

# Sam's F-Lamp FAQ

## Fluorescent Lamps, Ballasts, and Fixtures

### Principles of Operation, Circuits, Troubleshooting, Repair

### Version 1.90

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Samuel M. Goldwasser  
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Corrections or suggestions to: [sam@stdavids.marconimed.com](mailto:sam@stdavids.marconimed.com)

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## Preface

### Author and Copyright

Author: Samuel M. Goldwasser

Corrections/suggestions: [sam@stdavids.marconimed.com](mailto:sam@stdavids.marconimed.com)

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### Acknowledgements

Thanks to Don Klipstein ([don@misty.com](mailto:don@misty.com)) for his comments and additions to this document. His Web site (<http://www.misty.com/~don/>) is a valuable resource for information relating to lighting technology in general and also includes additional articles dealing with fluorescent and other discharge lamps.

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# Introduction

## Fluorescent Lamp Basics

The fluorescent lamp was the first major advance to be a commercial success in small scale lighting since the tungsten incandescent bulb. Its greatly increased efficiency resulted in cool (temperature wise) brightly lit workplaces (offices and factories) as well as home kitchens and baths. The development of the mercury vapor high intensity discharge (HID) lamp actually predates the fluorescent (the latter being introduced commercially in 1938, four years after the HID). However, HID type lamps have only relatively recently become popular in small sizes for task lighting in the home and office; yard and security area lighting; and light source applications in overhead, computer, and video projectors.

Fluorescent lamps are a type of gas discharge tube similar to neon signs and mercury or sodium vapor street or yard lights. A pair of electrodes, one at each end - are sealed along with a drop of mercury and some inert gases (usually argon) at very low pressure inside a glass tube. The inside of the tube is coated with a phosphor which produces visible light when excited with ultra-violet (UV) radiation. The electrodes are in the form of filaments which for preheat and rapid or warm start fixtures are heated during the starting process to decrease the voltage requirements and remain hot during normal operation as a result of the gas discharge (bombardment by positive ions).

When the lamp is off, the mercury/gas mixture is non-conductive. When power is first applied, a high voltage (several hundred volts) is needed to initiate the discharge. However, once this takes place, a much lower voltage - usually under 100 V for tubes under 30 watts, 100 to 175 volts for 30 watts or more - is needed to maintain it.

The electric current passing through the low pressure gases emits quite a bit of UV (but not much visible light). The gas discharge's radiation is almost entirely mercury radiation, although the gas mixture is mostly inert gas and generally around something like 1 percent mercury vapor. The internal phosphor coating very efficiently converts most of the UV to visible light. The mix of the phosphor(s) is used to tailor the light spectrum to the intended application. Thus, there are cool white, warm white, colored, and black light fluorescent (long wave UV) lamps. There are also lamps intended for medical or industrial uses with a special envelope such as quartz that passes short wave UV radiation. Some have an uncoated envelope, and emit short-wave UV mercury radiation. Others have phosphors that convert shortwave UV to medium wave UV.

(Caution: Some specialty UV lamps emit shortwave or medium wave UV which is harmful and should not be used without appropriate protection or in an enclosure which prevents the escape of harmful UV radiation.)

Fluorescent lamps are about 2 to 4 times as efficient as incandescent lamps at producing light at the wavelengths that are useful to humans. Thus, they run cooler for the same effective light output. The bulbs themselves also last a lot longer - 10,000 to 20,000 hours vs. 1000 hours for a typical incandescent. However, for certain types of ballasts, this is only achieved if the fluorescent lamp is left on for long periods of time without frequent on-off cycles.

## Fluorescent Lamp Labeling

The actual fluorescent tubes are identified by several letters and numbers and will look something like 'F40CW-T12' or 'FC12-T10'.

So, the typical labeling is of the form FSWWCCC-TDD (variations on this format are possible):

- F - Fluorescent lamp. G means Germicidal shortwave UV lamp.

- S - Style - no letter indicates normal straight tube; C for Circline.
- WW - Nominal power in Watts. 4, 5, 8, 12, 15, 20, 30, 40, etc.
- CCC - Color. W=White, CW=Cool white, WW=Warm white, BL/BLB=Black light, etc.
- T - Tubular bulb.
- DD - Diameter of tube in of eighths of an inch. T8 is 1", T12 is 1.5", etc.

For the most common T12 (1.5 inch) tube, the wattage (except for newer energy saving types) is usually 5/6 of the length in inches. Thus, an F40-T12 tube is 48 inches long.

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## Safely Working with Fluorescent Lamps and Fixtures

There aren't many dangers associated with typical fluorescent lamps and fixtures:

- Electric shock. There is usually little need to probe a live fixture. Most problems can be identified by inspection or with an ohmmeter or continuity tester when unplugged.
  - Fluorescent lamps and fixtures using iron ballasts are basically pretty inert when unplugged. Even if there are small capacitors inside the ballast(s) or for RFI prevention, these are not likely to bite. However, you do have to remember to unplug them before touching anything!
  - However, those using electronic ballasts can have some nasty charged capacitors so avoid going inside the ballast module and it won't hurt to check between its outputs with a voltmeter before touching anything. Troubleshooting the electronic ballast module is similar to that of a switchmode power supply. See the document: [Notes on the Troubleshooting and Repair of Small Switchmode Power Supplies](#)
- Nasty chemicals: While the phosphors on the inside of fluorescent tubes are not particularly poisonous, there is a small amount of metallic mercury and contact with this substance should be avoided. If a tube breaks, clean up the mess and dispose of it properly and promptly. Of course, don't go out of your way to get gut on the broken glass!

And take care around sharp sheet metal!

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## Fluorescent Fixtures and Ballasts

### Fluorescent Fixtures

The typical fixture consists of:

- Lamp holder - the most common is designed for the straight bipin base bulb. The 12, 15, 24, and 48 inch straight fixtures are common in household and office use. The 4 foot (48") type is probably the most widely used size. U shaped, circular (Circline(tm).) and other specialty tubes are also available.
- Ballast(s) - these are available for either 1 or 2 lamps. Fixtures with 4 lamps usually have two ballasts.

See the sections below on ballasts. The ballast performs two functions: current limiting and providing the starting kick to ionize the gas in the fluorescent tube(s).

- Switch - on/off control unless connected directly to building wiring in which case there will be a switch or relay elsewhere. The power switch may have a momentary 'start' position if there is no starter and the ballast does not provide this function.
- Starter (preheat fixtures only) - device to initiate the electrode preheating and high voltage "kick" needed for starting. In other fixture types, the ballast handles this function.

## Fluorescent Lamp Ballasts

For a detailed explanation, check your library. Here is a brief summary.

A ballast serves two functions:

1. Provide the starting kick.
2. Limit the current to the proper value for the tube you are using.

In the old days fluorescent fixtures had a starter or a power switch with a 'start' position which is in essence a manual starter. Some cheap ones still do use this technology.

The starter is a time delay switch which when first powered, allows the filaments at each end of the tube to warm up and then interrupts this part of the circuit. The inductive kick as a result of interrupting the current through the inductive ballast provides enough voltage to ionize the gas mixture in the tube and then the current through the tube keeps the filaments hot - usually. You will notice that a few iterations are sometimes needed to get the tube to light. The starter may keep cycling indefinitely if either it or one of the tubes is faulty. While the lamp is on, a preheat ballast is just an inductor which at 60 Hz (or 50 Hz) has the appropriate impedance to limit the current to the tube(s) to the proper value.

Ballasts must generally be fairly closely matched to the lamp in terms tube wattage, length, and diameter.

## Types of Iron Ballasts

Instant start, trigger start, rapid start, etc. ballasts include loosely coupled high voltage windings and other stuff and do away with the starter:

1. The ballast for a preheat fixture (combined with a starter or power switch with a 'start' position) is basically a series inductor. Interrupting current through the inductor provides the starting voltage.
2. The ballast for a rapid start fixture has in addition small windings for heating the filaments reducing the required starting voltage to 250 to 400 V. There are probably the most common types in use today. Trigger start fixtures are similar to rapid start fixtures.
3. The ballast for an instant start fixture has a loosely coupled high voltage transformer winding providing about 500 to 600 V for starting in addition to the series inductor. The electrodes of "instant start" bulbs are designed for starting without preheating. In fact, they are shorted out internally and are thus incompatible with preheat and rapid start ballasts (and they have only a single pin at each end!). The electrodes still emit electrons due to thermal emission but since they are shorted out cannot be pre-heated. That is why they require a higher starting voltage from the ballast. They they light instantly, but this slightly reduces lamp life.

Starting voltage is either provided by the inductive kick upon interruption of the current bypassed through the starter for (1) or a high voltage winding in (2) and (3).

In all cases, the current limiting is provided primarily by the impedance of the series inductance at 60 Hz (or 50 Hz depending on where you live).

(From: Vic Roberts (kirther@ix.netcom.com).)

The most basic ballast is nothing more than a current limiting device, such as an inductor, resistor or capacitor. For 50 and 60 Hz applications, the most common current limiting device is an inductor.

A simple current limiter works best when the line voltage is at least 2 times the lamp voltage. So, a simple inductor can be used in Europe, where the line voltage is 220 to 240 VAC, to operate a 4 foot lamp, which operates at 85 to 100 volts, depending upon design.

In the US and other places that use 120 VAC lines the ballast is a combination autotransformer (to raise the voltage) and inductor (the current limiter).

In addition, a Rapid Start ballast has additional windings to supply about 3.6 VAC to heat the filaments.

(From: Asimov (Asimov@juxta.mn.pubnix.ten).)

