http://www.phantasmechanics.com/alf.html

ALF: The Asynchronous Lamp Flickerer

Text And Circuit Design By Scott Rider

Introduction

Hello, and welcome to the "howto" manual for the Asynchronous Lamp Flickerer ("ALF"). The ALF is the first in a series of lamp control devices suitable for theatrical lighting effects. The design goals of each device in this series is simple: low-cost, safe hardware that can be built with commonly available components from local electronic shops. I will try to keep each device as simple as possible, in most cases selecting components from the Radio Shack catalog. Radio Shack doesn't have the greatest variety in their selection of parts, but they do have the items needed to build the first three projects I have planned.

The Mechanics Of Flickering Light

The asthetic effects of flame-light are undeniable. A tiny flame, subject to the whims of air currents and variations in its fuel, will dance and oscillate with all the chaotic life an electric lamp never could... or could it? We'll get to that. For millenia humans sought comfort in the warmth and glow of fire. It drives back the darkness' hidden eyes, and a man huddled near his light was safe from the unknown.

Today, the world is lit by electricity. Even so, the century or so we've had to wire the world is nothing compared to the eon of years of fire man used since its discovery. Such a long time in the company of a tool such as fire cannot help but enter the equation of human evolution--a small variable, to be sure, but a distinct one nonetheless; the asthetics of flame are now part of our psyche.

Well, great--we like the light of flames. The problem in using it decoratively, however, is that it tends to burn things. Like houses. Unless a flame-light source is well-protected, it presents a potential fire hazard. What is needed is a way to control a safe light source in such a way so as to mimic the liveness of flame-light. Flame-light is most discernable by two properties: color and motion. The color, usually orange to yellow, is described as "warm" on the color scale of decorators (for the obvious reason that fires give off heat). The motion is what is most convincing, however. Flame-light sources actually move, causing the light-rays to change their incidence on objects. Since an object in the path of a light will cast a shadow, then if the light moves a little, the shadow also moves. It is the sharp contrast of surfaces being shadowed and lit by the "randomly" flickering light that convinces us that the light source is flame-light. (I say "random" because it isn't totally random. Like dripping faucets, the apparently random pattern of the drops, on in this case the flame movement, actually falls within a specified number of positions, but is random within those limits. Isn't chaos theory wonderful? :)

I've been working on a 4-channel flicker device, to be detailed here at a future date. While working with it, I discovered something: it is tougher to simulate a convincing lamp or candle flicker than it looks! The actual triac-lamp driver ciruit is simple enough, but the "random" voltage that drives this circuit is the curiousity...

Just driving the lamp circuit with random voltage isn't enough. It flickers allright, but it just doesn't seem natural. I decided to borrow a hurricane lamp from my mother to see what makes the flickering "real". After watching a while, it appears to have more of an oscillation than a random flicker. (I might note that a proper air/fuel mixture doesn't flicker much at all; it is when the air is too breezy or the fuel is too rich that it gets really noticable. Then, I went out to the family lake cottage and watched the gas lantern for a while. Similarly, the combustion inside the mantle envelope seems to oscillate in bursts. Sort of like this:

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The final item I observed was a guttering candle. It behaved in a much more random fashion, but even so the light was probably no more than 40% in varying intensity. Well, after some toying with circuits on my lab bench (now that I knew what waveforms were more or less responsible for the effect), I managed to work out a suitable prototype.

Electric Flame Light

Since Nikolai Tesla was kind enough to convince Thomas Edison to use alternating current (AC) in the transmission of electricity along power lines from generating stations to homes and businesses, it is fairly easy to control incandescent lighting. Side note: direct current (DC) lighting is also controlled without too much difficulty, but methods of controlling devices on the AC line are easier and more consistent. (Not to mention, the world isn't housewired for utility DC. :)

A bit of terminology: in the control of devices, a device, commonly called "the load," has two properties. The first is resistance. Resistance is the constricting of a flow of electrons along a path. A common example would be the heating wires in a toaster. As the current flows through the heater wire, it gets hot from the friction of the electrons banging around inside the metal of the wire as the metal "resists" the electrons' advance. The wire gives off heat--and light. Take the wire, put it in a glass envelope, evacuate the air in the envelope so the wire can't burn, and you have the good old incandescent lamp Edison made over a hundred years ago. Incandescent lamps are resistive loads.

