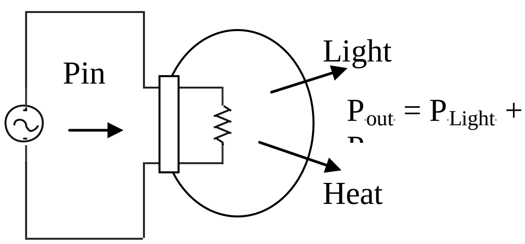
Lighting and Ballast Demo -- Lab Review Sheet

Objectives:

In this demonstration principles of incandescent and gas discharge lighting will be discussed. Magnetic and electronic ballast for gas discharge lamps will also be covered.

Incandescent Bulb:

The principle of an incandescent light bulb is extremely simple, it is essentially a filament contained within a near vacuum. When current flows through the filament it heats up and begins to glow. The filament is enclosed in a near vacuum or noble gas to extend its lifespan. The filament is nothing more than a small tungsten wire so it can be modeled as a resistor.



$P_{in} = P_{out} + P_{Loss}$

Typical Power Levels:

$P_{Light} \approx 0.10 * P_{in}$

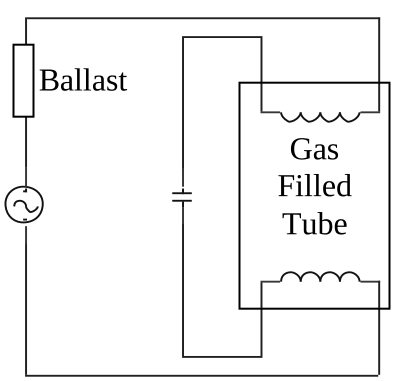
$P_{Heat} \approx 0.72 * P_{in}$

$P_{Loss} \approx 0.18 * P_{in}$

As stated above the visible light output is only about 10% of the input power while about 72% of the input power is output as heat. Since we are interested in getting light out of the bulb the efficiency of the incandescent bulb is only 10%. In addition repetitive heating and cooling of the filament stresses the material, eventually causing the filament to break at which point the bulb would need to be replaced. This bulb however is purely resistive and does have a good power factor.

Fluorescent and other Gas Discharge Bulbs:

Gas discharge bulbs include fluorescent, mercury vapor, metal halide, high pressure sodium, and low pressure sodium. All of these lamps operate off of the same principle and have similar characteristics. These bulbs are essentially a controlled air arc, current is passed directly though a gas which causes the atoms to emit electrons and visible and ultraviolet light, the containment tube may also be coated with phosphorus which glows when struck by electrons and ultraviolet light (as is the case with standard fluorescent tubes).



$P_{out} = P_{Light} + P_{Heat}$

$P_{in} = P_{out} + P_{Loss}$

Typical Power Levels (fluorescent tube):

$P_{Light} \approx 0.22 * P_{in}$

$P_{Heat} \approx 0.36 * P_{in}$

$P_{Loss} \approx 0.42 * P_{in}$

These lamps go through 5 stages to produce light:

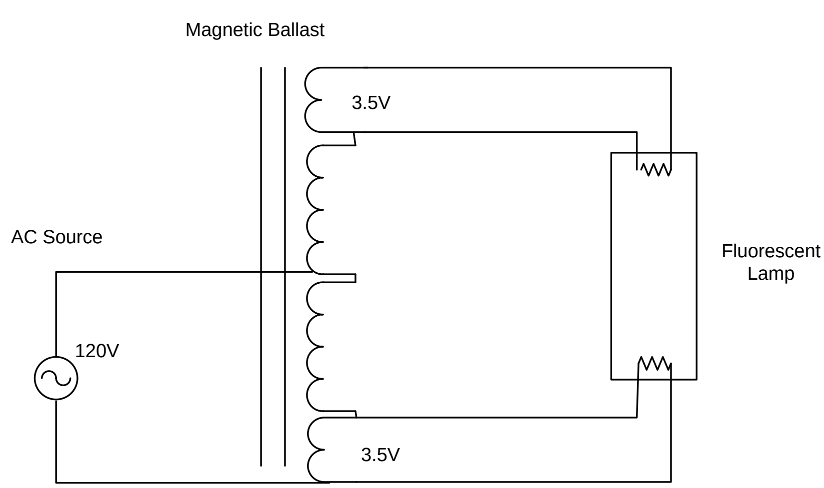
1. Before energizing the gas in the tube is cool and has a high resistance
2. When power is applied to the lamp current begins to flow through the cathodes (on the ends of the lamp) and capacitor
3. ***Pre-Heat Stage*** - Current flow in the cathodes begins to heat up the gas and the arc voltage of the gas starts falling (these filaments are needed to begin the heating process and reduce the required starting voltage)
4. ***Ignition Stage*** – Once the arc voltage of the gas falls to a low enough value the current arcs between the cathodes and the bulb begins producing light
5. ***Run Stage*** – As the current flows through the gas it continues to heat up and the resistance continues to drop.