A ballast is a simple transformer with a very high impedance secondary winding which makes its current self-limiting. It also has windings for each lamp filaments. At startup the filaments get most of the power and heat up to facilitate ionization.

Meanwhile the secondary builds up a very high EMF which finally fully ionizes the plasma between both filaments. At this point the effective resistance of the conducting plasma is quite low and the current flow is limited by the secondary's impedance. This also partially saturates the core and as consequence reduces power to the filaments.

The usual failure in ballasts is that the secondary's insulation deteriorates and it starts leaking to ground. Often because the proper wiring polarity was not observed. The secondary can thus no longer generate the high EMF required to start the plasma conducting.

The KISS test method is to use a known good lamp. If it lights, the ballast is good too. The ballast can also be tested with the power off by checking for continuity in the filament windings and a very high resistance to ground for each filament. Don't try this with power on!

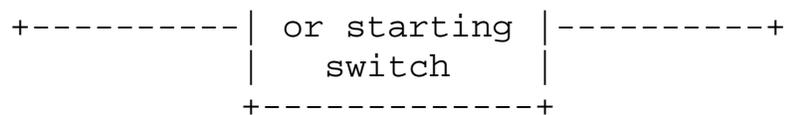
(From: Craig J. Larson (larson@freenet.msp.mn.us).)

Call Magnetek, a ballast manufacturer on 1-800-BALLAST. Ask for a copy of their Troubleshooting & Maintenance Guide for Linear Fluorescent Lighting Systems. Its a nice little guide book for teaching you the basics.

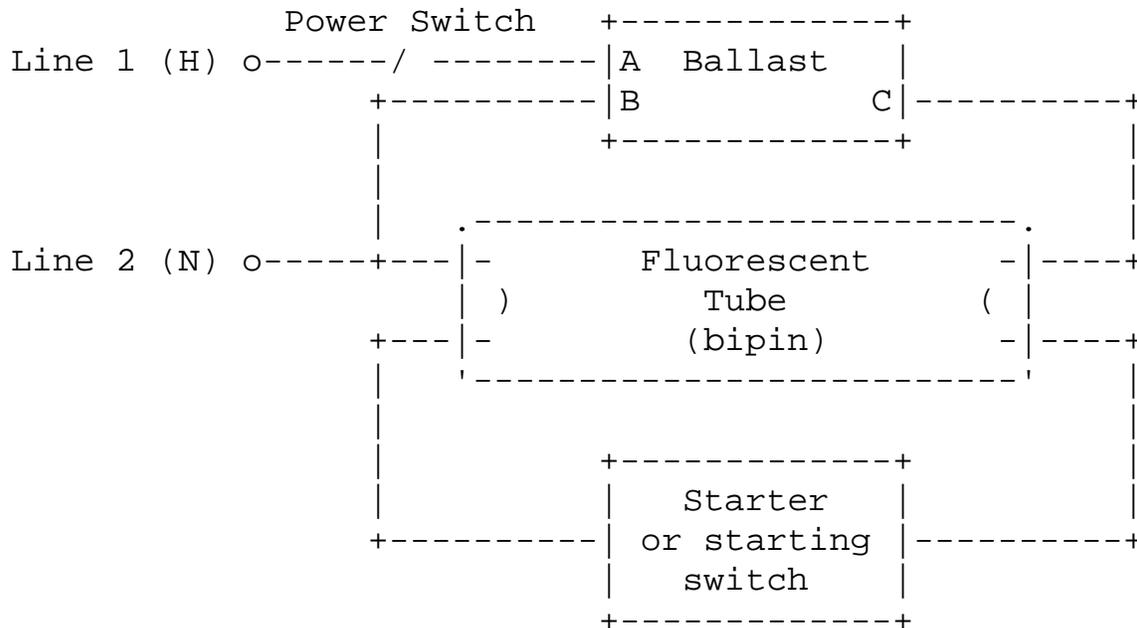
## Electronic Ballasts

These devices are basically switching power supplies that eliminate the large, heavy, 'iron' ballast and replace it with an integrated high frequency inverter/switcher. Current limiting is then done by a very small inductor, which has sufficient impedance at the high frequency. Properly designed electronic ballasts should be very reliable. Whether they actual are reliable in practice depends on their location with respect to the heat produced by the lamps as well as many other factors. Since these ballasts include rectification, filtering, and operate the tubes at a high frequency, they also usually eliminate or greatly reduce the 100/120 Hz flicker associated with iron ballasted systems. However, this is not always the case and depending on design (mainly how much filtering there is on the rectified line voltage), varying amounts of 100/120 can still be present.





Here is a variation that some preheat ballasts use. This type was found on a F13-T5 lamp fixture. Similar types are used for 30 and 40 watt preheat lamps. This 3-lead preheat ballast is a voltage-boosting "high leakage reactance autotransformer" used if the voltage across the tube is much over approx. 60 percent of the line voltage. For technical details on why a fluorescent lamp will not work with ordinary ballasts if the tube voltage is only slightly less than the line voltage, look at Don Klipstein's [Discharge Lamp Mechanics document](#).



## Fluorescent Starter Operation

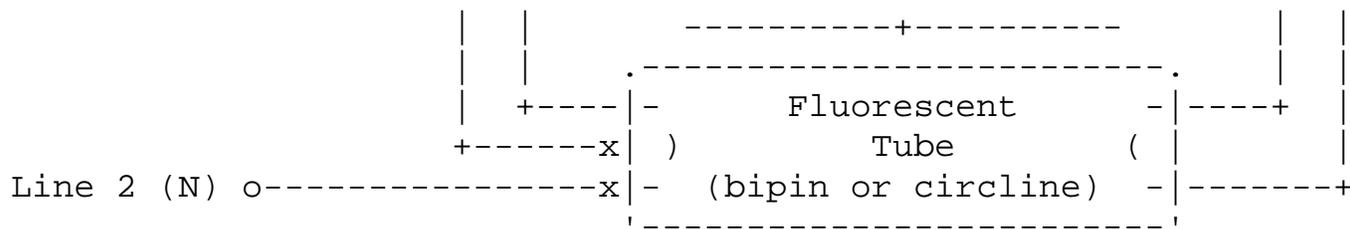
Starters may be either automatic or manual:

- Automatic - The common type are called a 'glow tube starter' (or just starter) and contains a small gas (neon, etc.) filled tube and an optional RFI suppression capacitor in a cylindrical aluminum can with a 2 pin base. While all starters are physically interchangeable, the wattage rating of the starter should be matched to the wattage rating of the fluorescent tubes for reliable operation and long life.

The glow tube incorporates a switch which is normally open. When power is applied a glow discharge takes place which heats a bimetal contact. A second or so later, the contacts close providing current to the fluorescent filaments. Since the glow is extinguished, there is no longer any heating of the bimetal and the contacts open. The inductive kick generated at the instant of opening triggers the main discharge in the fluorescent tube. If the contacts open at a bad time - current near zero, there isn't enough inductive kick and the process repeats.

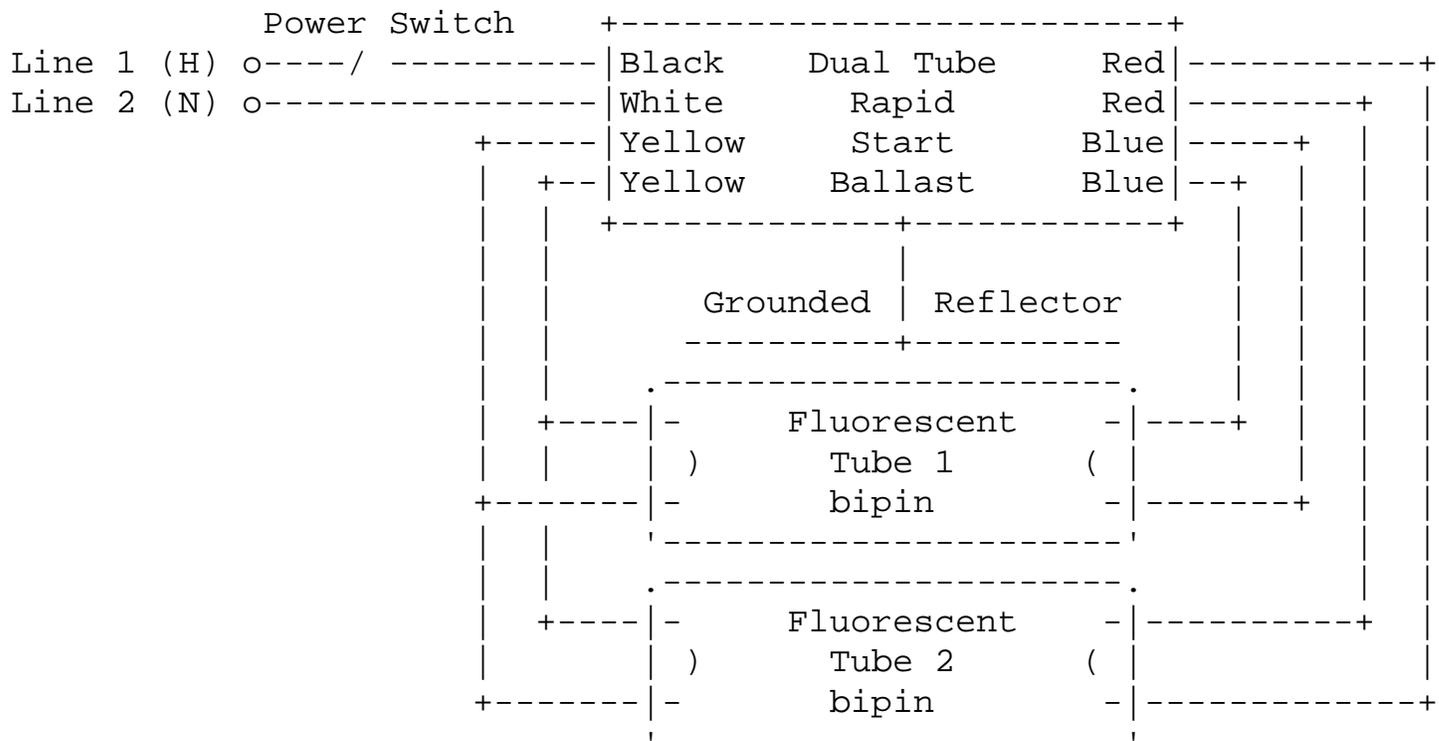
Higher-tech replacements called 'pulse starters' may be available for the simple glow tube type starter. These devices are pin compatible devices and contain a bit of electronics that detect the appropriate time to interrupt the filament circuit to generate the optimal inductive kick from the ballast. So, starting should be more reliable with few/no blink cycles even with hard-to-start lamps. They will also leave used-up





