three identical reference voltages differing by 120° are required.

The paper presents an approach to design a versatile integrated scheme for a 3-phase gate-driver for thyristor operated control systems. The designed scheme is a variable frequency, variable amplitude 3-phase sine-wave reference generator.

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The frequency and amplitude of the output pulses are independently capable of being controlled using individual dc-control voltages.

The developed scheme is fully built up using integrated circuits, is put into working order and showed well results. It is a self-contained functional unit which is capable of operating quite satisfactorily and independently of the power converter.

1- INTRODUCTION:

The most important weighting factor for the use of thyristors as active elements in control systems of static electrical power conversion equipment, is its gate-driving circuit. Gate-driving (or thyristor-firing) is the usual means of turn-on specified for thyristors. It allows stable on-off biasing of the thyristor for greatest circuit reliability.

In general the function of a gate-driver is to deliver correctly timed, properly shaped firing pulses to the gate of the thyristors in the power converter. Almost invariable, the phase of the firing pulses, relative to the converter input voltage, is controlled in accordance with an analog "reference" signal. Many alternative principles exist for achieving this end (Ref. 1), and much work is going to be done in an endeavour to simplify the design and to improve the performance of such circuits (Ref. 2).

In three-phase static electrical power conversions (such as 3-phase cycloconverters, constant-frequency

power supplies, etc.) where 3-phase controllable output is needed, the firing pulses applied to the different thyristors should be synchronized with the main supply. Moreover, to achieve controllability of the output, the firing angle of pulses applied to the different thyristors should be put under control.

Accordingly, the main objectives of a gate-driver to be used in a three-phase ac-line control are:

- i) provision of three-phase pulses.
- ii) Ability to control the firing angle.

Numerous approaches to the design of the firing pulse generator circuit are possible (Ref. 3). A scheme of a three-phase sinewave firing-pulse generator which fulfils the desired objectives has been given in (Ref. 4). The approach is schematically shown in Fig. (1) .

Briefly, the scheme visualized in Fig. (1) involves the use of three samplers time displaced through 120° using a three-stage ring counter. The filtered outputs of the samplers yield practically distortionless three-phase sinusoidal voltages that are displaced with respect to each other exactly by 120° . The amplitude of the output is controlled by the dc voltage, V_a , and the output frequency is controlled by the dc voltage, V_f . The output of the V/f converter drives the three-stage ring counter. It is clear then that the basic principle of this system depends mainly on the sample-and hold circuit used.

Fig. (2) shows the sample-and hold circuit diagram used in the approach of Ref. (4). In Fig. (2), the matching

