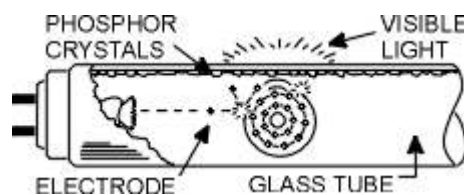
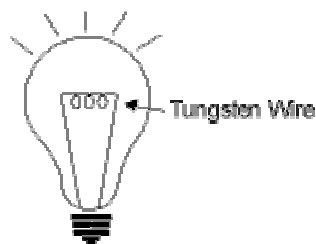


## Purpose of a Ballast

### Incandescent vs. Fluorescent Lamps

Even though nearly 90% of the energy consumed by incandescent lamps is dissipated as heat, they are still prevalent in most American homes and are used throughout business and industry. Their operation is simple and self-regulating: when electricity passes through the lamp's tungsten wire filament it heats until it glows (incandesces) and produces light. The amount of light generated depends upon the amount of electrical current that passes through the filament. In addition to producing light, the filament also limits the current to safe operating values. The quantity of light generated by a lamp is measured in lumens; for example, a 100 watt incandescent light bulb delivers 1700 lumens of light.

Fluorescent lamps are much more efficient than incandescent lamps in using energy to create light. Rather than using a wire filament, their operation relies upon an electrical arc passing between two electrodes, one at either end of the lamp. This arc is conducted by a mixture of vaporized mercury and purified gases—mainly Neon and Krypton or Argon—through a tube lined with phosphor. The mercury vapor arc generates ultraviolet energy which cause the phosphor coating to glow (fluoresce) and emit light.



### Ballast Function

Unlike incandescent lamps, fluorescent lamps cannot be connected directly to the power line. Unless the flow of current is somehow stabilized, more and more current will rush through the lamp until it overheats and destroys itself. The length and diameter of an incandescent lamp's filament wire limits the amount of electrical current passing through the lamp and regulates its light output. The fluorescent lamp, however, with its electrical arc instead of a wire filament needs an additional device called a "ballast" to regulate the current and stabilize the light output.

Fluorescent lamps sold in the US today are available in a wide variety of shapes and sizes. They range from miniature versions rated at 4 watts, six inches in length with a diameter of 5/8 inches to 215 watt models, eight feet or more in length with diameters exceeding 2 inches. Voltage required to start the lamps is dependent on lamp length and diameter, with larger lamps requiring higher voltages. Each fluorescent lamp must be operated by a ballast that is specifically designed to provide the proper starting and operating voltage required by that particular lamp.

**In all fluorescent lighting systems, the ballast performs two basic tasks:**

1. Provides the proper voltage to establish an arc between the two electrodes.

2. Regulates the electric current flowing through the lamp to stabilize light output.

In many fluorescent lighting systems the ballast also provides a controlled amount of electrical energy to heat lamp electrodes.

To receive peak performance from fluorescent lighting it is essential that the fluorescent lamp ballast match precisely the requirements of the lamp it is designed to operate.

## Construction of a Ballast

There are three types of ballasts available for use with fluorescent lamps. These are called Electromagnetic, Hybrid or Electronic ballasts.

### Electromagnetic Ballasts

Because ballasts are essential to fluorescent lamp operation, they have been available for as long as the lamps they start and operate. Throughout most of their history, fluorescent ballasts have been electromagnetic. As a result of their design, these ballasts are also called "core & coil" ballasts.

The primary component of an electromagnetic ballast is a core of stacked steel laminations surrounded by wound coils of insulated copper or aluminum wire. This core & coil design functions both as a voltage transformer and a current limiter (or choke). As heat produced by the ballast's operation can eventually break down the insulation around the coils and cause failure, the core & coil is "potted" in insulating material such as asphalt to conduct the heat away from the coils. This assembly is usually housed in a steel case.

Another component used in many electromagnetic ballasts is the capacitor. The capacitor allows the ballast to utilize energy from the power line more efficiently. An electromagnetic ballast that is equipped with a capacitor is generally known as a "high power factor" or "power factor corrected" ballast (see section F-6).

### Hybrid Ballasts

The "hybrid" ballast design combines the starting and operating characteristics of the electromagnetic ballast with the energy efficiencies of electronic circuitry to provide an alternative means of operating rapid start lamps.