## Wiring Diagram for Two Tube Rapid Start Ballast

The following wiring diagram is for one pair (from a 4 tube fixture) of a typical rapid start 48 inch fixture. These ballasts specify the bulb type to be F40-T12 RS. There is no safety interlock on this fixture. (A similar scheme could also be used on a dual tube Circline fixture though slightly different ratings may be needed for each tube since they would be of different sizes.)



## Schematic of Typical Rapid/Trigger Start Single Lamp Ballast

This ballast is marked "Trigger Start Ballast for ONE F20WT12, F15WT12, F15WT8, or F14WT12 Preheat Start Lamp. Mount tube within 1/2" of grounded metal reflector".

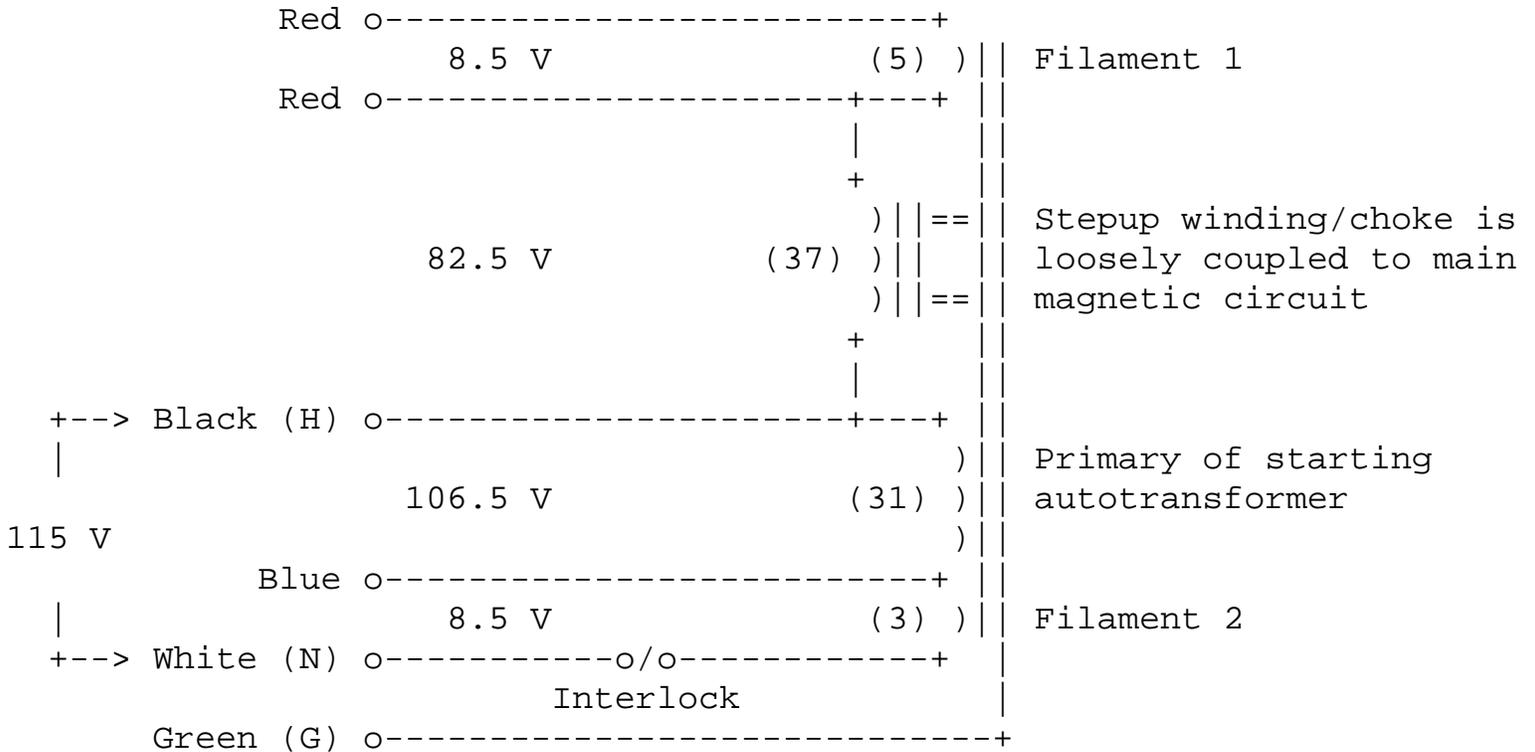
Voltages were measured with no bulb installed with safety interlock bypassed.

Internal wiring has been inferred from resistance and voltage measurements.

The lossy autotransformer boosts line voltage to the value needed for reliable starting with the filaments heated. It is assumed that part of the magnetic circuit is loosely coupled so that putting the lamp between Red/Red and Blue/White results in safe current limited operation once the arc has struck.

A complete fixture wiring diagram like those shown in the section: [Wiring for Rapid Start and Trigger Start Fixtures](#) will probably be provided on the label.

Numbers in ( ) are measured DC resistances.

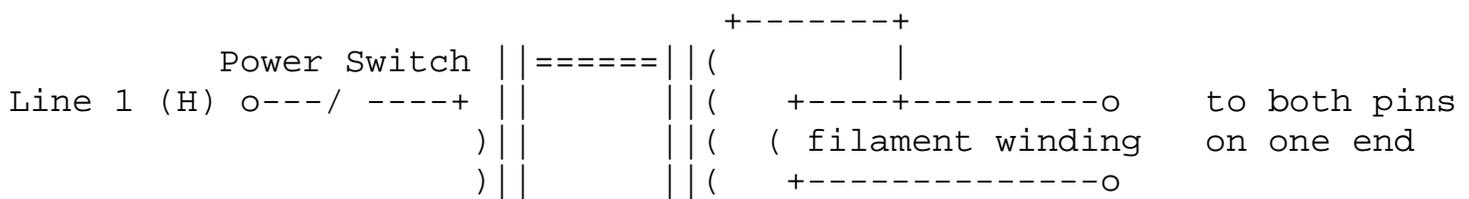


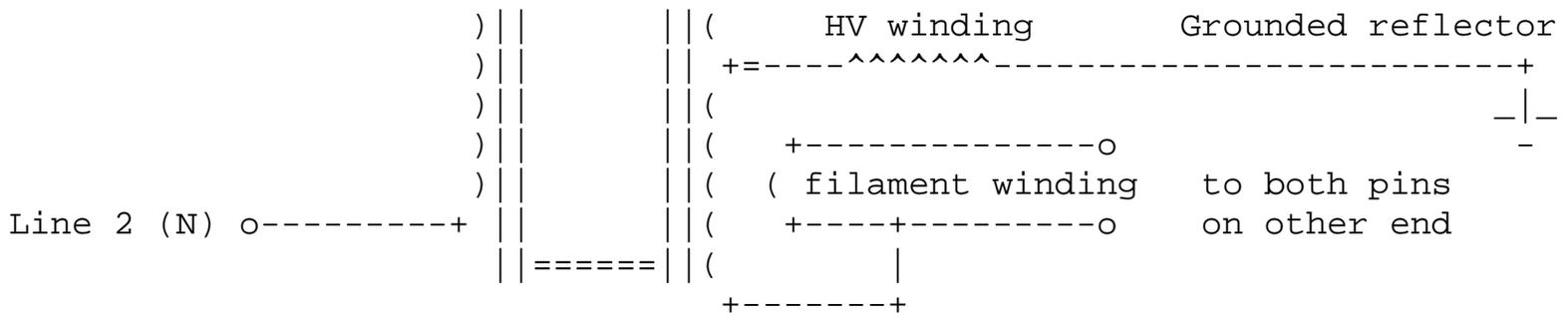
## Schematic for Rapid Start Ballast with Isolated Secondary

As noted, rapid start fixtures do not have a separate starter or starting switch but use auxiliary windings on the ballast for this function. Here is the schematic for a typical 1-tube rapid start fixture including the internal wiring of the ballast.

This ballast includes separate windings for the filaments and a high voltage winding that is on a branch magnetic circuit that is loosely coupled and thus limits the current once the arc is struck. It is not known if this design is common. The isolated secondary and separate high voltage winding would make it more expensive to manufacture.

A complete fixture wiring diagram like those shown in the section: [Wiring for Rapid Start and Trigger Start Fixtures](#) will probably be provided on the label.