The second property is a bit harder to explain. It is called *inductance.* An inductive load can store some of load-driving energy, and either kick that portion of energy back at the controlling device or consume it at a time other than when the electricity was delivered. This is possible because an inductive load sees the two components of AC electricity (voltage and current) as distinct elements that occur at slightly different times. (A resistive load does not--it sees the current and voltage simultaneously.)

Examples of inductive loads are electric motors and electric transformers. Both are essentially immense lengths of wire wound around bobbins which are in turn positioned on an iron core. Coils of wire have a special name as an electronic component: inductors. They get this name because they induce a magnetic flow in their core material. (Magnetism and electricity are closely related phenomena.) The end result is that electrical energy has been converted and stored on the core as magnetic energy. The act of converting and storing electromagnetic energy affects the load-driving electricity--it is this action that causes the voltage and current to become separated slightly versus time. If you've ever seen a power company substation, then doubtless you've seen those giant cylinders or boxes with the huge "rabbit ears" on top. Those objects are huge electronic components called capacitors--parts that store a voltage charge on a storage medium. Capacitors are the complement of inductors, and the huge ones at the substations are to help bring the separated voltage and current back together.

This whole business of separate current and voltage has its own engineering field of study--steady state analysis of multiphase AC systems. There is an overall term for the time-skewed voltage and current: power factor (P.F.) The P.F. is a number from 0 to 1; the ideal P.F. is 1, meaning the voltage and current are simultaneous. There are significant reasons for desiring a high P.F. The better the P.F., the more efficient the transfer of electrical power from generator to load. If the load is absorbing or reflecting too much (lowering the P.F.), then the power is wasted. Terms like "0.93 leading" or "0.87 lagging" are common in the jargon of power-plant employees. (Leading/lagging: is the voltage or current the one out in front.)

Now, why did I bother to tell you all this? Because the AC load control techniques are meant to be used on RESISTIVE LOADS ONLY! There are ways to control inductive loads, some of them even using the same parts, but the lamp control circuits presented in this series are not meant for inductive loads. In fact, trying to control a motor with this circuit will damage certain electronic components. Remember, resistive loads only.

A Word About Fluorescent Lighting

It used to be that fluorescent lights were essentially inductive loads. They had a heavy, transformer-related part in them called a ballast. The ballast was a series of voltage step-up coils, rectifiers and capacitors. The idea was to step the 120 volt AC power up to around 1,500V, a voltage sufficient to sustain the gas-discharge current that flowed from an electrode on one end of the lamp tube to the other. When those lamps started up, they had to have a "starting" voltage of about 2,500V in order to excite the cold gas atoms into conducting the current. After the conduction started, the tube voltage was automatically cut back to 1,500V.

