Fluorescent dimming using a magnetic amplifier

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In the context of the stringent requirements of manned spaceflight equipment, one design goal is continuous fluorescent dimming. The author discusses the magnetic amplifier concept which may have solved some of the problems associated with this type of lighting

Most fluorescent lamps in manned spacecraft prior to the Space Shuttle application[1,2] have not required dimming; however, in the Space Shuttle Orbiter, dimming is required because of the great number of tasks to be performed and because of the widely varying ambient light levels to be encountered.

A dimming range of 2 to 100 percent brightness is specified. The dimming control will often be placed remotely from the lamp. Dimming cannot detract from lamp service life or light levels, cannot significantly increase illumination system size and weight, and cannot significantly reduce efficiency. (Fig. 1 shows a luminare used in the Orbiter.)

As in earlier spacecraft, a 28-volt dc power source is used to power the lamp assemblies. An inverter is used (see Fig. 2) to step up the voltage for the lamp and to provide filament heat. This circuit, which was used in a Skylab light, is obviously reliable and is quite efficient (85 percent). It also has a fly-back high voltage effect under no-load conditions that greatly aids in starting the lamp. Consequently, in evaluating alternative dimming methods, minimum changes were made in the basic circuit.

The conventional method of fluorescent dimming consists of a standard Triac-phase control, a standard or modified inductive ballast, and some means of maintaining filament heat at low brightness settings in order to prevent cathode stripping (resulting from ion bombardment if the arc current falls below that required to maintain electron emission from a filament). These systems are, of course, designed for 60-hertz operation; switching losses prevent their use at our inverter frequency (20 kilohertz). Another approach involves duty cycling the inverter transistor base drive, thus controlling the power level in the transformer, but the problem of maintaining filament heat prevents its use in this application.

Approved for publication by the Papers Committee of the IES, May 1976. AUTHOR: Electronics Engineer, ILC Technology, Sunnyvale, California.

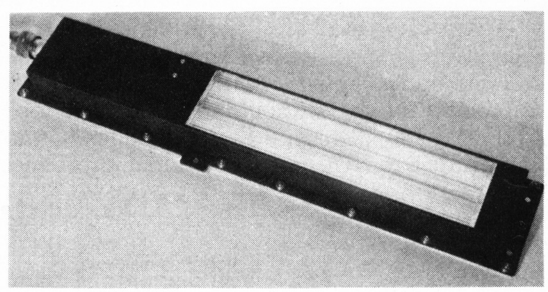
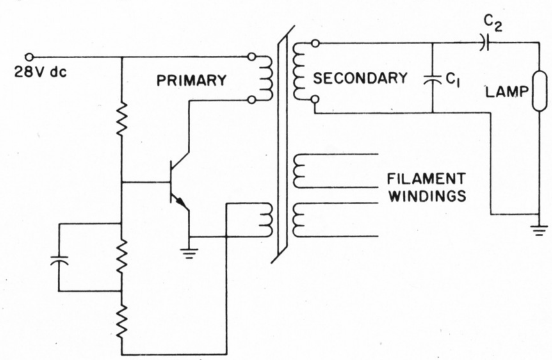


Figure 1. Example of the fluorescent luminaire used in the space shuttle orbiter.

Figure 2. Original circuit used in a skylab light.



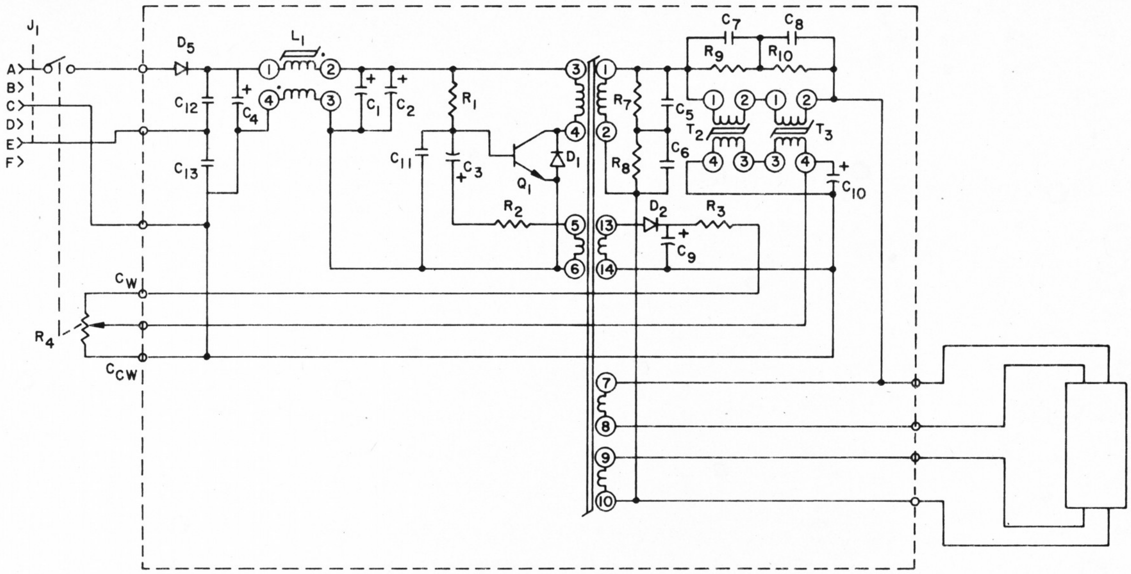


Figure 3. Circuit diagram with magnetic amplifier.