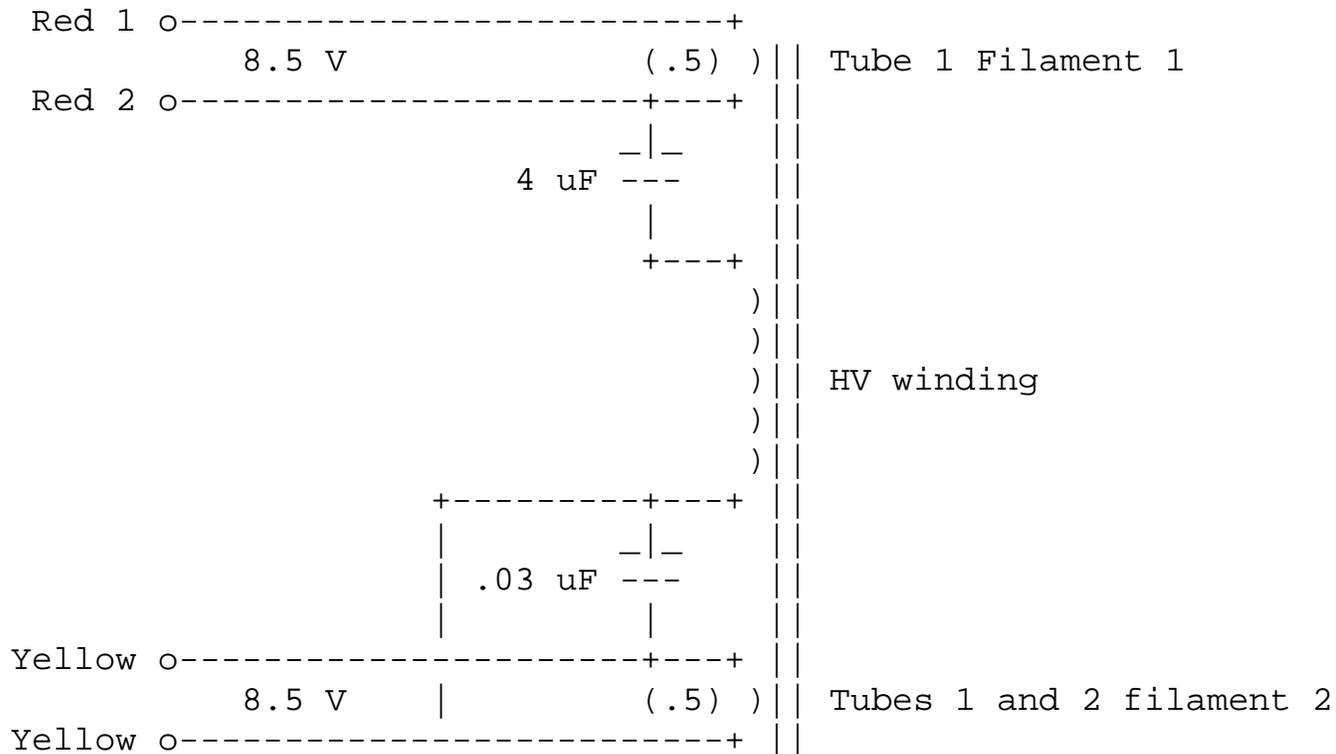
Loose magnetic coupling in the ballast core results in leakage inductance for current limiting.

## Schematic of Rapid Start Dual Lamp Ballast

This ballast is marked "Rapid Start Ballast for TWO F40WT12 Lamps. Mount tubes within 1/2" of grounded metal reflector". This circuit was derived from the measurements listed in the section: [Measurements of a Dual Tube Rapid Start Ballast](#).

The autotransformer boosts line voltage to the value needed for reliable starting with the filaments heated. The series capacitor of approximately 4 uF is used instead of leakage inductance to limit current to the tubes. Leakage inductance from loose magnetic coupling is used to smooth the waveform of current flowing through the tubes. The .03 uF capacitor provides a return path during starting to the yellow filament winding but is not really used during normal operation.

Numbers in ( ) are approximate measured DC resistances.









Note: The interlock normally present on most rapid/trigger start fixtures have been removed to permit one lamp to operate if other is removed.

For preheat ballasts, wiring the filaments in parallel would probably result in insufficient current to either lamp for it to start reliably. If the filaments were wired in series, one lamp would probably start, but if the filament of one lamp burned out or the lamp was removed, the fixture would cease to function kind of defeating the purpose of these gyrations!

## Wiring Fluorescent Lamps to Remote Ballasts

For reasonable distances, this should work reliably and be safe provided that:

1. This is only attempted with iron ballasts. The fire safety and reliability of electronic ballasts that are not in close proximity to the lamps is unknown. The ballast may fail catastrophically either immediately or a short time later as the circuit may depend on a low impedance (physically short) path for stability.

In addition, there will almost certainly be substantial Radio Frequency Interference (RFI) created by the high frequency currents in the long wires. The FCC police (or your neighbors) will come and get you! This may be a problem with iron ballasts as well - but probably of less severity.

2. Wire of adequate rating is used. The starting voltage may exceed 1 kV. Make sure the insulation is rated for at least twice this voltage. Use 18 AWG (or heavier) gauge wire.
3. There is no possibility of human contact either when operating or if any connectors should accidentally come loose - dangerous line voltage and high starting voltage will be present with tubes disconnected.

Note: one application that comes up for this type of remote setup is for aquarium lighting. My recommendation would be to think twice about any homebrew wiring around water. A GFCI may not help in terms of shock hazard and/or may nuisance trip due to inductive nature of the ballast (both depend at least in part on ballast design).

## Wiring diagram of Low Power 220 VAC Fluorescent Lamp

(From: Manuel Kasper (mk@mediaklemm.com).)

The circuit in [Low Power 220 VAC Fluorescent Lamp](#) is from an AC line powered 'light stick'. So there's no fancy inverter circuit inside, but a simple ballast without any nasty coils - just capacitors, resistors, and diodes. A few modifications would probably be necessary to make it operate from 110 VAC. It runs the tube brighter than a similar lamp power from a 12 V inverter. (See the section: "Automotive Light Stick Inverter" in the document: [Various Schematics and Diagrams](#). FWIW, the brand is "Brennenstuhl".

It was damn hard to open up because everything was made out of thick plastic with no screws (no wonder; it cost \$6) - but thanks to a huge saw I managed to get at the guts without destroying the tube or the circuit.

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# Specialty Fluorescent Lamp Types

## All Sorts of Less Conventional Lamps

In addition to the boring white ones (OK, well 'white' does come in various colors!), other interesting types of lamps include all sorts of real colors (red, green, blue, yellow), blacklight lamps, germicidal lamps in which there is no phosphor coating at all and a quartz tube to transmit short-wave UV light (e.g., EPROM erasers and PCB photoresist activation), sunlamps, plant lights and special purpose specific wavelength lamps such as reprography and copier lamps.

The basic technology is extremely flexible!

(From: Bruce Potter (s602531@aix2.uottawa.ca).)

There are also High Output and Very High Output types of lamps that have a discharge current of 0.8 A and 1.5 A instead of the standard 0.3 A. HO and VHO lamps are used when high light output is desired but are being outmoded by HID lamps like metal halide.

## Blacklight Fluorescent Lamps

(From: Don Klipstein (don@misty.com).)

BL in the tube designation (e.g., F40T12BL) means "blacklight", which is a fluorescent lamp with a phosphor that emits the longest largely invisible UV wavelengths that are both efficiently and fairly cheaply possible. This phosphor seems to emit a band of UV mainly from 350 to 370 nanometers, in the UV-A range.

BLB means "blacklight-blue", which differs from "blacklight" only in that the glass tube of this lamp is darkly tinted with something with a dark violet-blue color to absorb most visible light. Most UV gets through this, along with much of the dimly visible deep-violet 404.7 nanometer line of mercury. Most of the violetish-blue 435.8 nanometer line is absorbed, but enough of this wavelength gets through to largely dominate the color of the visible light from this lamp. Longer visible light wavelengths do not significantly penetrate the BLB's very deep violet-blue glass, which is known as 'Wood's glass'. The UV is the same as that of the BL lamp, being mostly between 350 and 370 nanometers.

There is a 350BL blacklight lamp, using a different phosphor that emits a band of slightly shorter UV wavelengths in the UV-A range. The reasoning for this lamp is that it is supposedly optimized for attracting insects. These lamps are one variety of UV lamps used in electric bug killers.

There are other UV fluorescent lamps. There are at least two different UV/deep violet emitting fluorescent lamps used mainly in the graphic arts industry, emitting mainly wavelengths between 360 and 420 nanometers. Possibly one of these is also used in bug killers. I have noticed one kind of UV fluorescent lamp for bug killers with a broadish band phosphor with significant output from the 360 nanometer range (maybe also shorter) into visible wavelengths around 410 to 420 nanometers or so.

There is an even shorter UV-A lamp used for suntanning purposes. I would guess the phosphor emits mainly within the 315 to 345 nanometer range. One brand of such lamps is "Uvalux".

There is even a UV-B emitting fluorescent lamp. Its phosphor emits mostly at UV-B wavelengths (286 to 315 nanometers). It is used mainly for special medicinal purposes. Exposing skin to UV-B causes erythema, which is to some extent a burn reaction of the skin to a slightly destructive irritant. Use of UV-B largely limits this to outer layers of the skin (perhaps mainly the epidermis) and to parts of the body where skin is thinner. UV-A

wavelengths just over 315 nanometers can also cause sunburn, but they are more penetrating and can affect the dermis. Please note that the deadliest varieties of skin cancer usually originate in the epidermis and are usually most easily caused by UV-B rays.