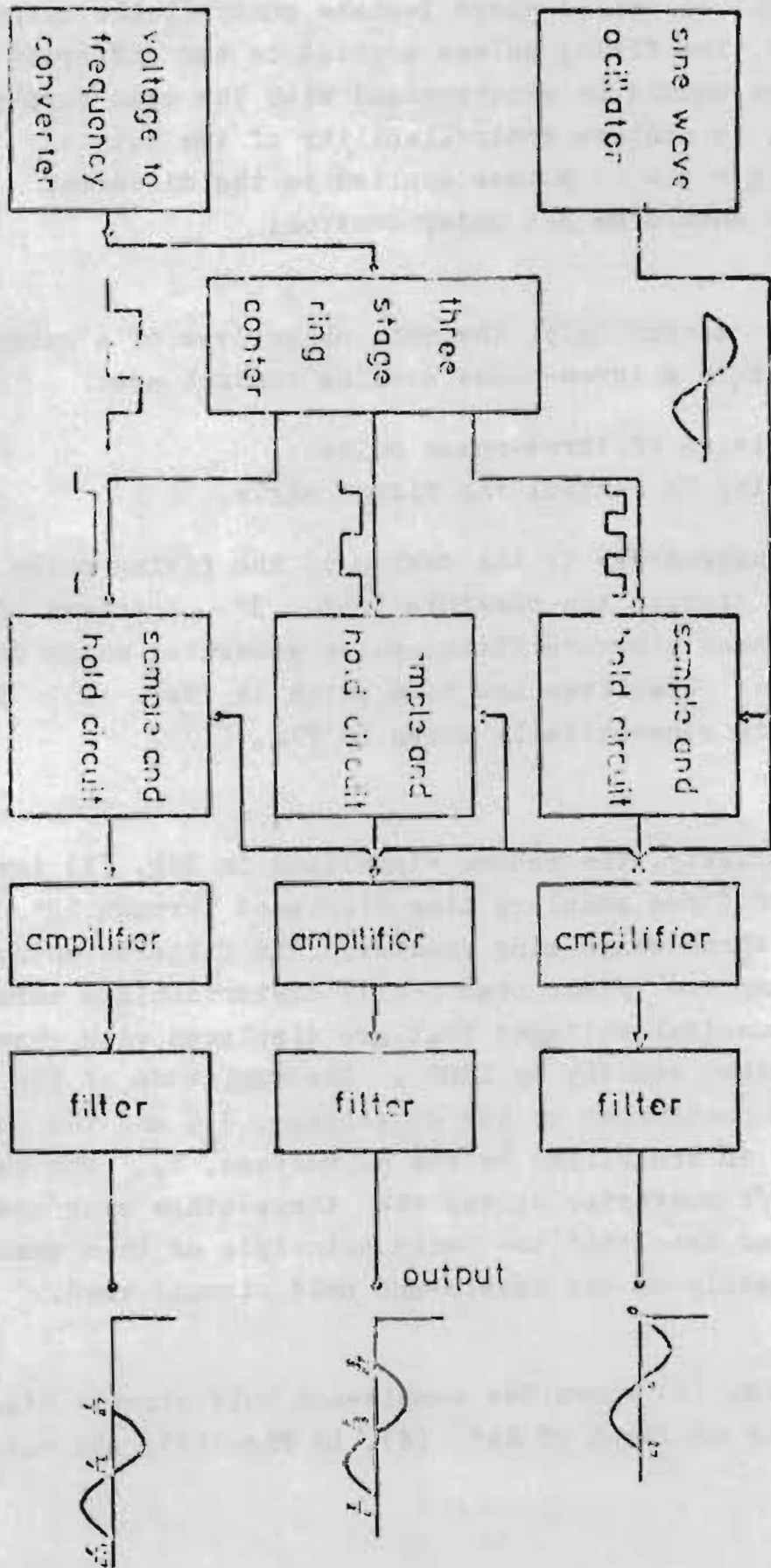


FIG. 1. Block diagram of the designed system.