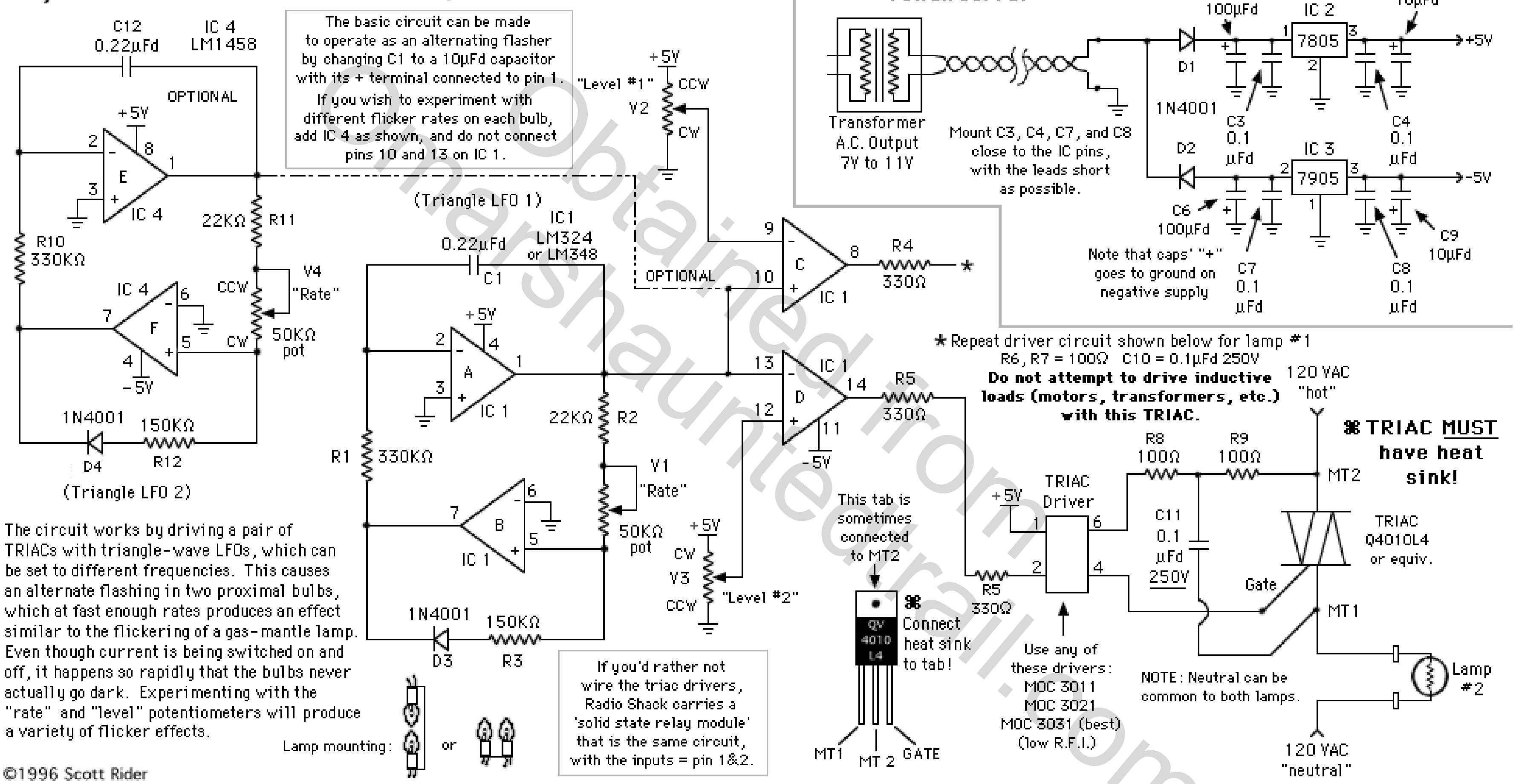
Today, most fluorescent fixtures use an electronic ballast; a charging circuit that develops the high-tension voltage. The circuit itself is much like that used in an electronic photoflash. (A flash tube usually fires for a few microseconds from a 4,000V trigger voltage, but otherwise uses the same charging circuit.) In this case, the circuit continually delivers the high voltage DC to the fluorescent tube, along with the higher starting voltage, when needed.

In either case, an incandescent lamp control will not operate fluorescent lights, unless the fluorescent fixture itself was designed to use AC control of lamp intensity. Fluorescent lighting control involves changing the amount of current flowing through the lamp tube. More current, more gas atoms give off UV rays to fluoresce on the phosphorescent tube coating painted inside the glass--more light. Less current, less UV to convert to visible light.

