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SQUARE-TO-SINE WAVE FILTER

BY

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William R. Limberis
Space Power Technology Branch

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ABSTRACT

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The design of a square-to-sine wave filter network is discussed. The network accomplishes a transformation and conversion of a 115-volt peak, 400 cps square wave to a 30-volt rms, 400 cps sine wave. The network will accommodate power levels on the order of one watt.

SQUARE-TO-SINE WAVE FILTER

INTRODUCTION

The Solar Physics Branch, Space Sciences Division, is using an inverter purchased from the Arnold Engineering Company to provide the necessary power for the instrumentation and experiments on the Advanced Solar Observatory Balloon Project. This inverter, supplied by a 28 VDC battery input, provides a 115-volt peak square wave at 400 cycles per second and two DC outputs of 15 volts of positive and negative polarity, respectively. The Stabilization and Control Branch, Spacecraft Systems and Projects Division, is supplying a resolver chain which forms part of an equatorial computer system. The resolver chain requires a 30- volt, 400 cps input for operation. The original intention was to use a commercially available transformer to step the 115-volt square wave from the inverter down to the required 30 volts. After careful consideration, it was determined that proper operation of the resolver chain would necessitate that the input be sinusoidal rather than of a square wave shape. A circuit had to be designed which would transform and convert the 115-volt peak, 400 cps square wave output of the inverter to a 30-volt rms, 400 cps sine wave. In addition, a 3-volt rms, 400 cps sine wave output was to be provided.

THEORY

The principle of superposition states that the response of a network to a signal composed of a sum of signals is equivalent to the sum of the responses of the network to each component of the sum acting separately. A square wave voltage of peak amplitude V_{max} and fundamental frequency f is composed of an infinite sum of sine waves. This voltage may be mathematically represented by a Fourier series as follows:

$$V(t) = \frac{4}{\pi} V_{max} \sum_{m=1}^{\infty} \frac{1}{2m - 1} \sin \left[(2m - 1)\ 2\pi\ ft\right],$$

where the frequency of each sinusoidal component of this sum is an odd integral multiple of the fundamental frequency. A network which will attenuate each sinusoidal component of this square wave signal of frequency other than a specified frequency, and pass the specified frequency component unaltered will accomplish the desired result, i.e., yield a sine wave output from a square wave input. A network which responds in the above manner consists of an inductance and a capacitance connected in series and/or in parallel. The values of the components required satisfy the familiar requirement for a resonant condition at a specified frequency, i.e.,

$$f_0 = \frac{1}{2\pi} \frac{1}{\sqrt{LC}},$$

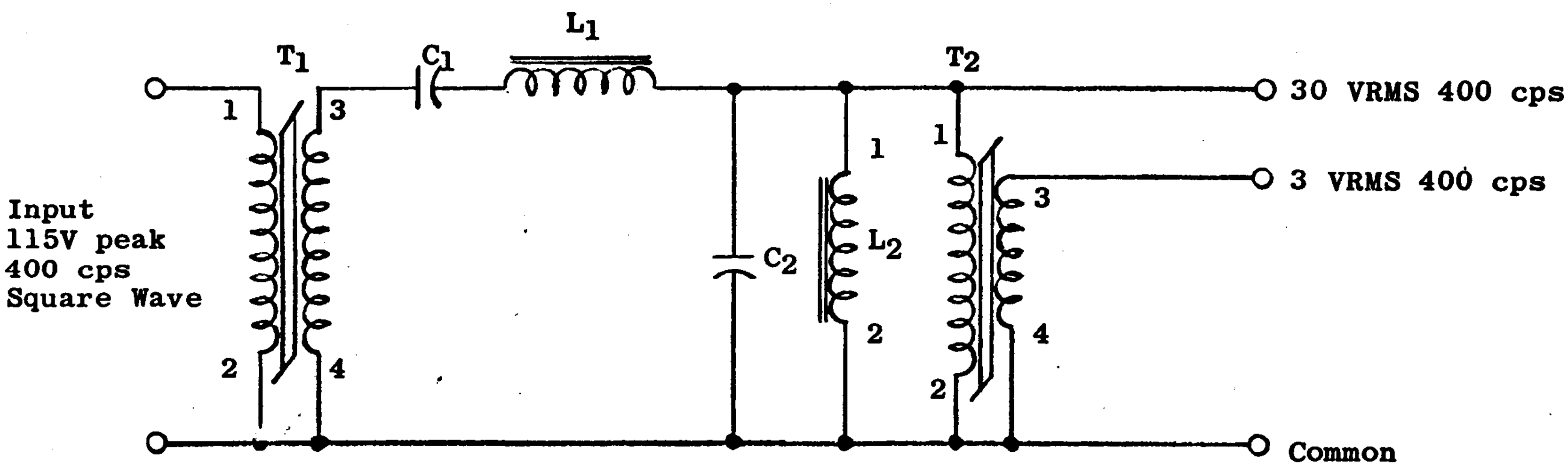
where L is the inductance in henries and C is the capacitance in farads.