The construction of a hybrid ballast is basically the same as an electromagnetic ballast - both have a core & coil, a capacitor and potting. But a hybrid ballast also incorporates electronic circuitry to disconnect the cathode heater windings after the lamp ignites.

The starting method for a hybrid ballast is identical to that of an electromagnetic rapid start ballast. The difference occurs during normal operation when the cathode heaters are disconnected and the energy consumption is reduced by about 3 watts per lamp.

### Electronic Ballasts

Like electromagnetic ballasts, electronic ballasts provide the necessary voltage to start lamps and regulate the current through the lamps after ignition. The electronic ballast, however, operates the lamp at a frequency of 20,000 Hz or greater, rather than the 60 Hz operation of electromagnetic and hybrid types. This allows users to take advantage of increased fluorescent lamp efficiencies obtainable at these higher frequencies. This high frequency operation is accomplished through the use of electronic circuitry, which generally results in a more efficient, smaller, lighter and quieter ballast design than the standard electromagnetic ballast.

## Operation of a Ballast (Operating Frequency)

The operating frequency of a ballast can be separated into two distinct frequencies: Input and Output Frequency. Input Frequency refers to the power line frequency the ballast is connected to. Output Frequency refers to the frequency at which the ballast operates the lamp.

### Input Frequency (Power Line Frequency)

Ballasts are usually connected to an AC (alternating current) power line operating at 50 Hz or 60 Hz (Hertz or cycles per second) depending on the local power company (50 Hz in Europe and 60 Hz in North America). Most ballasts are designed for one of these frequencies but not both. Some electronic ballasts, however, can operate on both frequencies. Also, some ballasts are designed to operate on DC (direct current) power, but these would be considered specialty ballasts for applications like bus lighting.

### Output Frequency (Lamp Operating Frequency)

Electromagnetic and hybrid ballasts operate the lamp at the same frequency as the power line: 50 Hz or 60 Hz (low frequency). Electronic ballasts operate the lamp above 20,000 Hz (high frequency) to take advantage of the increased lamp efficiency. The fluorescent lamp provides roughly 10% more light when operating at high frequency versus low frequency for the same amount of input power. The typical application, however, involves operating the fluorescent lamp at lower input power and high frequency while matching the light output of the lamp at rated power and low frequency. The result is substantial savings in energy consumption.

<b><u>BALLAST TYPE</u></b>	<b><u>TYPICAL FREQUENCY</u></b>
Electromagnetic 60 Hz in	60 Hz out
Hybrid 60 Hz in	60 Hz out
Electronic 60 Hz in	>20,000 Hz out

## Wiring of a Ballast

Ballasts can be connected, or wired, between the input power line and the lamp in a number of configurations. Usually this is determined by the type of lamp that the ballast will operate, as discussed in section E, but there are some exceptions. Multiple lamp ballasts for rapid start or instant start lamps can operate lamps connected in series or parallel depending on the ballast design.

### Series or Parellel

When lamps are connected in series to a ballast and one lamp fails, or is removed from the fixture, the other lamp(s) connected to that ballast will also not light. When lamps are connected in parallel to a ballast and one lamp fails, or is removed, the other lamp(s) will continue to light.

<b><u>BALLAST TYPE</u></b>	<b><u>LAMP TYPE</u></b>	<b><u>LAMP CONNECTION</u></b>
Electromagnetic	Rapid Start	Series
	Instant Start	Series
	Instant Start	Parallel
Hybrid	Rapid Start	Series
Electronic	Rapid Start	Series

	Rapid Start Instant Start	Parallel Parallel
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## Wiring Diagrams

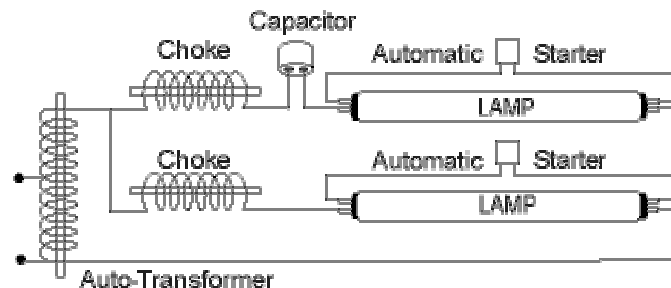
Ballast wiring diagrams are listed on the ballast label and designate the proper connections between the lamp, ballast and input power to correctly start and operate the lamp. Failure to follow this wiring diagram could result in damage to the lamp, the ballast or both. The integral leads of the ballast are color coded to industry standards for ease of installation and replacement.