There are clear UV-emitting lamps made of a special glass that lets through the main shortwave UV (UV-C) mercury radiation at 253.7 nanometers. These lamps are marketed as germicidal lamps, and ones in standard fluorescent lamp sizes have part numbers that start with G instead of F. These lamps will work in standard fluorescent lamp fixtures.

Cold-cathode germicidal lamps are also in use; these somewhat resemble "neon" tubing.

Be warned that the shortwave UV emitted by germicidal lamps is intended to be dangerous to living cells and is hazardous, especially to the conjunctiva of eyes. Signs of injury by the UV are often delayed, often first becoming apparent several minutes after exposure and peaking out a half hour to several hours afterwards.

Please note that non-fluorescent (high pressure mercury vapor discharge) sunlamps generally emit more UV-B rays rather than the tanning-range UV-A rays. These lamps do have substantial UV-A output, but mainly at a small cluster of wavelengths around 365 nanometers. Tanning is most effectively accomplished by wavelengths in the 315-345 nanometer range. In addition, no UV suntanning is completely safe.

## Compact Fluorescent Lamps

These are miniaturized fluorescent lamps that usually have premium phosphors which often come packaged with an integral ballast (either iron or electronic). They typically have a standard screw base that can be installed into nearly any table lamp or lighting fixture that accepts an incandescent lamp.

Compact fluorescents are being heavily promoted as energy savings alternatives to incandescent lamps. They also have a much longer life - 6,000 to 20,000 hours compared to 750 to 1000 hours for a standard incandescent. While these basic premises are not in dispute - all is not peaches and cream:

1. They are often physically larger than the incandescent bulbs they replace and simply may not fit the lamp or fixture conveniently or at all.
2. The funny elongated or circular shape may result in a less optimal lighting pattern.
3. The light is generally cooler - less yellow - than incandescents - this may be undesirable and result in less than pleasing contrast with ordinary lamps and ceiling fixtures. Newer models have been addressing this issue.
4. Some types (usually iron ballasts) may produce an annoying 120 Hz (or 100 Hz) flicker.
5. Ordinary dimmers cannot be used with compact fluorescents.
6. Like other fluorescents, operation at cold temperatures (under around 50-60 degrees F) may result in reduced light output. Starting may also be erratic, although most compact fluorescent lamps seem to start OK at temperatures near freezing. Many types start OK near zero degrees F. Operation in an enclosed fixture often results in full light output in cool surroundings after the lamp warms up for a few minutes, as long as the initial temperature is high enough to permit a good start. However, enclosing compact fluorescents often impairs their ability to work well at higher temperatures.
7. There may be an audible buzz from the ballast.
8. They may produce Radio Frequency Interference (RFI).
9. The up-front cost is substantial (unless there is a large rebate): \$10 to \$20 for a compact fluorescent to replace a 60 W incandescent bulb!
10. Due to the high up-front cost, the pay-back period may approach infinity.

11. While their life may be 20,000 hours, a wayward baseball will break one of these \$10 to \$20 bulbs as easily as a 25 cent incandescent.

Nonetheless, due to the lower energy use and cooler operation, compact fluorescents do represent a desirable alternative to incandescents. Just don't open that investment account for all your increased savings just yet!

For more information, see the separate document on [Compact Fluorescent Lamps](#).

## Cold Weather Fluorescent Lamps

(From: Bruce Potter (s602531@aix2.uottawa.ca).)

There are special lamps with heavy glass jackets and/or with krypton gas filling for cold weather/freezer applications. They work best at below room-temperatures. It really annoys me when I go to the grocery store or see outside installations with dim, flickering tubes! What a waste of electricity!

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# Troubleshooting of Fluorescent Lamps and Fixtures

## Problems with Fluorescent Lamps and Fixtures

In addition to the usual defective or damaged plugs, broken wires in the cord, general bad connections, fluorescent lamps and fixtures have some unique problems of their own. The following assumes a lamp or fixture with a conventional iron (non-electronic) ballast. Always try a new set of fluorescent tubes and starter (where used) before considering other possible failures. If two tubes dim or flicker in unison, this means that both are powered by the same ballast. Often this means that one tube has failed, although the other tube may also be in poor condition or approaching the end of its life. Both tubes must be replaced with known good tubes in order to rule out a defective ballast.

1. Bad fluorescent tubes. Unlike incandescent lamps where a visual examination of the bulb itself will often identify a broken filament, there is often no way of just looking at a fluorescent tube to determine if it is bad. It may look perfectly ok though burned out fluorescents will often have one or both ends blackened. However, a blackened end is not in itself always an indication of a bad tube. Blackened ends are a somewhat reliable means of identifying bad tubes in 34 or 40 watt rapid start fixtures. Blackened ends are not as reliable an indicator in preheat or trigger start fixtures, or for tubes of 20 watts or less.

Failure of the electrodes/filaments at one or both ends of the the fluorescent tube will usually result in either a low intensity glow or flickering behavior, or sometimes in no light at all. A broken filament in a fluorescent tube used in a preheat type fixture (with a starter) will almost always result in a totally dead lamp as there will be no power to the starter. Dim glow is rare in this case and would probably be confined to the region of the broken filament if it occurs. The best approach is to simply try replacing any suspect tubes - preferably both in a pair that are driven from a single ballast.

In fixtures where a rapid start ballast runs two tubes, both tubes will go out when one fails. Sometimes one or both tubes will glow dimly and/or flicker. If one tube glows dimly and the other is completely dead, this does not indicate which tube has failed. The brighter tube may be the good one or the bad one. The bad tube usually has noticeable blackening at one end. It may pay to replace both tubes, especially if significant labor costs are involved. Also, prolonged dim-glowing may degrade the tube that did not

initially fail.

In trigger start fixtures that use one ballast to power two 20 watt tubes, sometimes both tubes will blink or intermittently dim. Replacing either tube with a known good tube may fail to fix this. The tubes may continue blinking or intermittently dimming until both are replaced with brand new tubes. This sometimes indicates borderline low line voltage ("brownout", etc.), nonideal temperatures, or a borderline (probably cheaply designed) ballast.

2. Bad starter (preheat fixtures only). The little starter can may go bad or be damaged by faulty fluorescent tubes continuously trying to start unsuccessfully. It is a good idea to replace the starter whenever tubes are replaced in these types of fixtures. One way that starters go bad is to "get stuck". Symptoms of this are the ends of the affected tube glowing, usually with an orange color of some sort or another but sometimes with a color closer to the tube's normal color if arcs form across the filaments. Occasionally, only one end arcs and glows brightly, and the other end glows dimmer with a more orange color.

Please note that this is hard on both the tube and the ballast, and the defective starter should be immediately removed.

Should one or both ends glow with a bright yellowish orange color with no sign of any arc discharge surrounding each filament, then the emissive material on the filaments is probably depleted or defective. In such a case, the tube should be replaced regardless of what else is wrong. If both ends glow a dim orange color, then the filaments' emissive coating may or may not be in good shape. It takes approx. 10 volts to form an arc across a healthy fluorescent lamp filament.

3. Defective iron ballast. The ballast may be obviously burned and smelly, overheated, or have a loud hum or buzz. Eventually, a thermal protector built into many ballasts will open due to the overheating (though this will probably reset when it cools down). The fixture may appear to be dead. A bad ballast could conceivably damage other parts as well and blow the fluorescent tubes. If the high voltage windings of rapid start or trigger start ballasts are open or shorted, then the lamp will not start.

Ballasts for fixtures less than 30 watts usually do not have thermal protection and in rare cases catch fire if they overheat. Defective fixtures should not be left operating.

4. Bad sockets. These can be damaged through forceful installation or removal of a fluorescent tube. With some ballasts (instant start, for example), a switch contact in the socket prevents generation of the starting voltage if there is no tube in place. This minimizes the possibility of shock while changing tubes but can also be an additional spot for a faulty connection.
5. Lack of ground. For fluorescent fixtures using rapid start or instant start ballasts, it is often necessary for the metal reflector to be connected to the electrical system's safety ground. If this is not done, starting may be erratic or may require you to run your hand over the tube to get it to light. In addition, of course, it is an important safety requirement.

Warning: electronic ballasts are switching power supplies and need to be serviced by someone qualified in their repair both for personal safety as well as continued protection from electrical and fire hazards.

## Comments on Black Bands and Other Fluorescent Failure Issues

(From: Don Klipstein (don@Misty.com).)

Fluorescent tubes failing in this manner normally draw reduced current. The voltage across the tube is higher and the tube will sometimes draw more power, but the current flowing through the ballast is less.

Since the ends of the bulb usually burn out unequally, some "net DC" may try to flow through the ballast. My

experience is that the feared core saturation effects do not occur. Furthermore, the common rapid start ballasts have a capacitor in series with the secondary windings which would block any DC.

There is a different problem that I once knew of causing a fire: Starters getting stuck in the "closed" state. The symptom is the ends of the tube glowing brightly, either yellow-orange or a color closer to the normal tube color, sometimes even one end glowing yellow-orange and one end glowing a more normal color. Excessive ballast current flows in this case. This is not a problem with "instant start", "rapid start", or "trigger start" fixtures. It is only a problem where there are starters.

A dim orange or red-orange glow more likely indicates dead tubes on a rapid start or trigger start ballast. If the fixture is a preheat type, dim orange end glow indicates less current than a brighter yellow-orange, and the ballast is less likely to overheat. Different brands of ballasts are designed a little differently.

If a preheat fixture has the tube glowing only in the ends, it is recommended to immediately remove the tube to stop the ballast from possibly overheating. You should replace both the tube and the starter. The starter is bad if this occurs, and the tube is usually bad also. Typically, the starter goes bad after too much time trying to start a bad tube. In the unlikely event the starter had the initial failure, the tube will be damaged by prolonged excessive end glow.