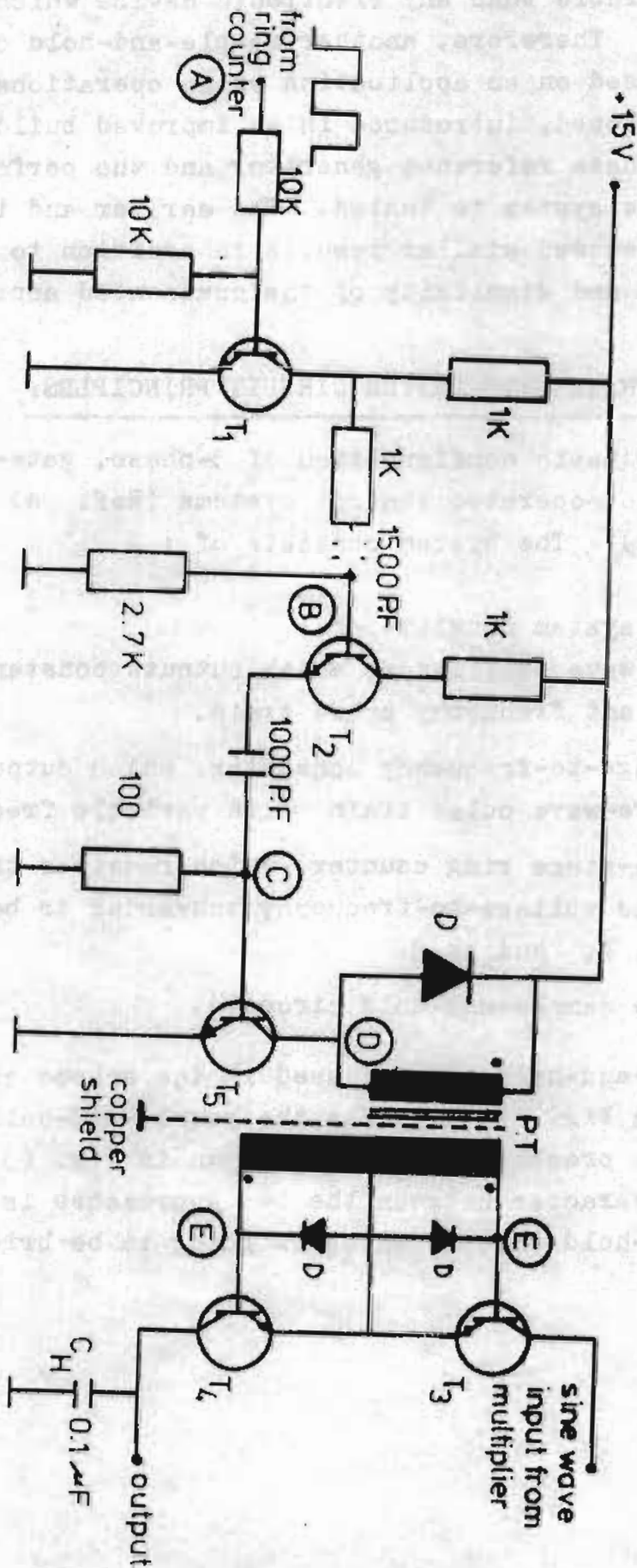


FIG (2) : sample-and-hold circuit using pulse transformer

element used is a copper-shielded pulse transformer which is less reliable than any electronic device which may replace it. Therefore, another sample-and-hold circuit which is based on an application of an operational amplifier is developed, introduced in an improved build-up of the three-phase reference generator and the performance of the whole system is tested. The earlier and the present approaches showed similar results in addition to the high reliability and simplicity of the presented approach.

2- Three-PHASE GATE-DRIVER CIRCUIT PRINCIPLES:

The basic configuration of 3-phase, gate-driver for thyristor-operated control systems (Ref. 4) is shown in Fig. (1). The system consists of :

- (1) . The system consists of :
 - i) Sine-wave oscillator, which outputs constant amplitude, constant frequency pulse train.
 - ii) Voltage-to-frequency converter, which outputs square-wave pulse train with variable frequency.
 - iii) Three-stage ring counter, which receives the output of the voltage-to-frequency converter to be divided by 2, 4, and by 8.
 - iv) Three sample-and-hold circuits.

The sample-and-hold circuit used in the scheme of Ref. (4) is shown in Fig. (2), whereas the sample-and-hold circuit used in the present approach is shown in Fig. (3). The dividing character between the two approaches is the sample-and-hold circuit which is going to be briefly discussed.

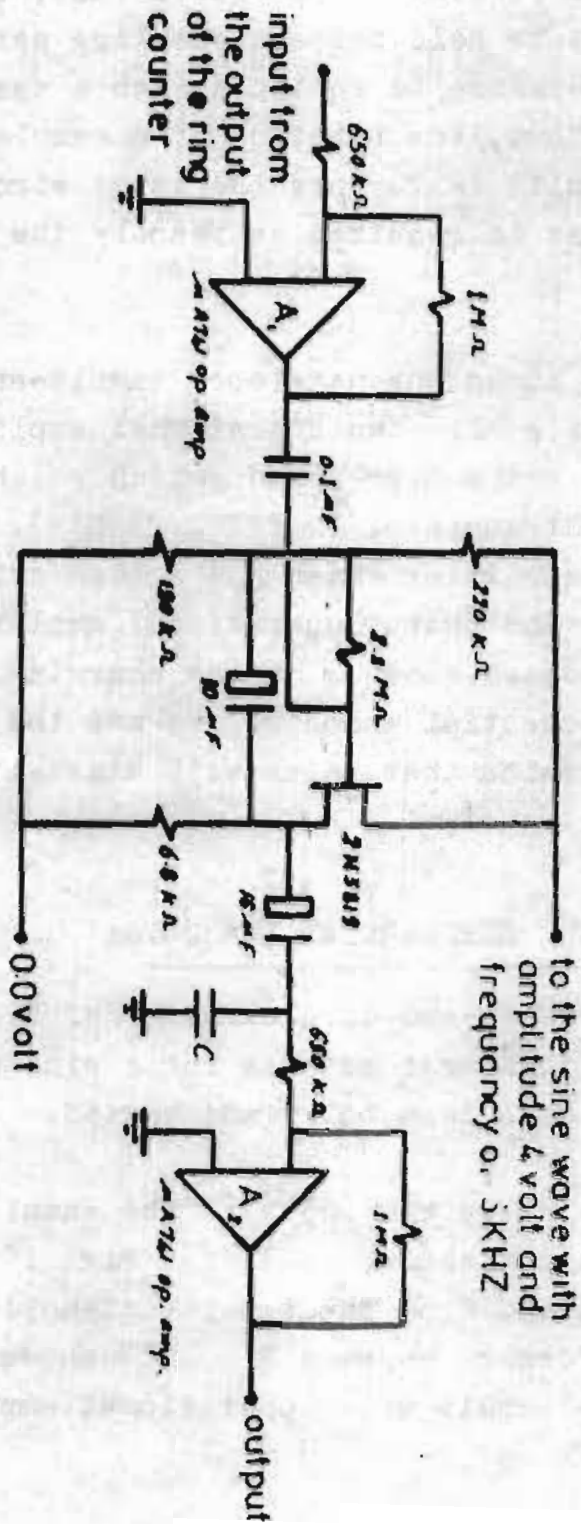


FIG. (3) : sample and hold circuit using operational amplifier.