The most attractive method is one that controls only the ballast, so that the filament power is unaffected. (The original ballast was a mica capacitor (C_2 in Fig. 2). After ruling out the giant variable capacitor concept, the magnetic approach was adopted. The magnetic amplifier offers the following advantages:

(1) In its simplest form, it appears as a variable inductance; therefore, it can serve as ballast without significant circuit changes.

(2) According to all available evidence it operates smoothly, is temperature stable, requires few circuit elements, and is capable of withstanding large overloads and transients without failure.

(3) At the 20-kilohertz operating frequency, small magnetic cores can achieve the desired impedance.

(4) Unlike semiconductor methods, it does not cause electromagnetic interference, for the reason that the magnetic material switches slowly.

The resulting circuit is shown in Fig. 3. A magnetic amplifier takes advantage of the abrupt saturation knee of certain magnetic materials. By applying a small dc bias current to a saturable inductor that controls an ac signal, it is possible to vary the point on the ac waveform at which saturation occurs; this changes the effective inductance. By employing two magnetic elements (T_2 and T_3 in Fig. 3), it is possible to have the same effect on both ac polarities; and by connecting one set of windings in opposition, to effectively isolate the power and control paths. Because of this latter effect, none of the ac lamp power ap-

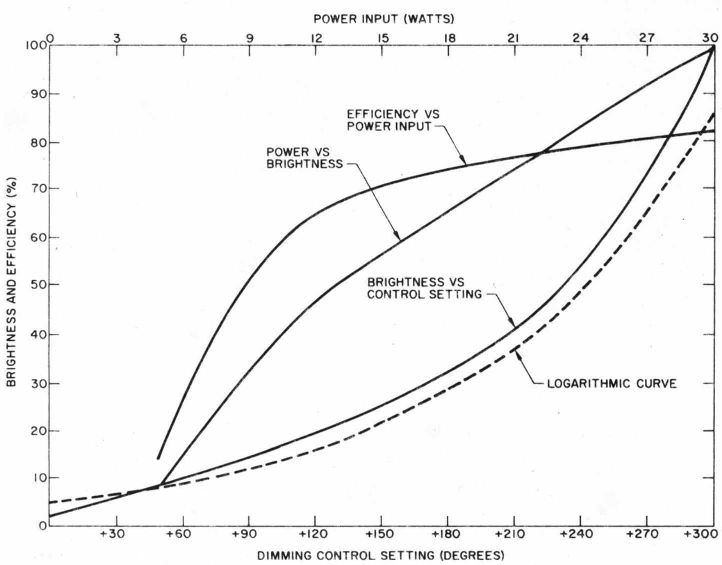


Figure 4. Effects of dimming on various aspects of inverter operation.

pears in the control circuit, contributing to high efficiency.[3]

When this circuit was first matched with the inverter, some problems appeared. In the original application, the capacitive ballast tended to decrease and stabilize the operating frequency of the inverter. Our inductive ballast has the opposite effect, raising the operating frequency so high that switching losses became excessive. A large capacitance (C_5 and C_6 in Fig. 3) placed across the secondary solved this problem but made fast inverter switching difficult.

This last problem was solved by selecting a high current transistor (Solitron S2N6215) that switches quickly and efficiently under these conditions.

Because of the necessity for fast switching in the presence of high impulse currents, high current transistors with acceptable speed and gain yield better efficiency. As a result, a 50 ampere transistor is used in a one ampere inverter.

Another efficiency feature permitted a small value of inductance (T_2 and T_3 in Fig. 3) to achieve the required minimum brightness. Originally, the number of turns required to achieve two percent of full brightness caused a substantial copper loss at high brightness settings. The method used was to make C_7, C_8 T_2 primary and T_3 primary self-resonant at minimum brightness.

The brightness control (R_4 in Fig. 3) is operated at a low power level and is separated from the lamp circuit to provide isolation from high voltages. It governs the dc control current to the magnetic amplifier, which is obtained from a small impedance matched supply (D_2 and C_9 in Fig. 3).

The value of R_4 was chosen with regard to other resistances in the circuit in order to obtain a logarithmic dimming-to-rotation correlation (see Fig. 4) with a linear potentiometer. This is desirable from a human engineering standpoint, as human visual response is approximately logarithmic.

The dimming performance of the system is excellent, brightness control is very stable and repeatible, and efficiency remains high (approximately 80 percent).

Thus, the design goal of continuous fluorescent dimming, in the context of the stringent requirements of manned spaceflight equipment, has been met, and in a package size of 1.3 cubic inches for the magnetic amplifier.

References

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