## Ballast Circuit Types

Three major types of lighting system circuits are in use today for electromagnetic ballasts: Preheat, Slimline Instant Start and Rapid Start. With the introduction of hybrid and electronic ballasts, two new circuits were introduced: Modified Rapid Start and Instant Start of Rapid Start Lamps.

### Preheat Circuit (Electromagnetic Ballast)

The Preheat circuit, which applies power to the lamp electrodes to preheat them before the lamp is started, was the original system developed for the operation of fluorescent lamps. Hot electrodes are necessary to establish the electrical arc within the lamp. This preheating is accomplished by using a separate manual or automatic starter switch along with the ballast.



When power is applied, the starter switch is closed and the ballast delivers a controlled amount of current through the electrodes to preheat them. In a few seconds the electrodes attain the proper temperature and the starting switch automatically opens. The opening of the starting switch, which acted as a short circuit across the lamp, leaves the gas in the lamp as the only other path for the current to travel. Because the filaments are hot and the arc is established, the lamp emits light. The Preheat circuit is generally used for low wattage linear and compact lamps (4 to 30 watts). Linear lamps require an external starter while compact lamps have the starter built into the lamp base.

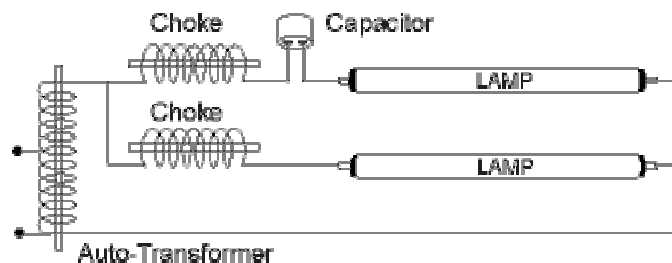
Linear preheat lamps can also be operated on a Trigger Start ballast which heats the electrodes by means of heater windings built into the ballast before the lamps ignite. No external starter is required with this type ballast. The Trigger Start ballast was developed later when the Rapid Start circuit was developed. The wiring of the Trigger Start is the same as the Rapid Start (see section E-3).

## Slimline Instant Start (Electromagnetic or Electronic Ballast)

The Slimline Instant Start system produces light instantly without the assistance of a starter. To achieve this quick response with no preheating of lamp filaments, the ballast must provide an open circuit voltage to the lamp electrodes about three times the normal lamp operating voltage, to initiate the arc. This high initial voltage requires a larger autotransformer as an integral part of the ballast. A larger current limiting "choke coil" or "reactor" must also be included because of this large difference between the starting and operating voltage of the lamp. This starting method makes the slimline ballast much larger than the preheat ballast.

Two-lamp electromagnetic slimline ballasts are available in two circuit types: Lead Lag and Series Sequence. Two-lamp electronic slimline ballasts are available as Electronic Instant Start.

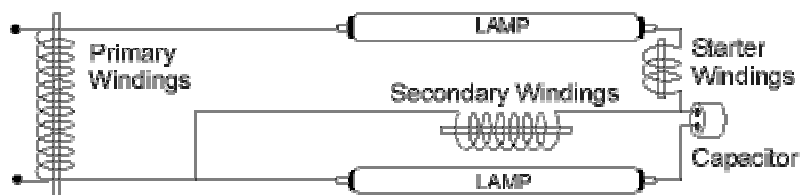
### a. Lead Lag Circuit (Electromagnetic Ballast)



The Lead Lag Slimline Instant Start circuit differs from the Preheat circuit only in the higher starting voltage produced and absence of lamp starters. This ballast, which was the original circuit design for Slimline lamps, also provides the necessary starting voltage to ignite each lamp independently of the other with the lamps wired in parallel. This instant starting and independent lamp operation is what makes the size of the ballast rather large.