CIRCUIT DESCRIPTION

The circuit decided upon is shown schematically in Figure 1. Transformer T_1 steps the 230-volt peak-to-peak square wave input down to 60 volts peak-to-peak. This is done to allow the remainder of the circuit to operate at a much lower potential. Consequently, a substantial reduction in the size of the components results, while still insuring sufficient derating to allow reliable performance. The transformer is operated at a flux density well below the saturation level of the core material to minimize the magnetizing current. This transformer uses a tape-wound core, and 4 mil tape is used to keep the core losses at the 400 cps frequency to a minimum. The capacitor-inductor pairs C_1-L_1 and C_2 - L_2 form a wave shaping network of a series and a parallel filter circuit resonant at 400 cps. The wave shaping network suppresses all frequencies other than its resonant frequency of 400 cps. The resultant 30-volt rms sine wave, which serves as one of the required outputs, is then transformed to 3 volts rms by means of transformer T_2. This approach eliminates the need for a filter circuit for each output.

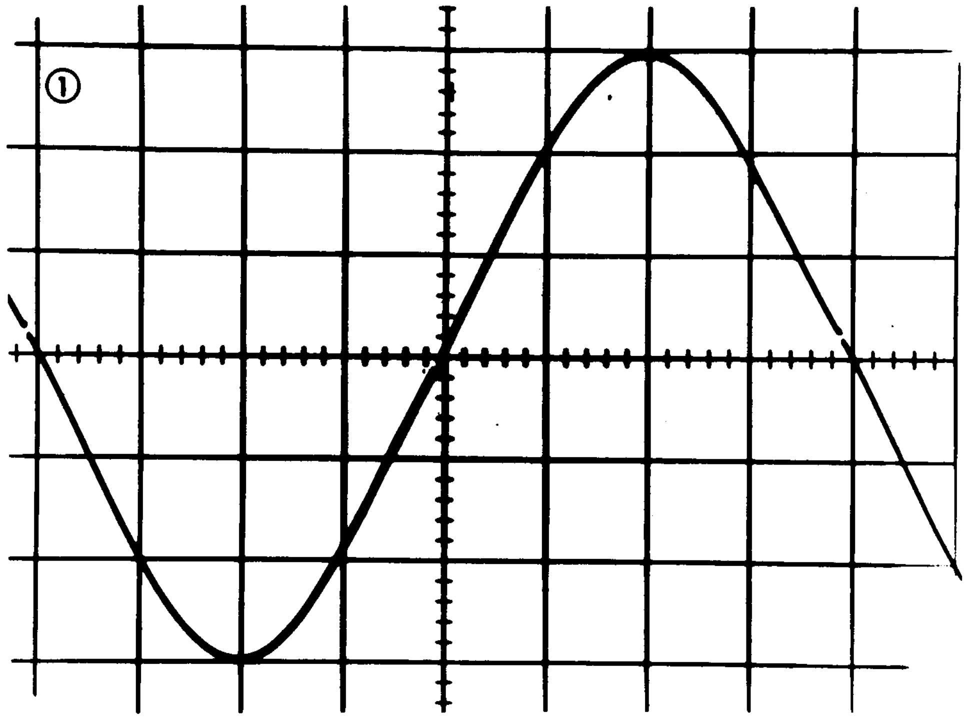
DISCUSSION OF RESULTS