## **Why is a Grounded Fixture Needed for Reliable Starting?**

Many fluorescent fixtures will not start reliably unless they are connected to a solid earth (safety) ground. This is most likely the case with rapid or trigger start magnetic ballasts. These will usually state on the label: "Mount tube within 1/2 inch of grounded metal reflector". If this is not done or if the entire fixture is not grounded, starting will be erratic - possibly taking a long or random amount of time to start or waiting until you brush your hand along the tube.

The reason is straightforward:

The metal reflector or your hand provides a capacitive path to ground through the wall of the fluorescent tube. This helps to ionize the gases inside the tube and initiate conduction in the tube. However, once current is flowing from end-to-end, the impedance in the ballast circuit is much much lower than this capacitive path. Thus, the added capacitance is irrelevant once the tube has started.

The reason that this is required is probably partly one of cost: it is cheaper to manufacture a ballast with slightly lower starting voltage but require the fixture to be grounded - as it should be for safety anyhow.

## **Why Do Fluorescent Lamps Buzz and What to Do About It?**

The buzzing light is probably a mundane problem with a defective or cheap ballast. There's also the possibility of sloppy mechanical construction which lets something vibrate from the magnetic field of the ballast until thermal expansion eventually stops it.

First check for loose or vibrating sheetmetal parts - the ballast may simply be vibrating these and itself not be defective.

Most newer fixtures are of the 'rapid start' or 'warm start' variety and do not have starters. The ballast has a high voltage winding which provides the starting voltage.

There will always be a ballast - it is necessary to limit the current to the tube(s) and for starting if there is no starter. In older fixtures, these will be big heavy magnetic choke/transformer devices - hard to miss if you open the thing. Cheap and/or defective ones tend to make noise. They are replaceable but you need to get one of the

same type and ratings - hopefully of higher quality. A new fixture may be cheaper.

The starter if present is a small cylindrical aluminum can, approximately 3/4" x 1-1/2" in a socket, usually accessible without disassembly. It twists counterclockwise to remove. They are inexpensive but probably not your problem. To verify, simply remove the starter after the lamp is on - it is not needed then.

The newest fixtures may use totally electronic ballasts which are less likely to buzz. Warning: electronic ballasts are basically switching power supplies and are maybe hazardous to service (both in terms of your safety and the risk of a fire hazard from improper repair) unless you have the appropriate knowledge and experience.

## Replacement ballast buzzes

Assuming the replacement is of the same type as the original and it is tightly mounted, there is probably nothing really wrong - it is just not as quiet as your previous ballast. Make sure it is the ballast and not its mounting sheet metal vibrating. If the sound is coming from the ballast, there really isn't a lot that can be done other than to try another manufacturer or sample. Also see the section: [Why do Fluorescent Lamps Buzz and What to Do About It?](#).

(From Brian Beck (jrdnut@utah-inter.net).)

There are 2 main types of ballasts; those for 'home' use and those for commercial use. The commercial type will last longer and the lamp life is better as well.

There are three sound ratings

- A - extremely quiet (e.g., libraries, churches).
- B - somewhat noisy (e.g., work areas, shops).
- C - outdoor noisy (e.g., 60 foot poles in parking lots).

My guess is you got a home rated ballast with a 'B' sound rating. There is nothing wrong with the ballast - it is just noisy. If the buzz bothers you, return it to the store you bought it and go purchase one at an actual electrical parts supplier (home centers and hardware stores may not have the highest quality components). For a 2 lamp F40/T12/CW/SS lamp fixture, you want an R2S40TP ballast.

## Why Fluorescent Lamps are Sometimes Dimmer than Expected?

"I recently replaced a kitchen overhead fixture with two 75 watt bulbs with a fluorescent one having two 20 W bulbs. Guess what? Not enough light!"

Somehow I was under the impression that a watt of fluorescent lighting produced many more candles than a watt of incandescent lighting, but obviously, I overestimated the ratio."

A 20 watt fluorescent bulb of a higher light output color should make as much light as a 75 watt incandescent (1170 to 1210 lumens), BUT:

1. A few fluorescent lamp colors are dimmer, such as Deluxe versions of cool white and warm white, and a few others.
2. Fluorescent lamps only make full light output in a somewhat narrow temperature range. The fluorescents will probably not make full light when they first get started. They typically make more light after warming up for a few minutes, then may lose a bit of light output if they warm up past optimum temperature.
3. Some ballasts do not make fluorescent lamps produce full light. Some 20 watt fixtures use a

multi-purpose ballast designed to be usable with a few different wattages of lamps, and which typically sends about 16 watts of power to a 20 watt tube. A few other ballasts send an inferior current waveform to the tube, impairing efficiency. I have found some fixtures by "Lights of America" to suffer slightly impaired efficiency from a less smooth current waveform generated by an instant-start ballast system that starts "preheat" tubes instantly without a starter. Some cheaper rapid start and trigger start ballasts produce slightly inferior current waveforms.

Some of the slightly popular 2-tube 20 watt "trigger start" ballasts are cheap and "fussy", and only work well if everything is optimum. These ballasts often don't work well with cool temperatures, slightly low line voltages, or slightly weak lamps. Their best may not be too great anyway. The same may be true of some cheaper two-tube 40 watt "shop light" ballasts. Also, some "shop light" fixtures that you may think are dual 40 watt are actually dual 25 watt 4-foot fixtures.

4. Some fluorescent lamp colors (especially warm white, white, and cool white) have a spectral distribution that dims most reds and most greens. This may make things look dimmer. For details of this effect, look for the appropriate section in <http://www.misty.com/~don/dschtech.html> (A web document of mine related mostly to discharge lamp mechanics)

"What will happen if I replace the two T20s with higher powered lamps? (If some will burn out, can I replace it as well?"

The ballasts in nearly all 20 watt fixtures will not send much over 20 watts of power to any size tube. Sometimes even not much over 16 watts to any size tube. You need a different fixture, more fixtures/tubes, or possibly tubes of the same wattage but better brightness and/or color brightening (more modern '3000', 'D830', '3500', 'D835', '4100', or 'D841' tubes with higher lumen ratings but of wattage and size for the fixture).

## Replacing fluorescent lamp or fixture components

Most of these parts are easily replaced and readily available. However, it is usually necessary to match the original and replacement fairly closely. Ballasts in particular are designed for a particular wattage, type and size, and tube configuration. Take the old ballast with you when shopping for a replacement. There may be different types of sockets as well depending on the type of ballast you have.

It is also a possible fire hazard to replace fluorescent tubes with a different wattage even if they fit physically. A specific warning has been issued about replacing 40 W tubes with 34 W energy saving tubes, for example. The problem is that the ballast must also be correctly sized for the new tubes and simply replacing the tubes results in excessive current flow and overheating of the ballast(s).

## Rings or Swirls of Light in Fluorescent Lamps

Complaints are generally of the following form:

"I just replaced my bulbs because they had the black bands at the end and finally went out altogether. The new bulbs light fine but they have subtle rings of light running down the inside of them."

or

"My fluorescent tubes look like a they have a writhing snake inside trying to get out."

(From: Don Klipstein (don@Misty.com).)

The rings sometimes happens. I forget the name of this, but it is a sometimes normal feature of the main discharge column in low pressure lamps. In fluorescent tubes, it is more common if the bulb is cold or not fully warmed up, brand new or not-yet broken in, or if the ballast is of poor quality or there is a bulb/ballast

mismatch.

Double check the label on the ballast and the lamp type to be sure they are compatible with each other.

If the bulb is an "energy saver" 34 or 35 watt model (part number usually begins with F40, which is the same for a normal 40 watt bulb), be sure the ballast is compatible with that bulb. If it is compatible with both 34's and 40's, it is compatible with 35's. Matching bulbs/ballasts is important for these models mainly to ensure long bulb life and to avoid overheating the ballast. 34 and 35 watt bulbs are prone to rings and flickering and being dim and being unusually sensitive to cold because of the nature of these bulbs and can do so no matter what ballast you use. They will normally behave properly after warming up, especially in ceiling fixtures where heat builds up.

Fluorescent tubes sometimes also "swirl" before being broken in, or if they are underpowered by an incorrect or low quality ballast.

## Comments on Instant Start/Rapid Start Compatibility

(From: Ken Berg (goken@inreach.com).)

The problem with premature lamp failures using Instant Start ballast lies in the fundamental difference in the basic operating principles between Rapid Start and Instant Start lamps. It has really nothing to do with whether the ballast is magnetic or electronic. Instant Start ballasts are really designed to be used with the standard T12 single pin Slimline lamps. Instant Start ballasts deliver a higher striking voltage on starting than Rapid Start ballasts do. Slimline (the single pin) lamps have a slightly heavier cathode to tolerate the starting cycle. With Instant Start, the lamps are really started "cold cathode" style, and then they of course run as hot cathode.

On occasion, even the standard T12 Slimlines refuse to "die like gentlemen" and flash and swirl wildly. Maintenance guys have known for decades that they need to replace Slimlines promptly if they start doing this. They will need to keep this in mind when dealing with the F32T8 lamps as well. Even though the lamps are bi-pin, and so look like the old Rapid Start T12's, they are more than likely running on an Instant Start circuit, and will sometimes go like this.

The cathodes in most bi-pin lamps are made for Rapid Start, which is a starting method that is easier on the filaments. The lamp manufacturers are supposed to have already taken the starting characteristics of the new F32T8 Instant Start ballasts into account, but some might just be going on the cheap, and skimping of the lamp filaments.