A capacitor is added to the ballast circuit in series with one of the lamps in order to improve power factor (see section F-6). Circuits with only a choke in series with the lamp are designated as "Lag" circuits while circuits with a capacitor in series with the lamp are designated as "Lead" circuits. The name "Lead Lag" was developed since there is a capacitor in series with only one of the lamps.

### b. Series Sequence Circuit (Electromagnetic Ballast)

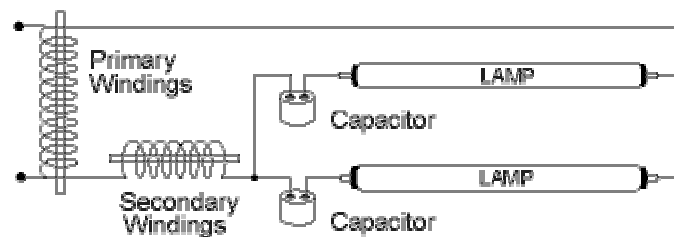


To reduce the size, weight and cost of the Slimline Instant Start Lead Lag Ballast, a Series Sequence Ballast was introduced. In this ballast circuit two lamps are operated in

series with the lamps starting in sequence. This circuit was pioneered by Advance and helped to establish slimline lighting circuits.

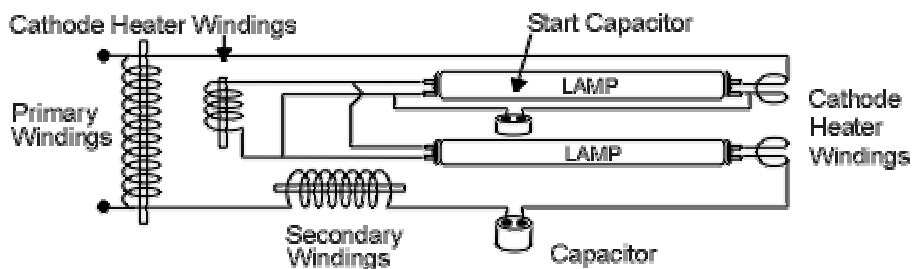
In the Series Sequence circuit, the starting section supplies sufficient voltage and current to light one lamp with the remaining lamp igniting in sequence from the same voltage and current. Because the lamps are in series, the ballast is not required to supply individual lamp currents like the Lead Lag ballast does. This reduction in power requirements makes it possible to operate Slimline Instant Start Lamps with a fluorescent lamp ballast which is lighter, and more efficient at about one-third the size of comparable Lead Lag types.

### c. Electronic Instant Start Circuit (Electronic Ballast)



The Electronic Instant Start circuit operates in a similar manner to the Lead Lag circuit by providing a high starting voltage to ignite each lamp independently with the lamps wired in parallel. The ballast then regulates the current through the lamps. The size of the ballast, however, is much smaller since it is an electronic ballast.

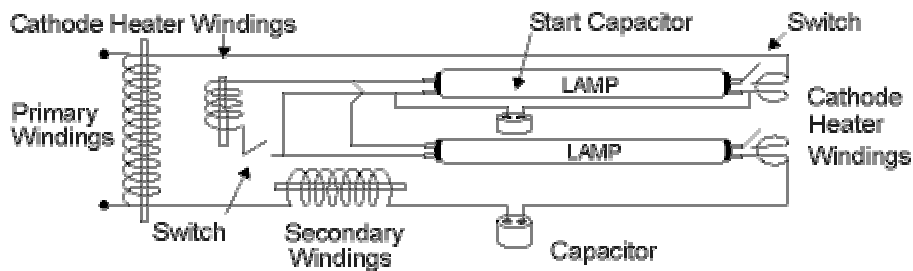
### Rapid Start Circuit (Electromagnetic or Electronic Ballast)



Rapid Start lighting system circuits are today's most popular design and are used for virtually all 4 foot lamps as well as 800 mA HO & 1500mA VHO lamps. The lamp electrodes, or "cathodes," are automatically preheated by means of heater windings built into the fluorescent lamp ballast. This eliminates the need for a separate starting switch, but the fixture must be properly grounded to ensure good starting of the lamps. The lamps must also be positioned within  $\frac{1}{2}$  inch (F40T12),  $\frac{3}{4}$  inch (F32T8) or one inch (800 mA HO and 1500 mA VHO) of the fixture for proper starting. Continuous lamp filament heating is provided by the ballast after the lamps are started.