3- THE SAMPLE-AND-HOLD CIRCUIT:

When more than one signal are controlled by a single pulse as the present investigated case, different output signals must be held between sampling periods and the output must therefore be equipped with a sample-and-hold amplifier. Thus, the function of a sample-and-hold amplifier (or circuit) is to hold the input signal constant during the time that is required to reapply the signal again.

Fig. (3) shows the developed sample-and-hold circuit. It consists of: two operational amplifiers A_1 , A_2 (UA 741) and a high-speed switch which is a metal oxide field effect transistor (MOSFET, 2N3819). A_1 is the input operational amplifier which has a high current capability. A_2 is the output operational amplifier. The sample-and-hold process depends on the charging of the capacitor C to a potential which represents the sampling amplitude and maintains that value with minimal drop between sampling times.

4- CONCLUSION AND EXPERIMENTAL RESULTS:

The two sample-and-hold circuits of Figures (2) and (3) yield two different schemes for a sine-wave pulse gate-driver which have been built and tested.

Fig. (4) shows the input to the sample circuits and the sampled output before holding. Fig. (5) shows the sine-wave obtained from the sample-and-hold circuit using pulse transformer, whereas Fig. (6) shows that obtained from the sampling-circuit using operational amplifiers.

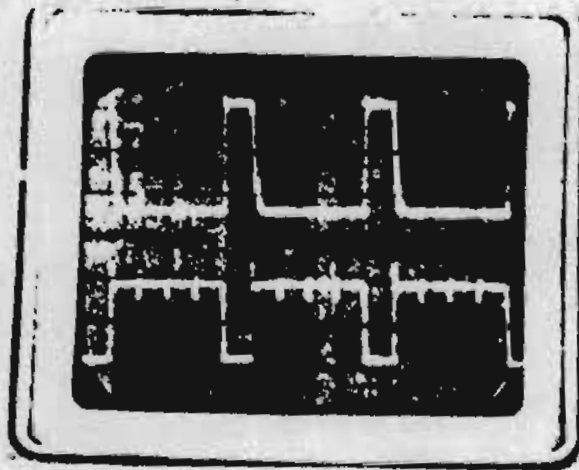


Fig.(4)

- a) The input to the sample circuit.
- b) The sampled output before holding.

Amplitude 2 Volt/division.

The trend of Figures (5) and (6) is the same but the integrated 3-phase gate-driver using operational amplifiers for the sample-and-hold process is more efficient than that which uses pulses transformers because it can not be affected by stray magnetic or electric fields, has rigid reliability and long life.

It is hoped that the present work may be useful guide for the design of gate-drivers for the ever-developed thyristorized control systems.

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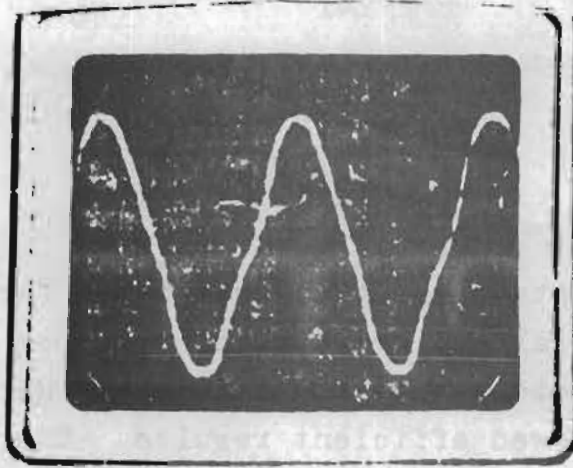


Fig. (5)

The sine wave obtained from the sample and hold circuit using pulse transformer.

Amplitude 0.1 Volt/divition.

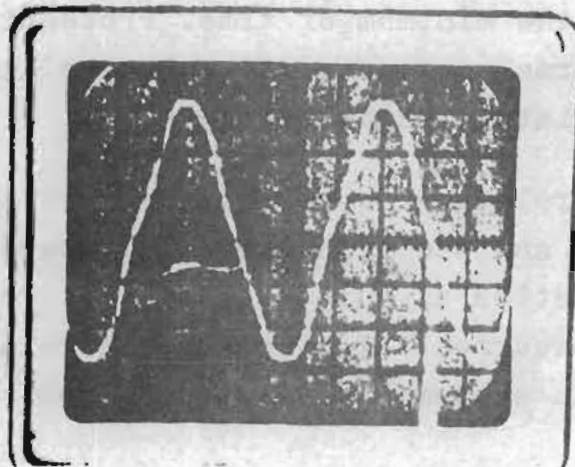


Fig. (6)

The sine wave obtained from the sampling circuit using op. amp.