## Premature Cathode Failure in Dimmed Fluorescent Lamps

"I have been experimenting with 15 W T8 lamps running from a dimmable electronic ballast. I have found that if set to a low light level after a few days of being left on, one of the cathodes in the tube often goes open circuit."

(From: Clive Mitchell (clive@emanator.demon.co.uk).)

The only explanation that I can come up with is that there isn't enough current flow to keep the cathodes warm and this is causing the discharge to be concentrated on a small point. The discharge will tend to stay on that point since it's the only warm bit, and as such is emitting electrons, making it the easiest path for current flow.

The voltage drop across this point will be higher than normal since the heat being generated is being dissipated by the rest of the cathode and this means that more power than normal is being dissipated from that point causing sputtering. This could be causing the early burn-out.

The best way to validate this would be with a clear tube to see the cathode discharge activity.

I've seen a phenomenon like this when I've lit a halide lamp at low level with a small voltage multiplier circuit. The glow discharge led to a white hot point on the electrode that caused sputtering.

If this is the case, then the cure is to use a ballast that can supply a continuous heating current to the cathodes.

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## Items of Interest

### All Those Different Wattage 4-Foot and F40 and "Shop Light" Lamps?

The original 4-foot fluorescent lamp was the F40T12, which is 47.75 inches (approx. 121.3 cm) long from pin tip to pin tip and 1.5 inches (approx. 4 cm) in diameter and designed to consume 40 watts. Not too many years ago, this was the most common and least expensive fluorescent lamp.

There is the "HO" (high output) 4-foot tube and the "SHO" (super high output) 4-foot tube. These are not common and are only used where there is not enough room to fit enough standard F40 tubes to make enough light. These lamps are slightly less efficient than standard fluorescent lamps. These tubes require more current than standard 4-foot tubes and require special ballasts. These tubes should only be used with their respective ballasts, and these ballasts should only be used with the tubes they were designed for.

In response to the energy shortages of the 1970's, the 34 watt lamp with the same physical dimensions was introduced. It works in most 40 watt fixtures and draws 34 watts in these fixtures. However, some 40 watt ballasts can overheat with this lamp. The ballast should say that it is rated for use with 34 watt lamps. Please note that a 34 watt tube can say F40 and still be a 34 watt tube and not be a 40 watt tube. It will in some way say near the F40 designation that it is an energy-saving tube. There have also been a few 35 watt tubes, which are similar enough to 34 watt tubes to work anywhere both 34 and 40 watt tubes can work. 34 watt lamps sometimes produce noticeably less light than 40 watt lamps, especially in cooler environments.

Nowadays, there is the 25 watt "shop light" lamp. The 25 watt tubes should only be used with appropriate 25 watt shop light ballasts, and these ballasts should only be used with these tubes. Please do not confuse these with other wattage tubes/fixtures of the same physical dimensions which are also sometimes called "shop lights".

A more recent development is the 32 watt T8 lamp, which is 4 feet long but only one inch (2.5 cm) in diameter. These require ballasts made for them. Many of the ballasts made for these lamps are electronic ballasts.

The confusion has increased in recent years now that the USA has an energy-conservation law against manufacturing and importing standard 40 watt white fluorescent lamps. Specialty lamps and white ones with a color rendering index of at least 82 (out of a maximum of 100) are exempt and are still available in the USA as true 40 watt lamps.

Again, be sure that you are not mismatching the bulb and the ballast. If the ballast is not rated to operate the bulb type being used, the bulb life will probably be shortened and the ballast life may be shortened. In a few cases, the ballast may catch fire after failing.

## What's with All Those Different Shades of White?

At one time, most fluorescent lamps were "cool white" which is a plain-old white with a color like that of average sunlight.

One bad thing about "cool white" is that the spectrum of "cool white" has a surplus of yellow and a shortage of green and red. Since mixing red light with green light makes yellow, the white light of a cool white lamp still looks white. Since yellow objects usually reflect green through red, they look yellow as usual in this light. But red objects reflect mainly red light and green objects reflect mainly green light, and look dim and dull due to the shortage of red and green wavelengths in "cool white". Impure reds and greens will look less red and less green as well as darker - making them look more brown.

Other early whites were "warm white" and "daylight". Warm white is a color similar to that of incandescent lamps, although it usually looks slightly less yellow and more white-pink. A warm white lamp's spectrum has a surplus of yellow and violet-blue, and a shortage of red, green, and green-blue. Like cool white, warm white can distort colors in unflattering ways.

Both "warm white" and "cool white" are obtained using "halophosphate" phosphors. The surplus of yellow and shortage of red and green is a general characteristic of halophosphate phosphors.

"Daylight" is a bluish white, and does not have as bad a surplus of yellow as the other halophosphate whites. But it is also slightly dimmer.

Next were the "deluxe" versions of cool white and warm white. These have "improved" halophosphate phosphors and are sometimes known as "broad spectrum" lamps. They have a less severe yellow surplus and red/green shortage than standard halophosphate lamps. They also produce slightly less light.

Another slightly common halophosphate white is "white", which is between "cool white" and "warm white" in color.

Other halophosphate whites, whether of differing spectral quality or different shade of "warmth/coolness" include "supermarket white", "sign white", "north light", "merchandising white", etc. Please note that some of these are not made by all fluorescent lamp manufacturers, and some of the less standard color names are trademarks of their respective manufacturers.

One earlier fluorescent lamp color with enhanced red spectral content is the "natural". This lamp has "cool white" halophosphate phosphor with a red-glowing phosphor of a different type added in. These lamps look slightly pinkish in color, sometimes purplish when compared to warmer colored light such as incandescent light. "Natural" fluorescent lamps make skin tones look pinkish, unlike the usual halophosphate types which make skin tones look green-yellowish. Some meat displays have "natural" fluorescent lamps to make the meat look more red.

Nowadays, there are "triphosphor" fluorescent lamps. These have a spectrum very different from that of the halophosphate lamps. Triphosphor lamps have their spectral content mostly in distinct bands and lines: Orangish red, slightly yellowish green, green-blue, and violet-blue. For cooler color lamps, there is an additional band in the mid-blue. Triphosphor lamps do not distort colors as badly as halophosphate lamps, and triphosphor's color distortions are usually not as unpleasant as those of halophosphate. Also, triphosphor lamps often make reds and greens look slightly brighter than normal, unlike halophosphate lamps which usually make these colors look dimmer than normal.

Most compact fluorescent lamps and most 4-foot T8 (1-inch diameter) lamps are triphosphor lamps.

Triphosphor lamps come in various warm and cool shades, usually designated by "color temperature". This is the temperature that an ideal incandescent radiator would be heated to in order to glow with a similar color.

Color codes on fluorescent lamps may include the color temperature or 1/100 of the color temperature. Osram/Sylvania brand lamps often have D8 immediately preceding the color code.

2700 or 27 - orangish shade common for compact fluorescent lamps, similar to many incandescent lamps.

3000 or 30 - "warm white", similar to whiter shades of incandescent.

3500 or 35 - between warm white and cool white, similar to the whitest halogen lamps and projector lamps.

4100 or 41 - "cool white" or the color of average sunlight.

5000 or 50 - an icy cold pure white like that of noontime tropical sunlight.

6500 or 65 - slightly bluish white or "daylight".

There are still other specialty whites, including ones with a mixture of "broad spectrum" and "triphosphor" phosphor formulations to get a spectrum more like that of daylight. Some others have particularly good "broad spectrum" phosphors, sometimes mixed with other phosphors for a tailored spectrum. Many of these, like most triphosphor lamps, have color temperature designations.

## **Why Small Fluorescent lamps Cost More than 4-Foot Ones**

Can you say 'supply and demand' and 'economies of mass production'. You are comparing the price of the common F40CW-T12 lamp manufactured by the zillions and sold in home centers for about \$1 with specialty bulbs used in a relatively few devices like battery powered fluorescent lanterns and makeup mirrors. These little bulbs may indeed cost up to ten times as much as the much larger ones.

By any measure of materials and manufacturing cost, the 4 foot bulb is much much more expensive to produce. There is nothing special involved.

## **Energy Consumption and Wear-And-Tear due to Starting**

(From: John Gilliver (g6jpg@gmrc.gecm.com).)

The amount of energy used in starting isn't worth worrying about. However, in addition to the turn on/off deterioration, there is also the steady-state `on' deterioration (they don't last for ever even if left on), so...

As far as turn-on deterioration:

I can't give it as a percentage, but for ordinary striplights I heard a figure of 15 minutes (about 15 years ago), i. e. turning it on stresses it as much as leaving it on for that long. Things have perhaps changed by now (and there are so many kinds these days as well).

For low-energy use, I'd go for fluorescents any day, unless size is a major factor (Bosch [I think] and others have been trying to get some sort of discharge lamp for headlights for some time, but I haven't seen any yet). You might also look into LEDs, but I doubt they will match the efficiency; certainly only the high-efficiency types (all seem to consume about 10, 20, or 30 mA, but the output power in light seems to vary widely, from a few millicandelas to about three candelas!). They are narrow band (i. e. coloured) as well of course.

## What Happens when Fluorescent Lamps Wear Out?

(From: Charles R. Sullivan (charless@crissy.EECS.Berkeley.EDU).)

The usual failure mode is depletion of the emission mix on the filaments. Then they do not emit electrons, and the arc can't be sustained. Unless the ballast supplies a high enough voltage that very high field can be set up near the electrode. Then the ions bombarding the electrode have a high enough energy to knock electrons out of the metal even with no emission mix, or to heat the metal to the point it emits electrons. The high field is also sufficient to ionize the argon fill gas---normally only mercury is ionized. The argon radiation is of a more purple color. That is probably what you see.