So, again, the flicker circuits are for incandescent lights only. Note: well, you can also drive heater loads with the lamp circuits (the lamp circuits are in fact derived from heater control systems), but heaters don't light up rooms very well. :) Besides, there is a 300W maximum lamp load on each lamp output, and few heaters are that low-power.

Asynchronous Lamp Flickerer (ALF)

Asynchronous Flicker Circuit By Scott Rider



The circuit works by driving a pair of TRIACs with triangle-wave LFOs, which can be set to different frequencies. This causes an alternate flashing in two proximal bulbs, which at fast enough rates produces an effect similar to the flickering of a gas-mantle lamp. Even though current is being switched on and off, it happens so rapidly that the bulbs never actually go dark. Experimenting with the "rate" and "level" potentiometers will produce a variety of flicker effects.

What ALF does is provide a method of simulating candlelight or gaslight, using a circuit that can be built for about $35. All of the electronic components can be purchased at Radio Shack. I might remark, however, that parts purchased via popular mail-order firms such as Digi-Key will be significantly less expensive. (Exact same parts, too!)

ALF is an "asynchronous" controller. What this means is that, unlike a household lamp dimmer, the control signal that turns on the lamp is not synchronized to the AC line. A synchronous controller (lamp dimmer) will always provide an adjustable intensity where each intensity is stable and does not jitter around. Since a synchronous controller is re-synced every 120th of a second, the lamp will be triggered at the exact same time from the sync point. The result is a steady brightness.

In the case of the asynchronous controller, when set to some intensity less than full on the lamp will flicker erratically as it turns on and off. The AC line and the flicker rate aren't synced together and the lamp lights at varying times from the AC line's "zero" points. (The zero points are what a synchronous controller uses for the synchronization.)

This asynchronous flicker can be put to good use, however:

By following the circuit schematic, note that there are 4 distinct sections: the low-frequency oscillator(s), the level comparators, the triac driver circuits and the DC power supply. Analysing them in in order:

Low-frequency oscillator (LFO). This circuit section uses two operational amplifiers and a few other parts to generate a low-voltage "triangle" waveform. A triangle waveform is an electrical voltage pattern that, well, looks like an endless row of triangles: /\/\/\/\/\/\/\/\/\/\/\/\ How many triangles per second (the frequency) generated is adjustable by the variable resistor V1. The minimum rate is about 8 to 10Hz, the maximum is around 70Hz or so. The voltage output swings from 0 volts to about 4 volts.

Level comparators. The triangle waveform is connected to one input of an op-amp, and a level control to the other. When the triangle slope gets as high as the voltage on the level control, the op-amp output will turn on until the triangle slope falls below the the voltage on the level control. Note there are two level comparators; each is wired with an opposite input polarity. (V2 control goes to "-" input of op-amp C, while V3 control goes to "+" input of op-amp D). The reason for this is to allow one lamp to turn on when the other is off (and vice cersa). The level controls allow some overlap, however.

Triac drivers. This is the standard circuit used to drive resistive AC loads with triacs. The op-amps in the comparator circuit section will turn on a small light-emitting diode buried in the triac driver. This light will be sensed by the triac driver circuit also buried in the plastic of the part and turn on the triac, which lights up the AC lamp. Triacs, by the way, are close cousins of SCRs, that is, silicon controlled rectifiers. However, since an SCR is a rectifier, it will only allow half the AC to pass through it, provided the SCR is "turned on" by a signal on its gate pin. Triacs are similar to two SCRs with the gates coannected, the anode of SCR1 connected to the cathode of SCR2 and vice versa. Much easier to use a single triac, however. Side note: inductive loads are frequently operated by inverse-parallel SCRs (back-to-back SCRs). Power supply: +5 and -5 volts DC are used to run the actual circuit doing the flickering. Heat sinks are not needed on the regulator ICs.