The circuit was tested for regulation and stability under fixed loads of 620 + j772 ohms for the 30-volt rms output and 56 + j5.625 ohms for the 3-volt rms output over the temperature range of -10°C to +60°C. The regulation fell well within a ±10% tolerance. In addition, the per cent distortion of each sine wave output, measured with a Hewlett-Packard model 302A wave analyzer, was less than 5%. Photographs of one of the outputs and the output from a Hewlett-Packard model 201C audio oscillator observed on a Tektronix model 561A oscilloscope are shown in Figure 2 for comparison. Photographs of one of the flight units are shown in Figures 3 and 4. Figure 5 is a photograph of the equatorial computer in which the filter was installed.

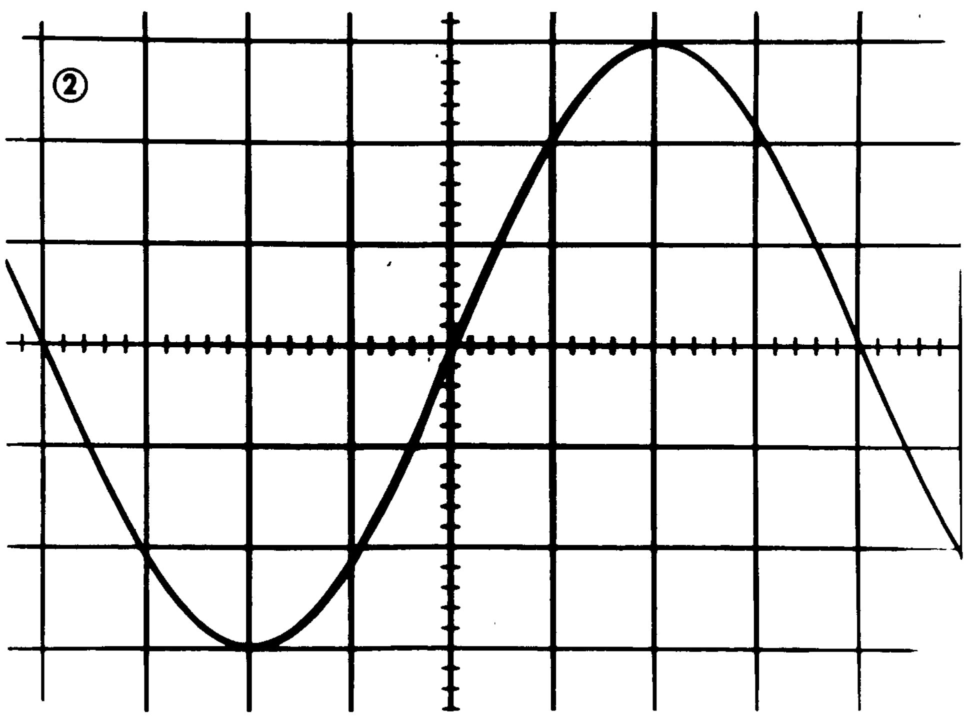


T_1 Core #50188-4A Magnetics, Inc., Pri. 1888 Turns AWG #34 Wire, Sec. 550 Turns AWG #30 Wire
T_2 Core #50033-2A Magnetics, Inc., Pri. 991 Turns AWG #32 Wire, Sec. 99 Turns AWG #28 Wire
L_1 Core #55928-A2 Magnetics, Inc., 657 Turns AWG #30 Wire, Inductance 79 mh.
L_2 Core #55083-W4 Magnetics, Inc., 1049 Turns AWG #26 Wire, Inductance 79 mh.
$C_1 - C_2$ 2μf., 100 Volt Cerol Capacitors, Aerovox Corp.