## Blackening at Ends of Fluorescent Tubes

This is a common phenomenon with most common fluorescent tubes as they age. However, frequent or repeated starting can accelerate the process. The black areas in themselves don't affect operation except to slightly reduce the amount of light available since the phosphor in that area is dead. However, they do represent a loss of metal from the electrodes (filaments).

The cause is sputtering from the filaments, mostly when cold. Thus, this happens mostly when starting or with a defective rapid start ballast which doesn't heat the filament(s) or a ballast or starter that continuously cycles. When the filament is cold and is the cathode (on the negative half of the AC cycle for that end of the tube), the work function is higher and ions have a higher velocity when impacting, knocking off metal atoms in the process. This is greatly reduced once the filament is up to normal operating temperature (though even then, some sputtering is inevitable).

(From: Greg Grieves (ggrieves@home.com).)

Lamps with the longest lifetimes typically use the heavier noble gasses as the buffer gas, ( Xenon or Krypton instead of Argon) because the sputtering that occurs at the cathode is due to fast ion bombardment from the ionized gasses in the tube. the heavier atoms have a smaller velocity for a given kinetic energy of acceleration. its not the total energy of the ion that sputters but its the momentum at impact that knocks other atoms loose. I presume thats why Kr and Xe bulbs can run brighter, because they can crank up the power and still have about the same lifetime. Some tubes use a "hollow cathode" design in which the shape of the cathode is designed to deflect impacting ions rather than be sputtered by them. That's my understanding, anyway, theres much more to the story...

(From: PBerry1234 (pberry1234@aol.com).)

I recall one brand of lamp that positioned shields around the electrodes to prevent the blackening. I suppose this improved the appearance in exposed lamp applications, but don't know of any other benefits.

## Hot Cathode Versus Cold Cathode Operation

The cathode is the negative electrode of a vacuum tube or gas filled discharge tube. Current flows by way of electrons emitted from the cathode and attracted to the positive electrode, the anode.

A hot cathode is one which must be heated to operate properly - to emit sufficient electrons to be useful. Examples: TV and monitor CRTs, most vacuum tubes (or valves), vacuum fluorescent displays (like those on your VCR). This is called thermionic emission - the boiling off of electrons from the surface of the cathode. Normal fluorescent lamps are hot cathode devices - partially maintained by the discharge current itself. They all have some sort of warmup period (though it can be quite short).

(From: Phil Rimmer (primmer@tunewell.com).)

A cold cathode is one where operation takes place without depending on heating of the surface above ambient. There are all sorts of devices that use 'cold' cathodes - neon lamps and signs, fluorescent backlight tubes, and helium neon laser tubes. Naturally, cold cathode devices don't have much of a warmup requirement.

The purpose of a cathode is to feed electrons into the negative end of the positive column (the discharge) so they can variously excite and ionise gas or vapour atoms.

Electrons are released from cathodes by the action of the positive ions being accelerated towards them due to an electric field in the vicinity of the cathode.

Electrons are broadly released in two ways: Thermal emission and secondary emission.

- Thermal emission is the primary process used in "hot cathode" lamps which include standard fluorescent tubes. The ions are accelerated towards the cathode through a small cathode voltage (less than 10 volts) and gain just enough energy to heat a small part of the very fine wire electrode when they collide with it. They heat it until it glows dully and electrons are "boiled off", liberated by the thermal energy. This process is very efficient in producing lots of electrons and results in efficient lamps.
- Secondary emission is a more brutal process for generating electrons. It requires an accelerating voltage drop of 130 to 150 volts. It is used in cold-cathode lamps that have relatively huge cylinders of iron for electrodes. These massive electrodes require much too much energy input to make them into thermal emitters. The energetic ions simply "knock" electrons off the metal surface. In so doing they also knock some of the metal off as well, a process called sputtering. The big electrodes have enough material to last before other effects cause lamp failure.

Hot cathode lamps operate in cold cathode mode if the cathode receives too little energy to keep it glowing. The colliding ions are thirty times more energetic than usual and soon sputter enough metal off the tiny electrodes to destroy them.

Moral: Pre-heat the electrodes before starting the discharge and maintain auxiliary current in the electrodes if the discharge current is low (e.g, when dimming).

## Comments on Small Inverter Powered Fluorescent Lamps

(From: Paul Bealing (paul@pmb.co.nz).)

Many small low cost inverters use a 2 transistor (one quite small) self oscillating circuit. Simply minimum function, low cost. These circuits can be quite efficient at low power levels. I have seen them used up to 50 watts.

Losses are usually in the transformer and the switching transistors. As the currents increase, the losses usually increase for a given power output.

The lamp requires a high voltage, usually 300 to 500 V, to strike. The voltage depends on the length/wattage of the lamp. Once struck, the current through the lamp is limited to achieve the wattage. The voltage across a small running lamp will be in the order of 60 to 100 volts AC.

Many simple inverters use a series resonant circuit to generate the high strike voltage, which is disabled by the run current.

A couple of years ago I designed an inverter for a PL11 11 Watt lamp based on a switchmode power supply controller IC, 2 power mosfets, and a push-pull transformer, running at about 200 kHz. The main application

was in diesel locomotives running from 75 V DC. I've had the circuit operating down to 10V DC (different transformer winding). The primary current rises and the dissipation increases.

## Operating a Fluorescent Lamp on DC

"I have a application in mind that will use a DC power source around 100 volts and fluorescent lighting. What kinds of voltage do I need to sent the fluorescent? Are there any good sources of info. for the circuitry I would need?"

(From: Don Klipstein (don@Misty.com).)

If it is a preheat tube of 22 watts or less, the cheap-and-dirty way to do it is to use a normal preheat fixture. The only change is to add a resistor in series with the ballast. This resistor should be maybe 100 ohms for 20 and 22 watt lamps, slightly higher for lower wattage ones. It should be able to safely dissipate a wattage comparable to that of the lamp.

The above includes most simple "PL"/twin-tube compact fluorescent lamps with removable bulbs with two pins, as well as most compact fluorescent bulbs with "choke" type ballasts running from 120 volts AC.

Should you need anything more energy-efficient than this, then there is the world of electronic ballasts.

BTW, most low-power-factor screw-in 120 VAC compact fluorescent lamps with electronic ballasts work fine "as-is" with about 160 volts DC or squarewave.

## Ballasts and PCBs (The Hazmat Type)

(From: David Morris (allane@ix.netcom.com).)

Ballasts that were made after the late 70's do not contain PCB's. I spoke with an Advance and GE ballast rep. a few years ago about this and I was told the only sure-fire method to tell that there are no PCB's is if the ballast says no PCB's. Any ballast that doesn't say that has a better than 80% chance of having it. The amount in the ballast is VERY minute. Less than a thimble full. It is used to cool a capacitor in the ballast. Since he said the light is about 12 years old, I am quite certain that the ballast does not contain PCB's. In our state, it is legal to dispose of these ballasts in a limited quantity in your local landfill or throw them in the trash. Larger quantities require Hazmat disposal methods. Our company policy is to leave any old ballasts that is not marked 'no PCB's' with the customer for their disposal.

As a side note, I read in one of the Electrical trade rags that the liquid that replaced PCB's is testing out to be more dangerous than PCB's themselves. Go figure!! :-)

As for catching fire, ballasts contain a thermal protector that will cut the power if the ballast gets too hot. Only real old ballasts do not have this feature. Ballasts marked Class P have this protection. It is very rare for one of these ballasts to actually catch fire, although it does happen. More often, they will smoke up the house if they overheat and the thermal protector fails.

## Driving Cold Cathode Fluorescent Lamps

(From: David VanHorn (dvanhorn@cedar.net).)

[Linear Technology](#) has several extremely detailed app notes written by Jim Williams on this topic. It's more complicated than you might imagine to do it right. Just making the tube light is perhaps only 10% of the job. The rest includes keeping it running a long time without blackening, providing the ability to set the brightness,

not loosing all your energy to wiring capacitance, and not creating an EMI nightmare.

Definitely read and understand those app notes, even if you go to another vendor! The good news is that the actual circuit isn't that bad!

## What is the E-Lamp?

The E-Lamp is one of those inventions that sounds like a really good idea but still hasn't (as far as I know) made it into wide scale production. In essence, it is an RF excited compact fluorescent lamp. Some of the E-lamp's basic characteristics include.

- Fits into standard household light bulb bases.
- Radio frequency radiation was emitted, then converted to light.
- Dimmable using standard phase control dimmer - no special devices needed.
- Very efficient so runs cool and consumes much less power than incandescent lamps (don't know how it compares to compact fluorescents).
- Desirable white spectral characteristics.
- No filament to wear out (and no wires through glass) so potentially very long life.

Aside from cost issues, there could also be concerns with respect to RF emissions effects on health and interference with other household appliances and electronics.

(Victor Roberts (robertsv@ix.netcom.com).)

E-lamps are electrodeless fluorescent lamps. They use a high frequency or RF magnetic field to create a time varying electric field which in turn drives a discharge which is very similar to the discharge in an ordinary fluorescent lamp. Except for the means by which the discharge is created, these E-lamps are identical to all other fluorescent lamps. There is no magic other than the fact that electrodeless excitation allows for the elimination of the electrodes, so electrode failure and wear out are no longer a problem. Also, electrodeless excitation removes the requirement that the lamp be long and thin to achieve high efficacy. Proof of this is beyond the scope of this note. :) Hence, an electrodeless fluorescent lamp can be more easily made in the shape of an incandescent lamp.

There are also electrodeless metal halide lamps and, of course, the electrodeless sulfur lamp.

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