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Parts List: (using Radio Shack catalog numbers)

ID Part# Description RS cat# qty. price

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IC1 LM324 Quad op-amp IC 276-1711 1 $1.29
IC2 7805 +5VDC regulator 276-1770 1 $1.49
IC3 7905 -5VDC regulator RSU 11513736 1 $1.49
IC4* LM458 Dual op-amp IC 276-038 1 $0.99
--- MOC3010 Triac Driver IC 276-134 2 $1.99 ea
--- Q4010L4 400V, 6A Triac 276-1000 2 $1.49 ea

R1 330K 1/4 watt resistor RSU 11345352 1 5 for $0.49
R2 22K 1/4 watt resistor 271-1339 1 5 for $0.49
R3 150K 1/4 watt resistor RSU 11345287 1 5 for $0.49
R4,R5 330 ohm 1/4 watt resistor 271-1315 2 5 for $0.49
R6-R9 100 ohm 1/4 watt resistor 271-1311 4 5 for $0.49
R10* 330K 1/4 watt resistor (use spare from 330K pack for R1)
R11* 22K 1/4 watt resistor ( " " " 22K " " R2)
R12* 150K 1/4 watt resistor ( " " " 150K " " R3)

C1 0.22 uF dipped mylar cap. 272-1070 1 2 for $0.89
C2,C6 100 uF aluminum cap. 272-1028 2 $0.99 ea
C3,C4 0.1 uF monolithic cap. 272-109 4 5 for $1.89
C7,C8
C5,C9 10 uF aluminum cap. 272-1025 2 $0.59 ea
C10,11 0.1 uF metal film cap. 272-1053 2 $0.79 ea
C12* 0.22 uF dipped mylar cap. (use spare from 0.22 pack for C1)

V1-V3 50K potentiometer 271-1716 3 $1.49 ea

D1-D4 1N4001 1 amp rectifier 276-1101 4 2 for $0.49 ea
XFMR wallpak 9 VAC output 273-1455 1 $7.99
(alt. 273-1665 $7.99)

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subtotal: $35.63
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Jeez, I didn't realize how expensive Radio Shack parts were until I tallied this up! This is about twice the cost of ordering the same parts from an industrial supplier. For those who know about mail-order parts houses like Digi-Key, they will be cheaper than Radio Shack.

You might want to get a small enclosure for the project at Radio Shack; they have several different sizes/styles of boxes to choose from.

Triac notes:

1) You MUST use heatsinks on the triacs. Radio Shack sells them, cat# 276-1363. Two are needed. Alternatively, use small pieces of sheet metal. Do NOT mount the triacs to the same heatsink. Also do not mount the triacs to the side of an enclosure.

2) Radio Shack seems to have more than one manufacturer's model of the 400V, 6A triac. The pinouts for the triac *should* match the picture on the flicker1.gif image, but sometimes a different pinout will be printed on the package of the part. Use that pinout instead.

3) The mounting tab of the triac may or may not be connected to the middle triac pin. I wish Radio Shack would pick one specific triac manufacturer and model and stick with it. It is possible to have a 400V, 6A triac with the tab hooked to the middle pin, and it is also possible to have a 400V, 6A triac where the tab is isolated. Treat all triacs as if the tab was connected to a pin: don't attach the triac to the side of an enclosure, don't let exposed wires or parts touch the tab. Don't let the heatsink touch the case or wires/parts either. Don't let the triacs touch each other, or their heatsinks.

Adjusting the controls:

There is no "official" setting for the controls; what they are set to is largely a matter of taste. The "rate" control will make the flicker of the AC lamps go from a slow, "popping" action all the way up to a quick, nearly constant light. The "level" controls will go from making each lamp dark all the way up to 100% on. The basic idea is to set the "rate" to a pleasing flicker speed, then set one of the "level" controls such that a lamp flickers then goes dark for a moment at about a 75% on, 25% off cycle. Then, set the other "level" control so that the second lamp comes at just before the first one turns off. This way, the flickering will appear to jump up and down, like a gas mantle. Experiment with the controls; this is the only way to really learn how to make various kinds of flicker simulations.