Figure 1–Square-to-Sine Wave Filter



Oscillograph of an output of the Square-to-Sine Wave Filter



Oscillograph of the output of a Hewlett-Packard Model 201C Audio Oscillator

Figure 2

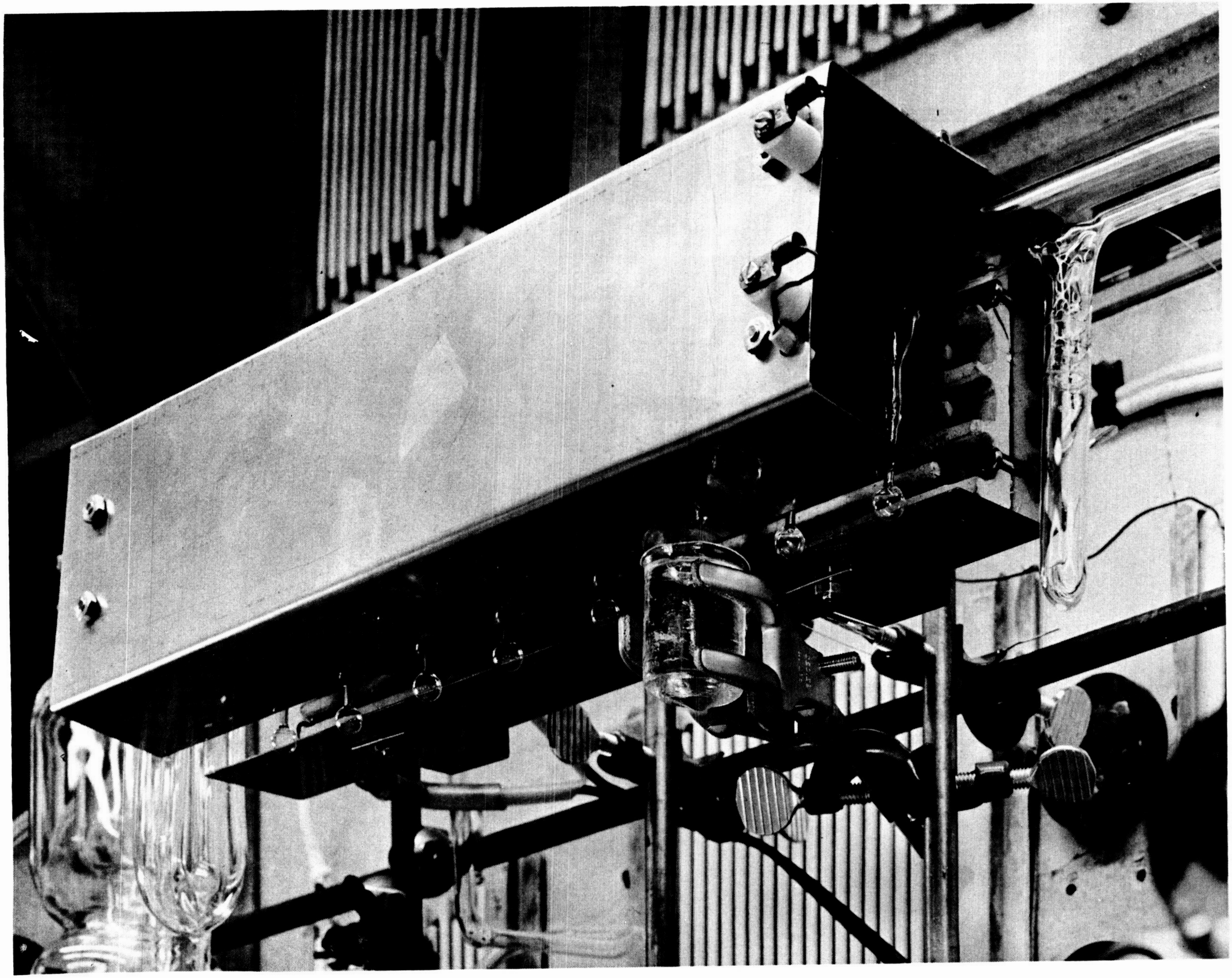


Figure 3

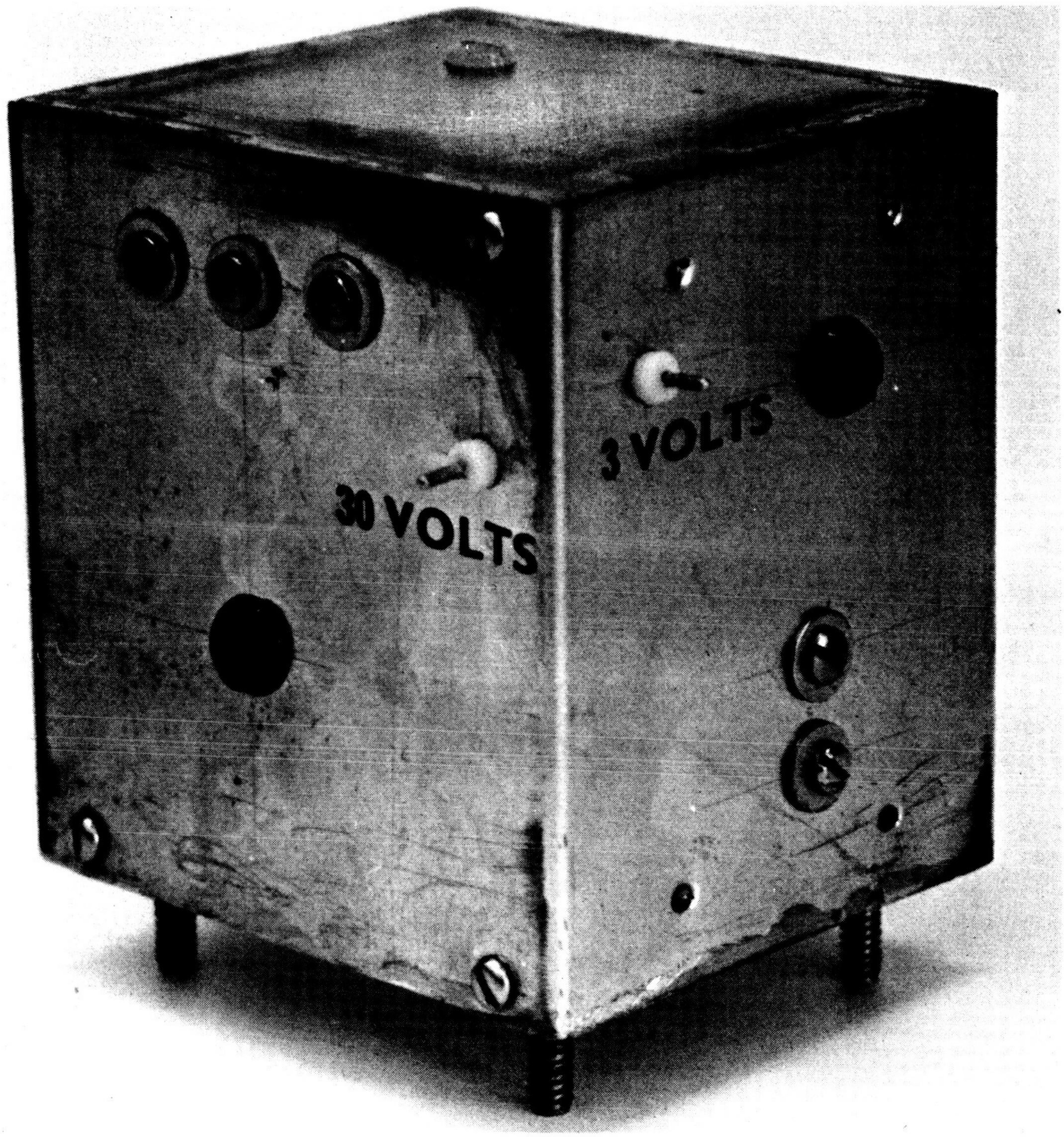


Figure 4

Figure 5