Gas discharge lamps have negative incremental impedance (the impedance falls as you run the device) so the resistance of the lamp falls to a short circuit after it has been run for an extended amount of time. To prevent the source from seeing this short circuit the ballast needs to be added to the system. Efficiencies in terms of light for gas discharge lamps are in the area of 20% - 30% depending on the type of gas and ballast used. Meaning that in terms of light output gas discharges lamps are 2 to 3 times more efficient than incandescent bulbs. Gas discharge bulbs also have better lifespan and lumen depreciation (the amount of light output versus bulb age) than incandescent bulbs. These advantages are countered by the fact that gas discharge lamp have a less ideal power factor and require a ballast to be operated.

Types of Ballast for Gas Discharge Lamps:

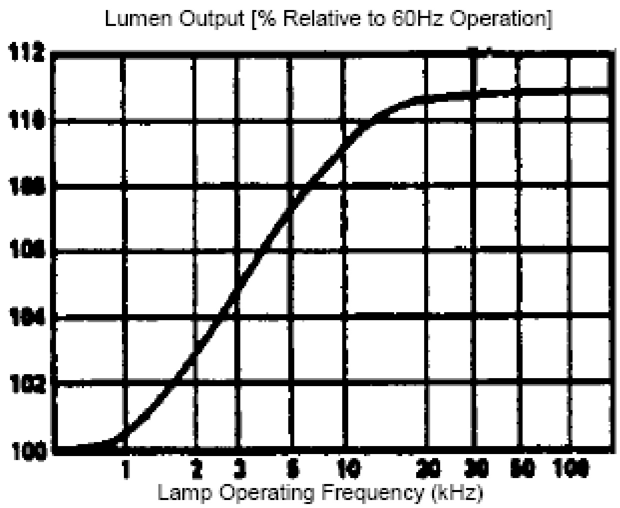
Magnetic Ballast:

This form of ballast is essentially a large inductor in series with the discharge lamp to maintain a constant current. The impedance of the inductor is used so that a short is not placed across the terminals of the source. The magnetic ballast used on 120V source needs to include a step up autotransformer to reach the starting voltage of 250V for a heated cathode fluorescent lamp. Once the lamp starts the voltage collapses to about 108V running voltage.



Electronic Ballast:

This type of ballast is composed of a small power electronics device and performs the same function of hiding the short from the supply. The electronic ballast uses a voltage doubter circuit to increase the lamp voltage to 250V to start the lamp. In addition the electronic ballast is designed to step up the frequency so that on the lamp side the frequency is in the range of 100 kHz, the reason for this is explained below.



The graph to the left shows lamp light output relative to 60 Hz as a function of operating frequency. From this graph it is seen that if the lamp is operating at 100 kHz the light output is about 111% of what it would be if operating at 60 Hz.

Since the electronic ballast is capable of increasing the frequency and thus increasing the light output for a given power level it can improve the efficiency of the discharge lamp. Going back the previously stated efficiency of a fluorescent tube with magnetic ballast of 22%, if we used electronic ballast instead of a magnetic ballast the light efficiency would become 24%.

Comparison of Magnetic and Electronic Ballast

Magnetic Ballast	Electronic Ballast
Operates at 60 Hz	Frequency step up with power electronics
--Lower Efficiency	--Better efficiency
--High Time Constant	--Low Time Constant
Big, Heavy Inductor	Smaller and lighter
	More expensive