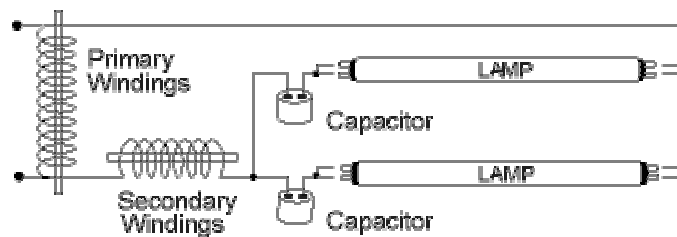
Because of the continuously heated electrodes, less voltage is required for the initial surge to start the lamp than with Slimline Instant Start which allows for a smaller size ballast. Rapid Start Lamps light immediately at low brightness and are fully lighted in about two seconds. The lamps are mostly wired in series, but some parallel electronic ballasts are available.

## Modified Rapid Start Circuit (Hybrid Ballast)



Modified Rapid Start circuits start the lamps in the same manner as Rapid Start circuits do, but automatically switch off filament heating after the lamps ignite. Once the fluorescent arc is established, it is no longer necessary to maintain filament heat to sustain the arc. The lamp filament heating is eliminated to save energy. Approximately 3 watts per lamp can be saved by switching off the filament heating.

## Instant Start of Rapid Start Lamps (Electronic Ballast)



Instant Start of Rapid Start Lamps is only recommended by lamp manufacturers for Rapid Start T8 lamps. Like Slimline Instant Start systems, the ballast must provide an open circuit voltage high enough to start the lamps without the lamp filaments being preheated. The lamps ignite independently and are wired in parallel.

This type of instant starting however, wears out the cathodes faster than true rapid starting so rated lamp life is reduced by up to 25% depending on the number of starts per day. The cathodes in T8 lamps are specially designed to accommodate this type of circuit. Operating other rapid start lamps on instant start circuits will greatly reduce their life.

## Specifications / Terms

### Certification

There are several organizations involved with ballast standards and testing. They are:



**CBM**—Certified Ballast Manufacturers Association, manufacturers who produce fluorescent ballasts to conform to ANSI specifications C82.1, C82.11, C82.2, C82.3 and C78.



**ANSI**—American National Standards Institute, originates standards on a national level. Composed of over 120 trade associations, technical societies, professional groups and consumer organizations, it creates Performance Standards for both lamps and ballasts to insure proper operation and interchangeability.



**ETL**—Electrical Testing Laboratories Inc., a private, independent organization, is a recognized authority in measurements and testing of lamps and lighting equipment. Certified Ballast Manufacturers Association retains Electrical Testing Laboratories, Inc., to test ballasts produced by members, to ensure they conform to ANSI and CBM specifications.



**UL**—Underwriters' Laboratories, Inc., is an independent, not-for-profit organization testing for public safety. Its function is, through study, experiment and tests, to prevent the loss of life and property from the hazards of fire or casualty.



**CSA**—Canadian Standards Association, is the safety testing authority for ballasts used in Canada.



**E**—Energy Efficient Ballast, indicates ballast complies with National Energy Conservation Amendments (NAECA) of 1988 to Energy Policy and Conservation Act (EPCA) of 1987. Applies to most popular 4' and 8' linear lamps.



**CSA-E**—Canadian Standards Association Energy Efficient Ballast, indicates ballast complies with Canadian Energy Standards. Applies to most popular 4' and 8' linear lamps.

## Basic Information

In order to choose a ballast for a particular application, there are three pieces of information that must be supplied. These are lamp type, number of lamps the ballast must operate, and input voltage to the lighting system. Once these three criteria are identified, a ballast can be chosen based on the performance characteristics that follow.

## Input Watts

Input Watts refers to the total watts required to operate both the ballast and lamp together as a system. Ballast watts and lamp watts cannot be added together to provide an input watts figure because most ballasts do not operate the lamps at full wattage. Input watts is the more accurate measurement of system watts since it includes the actual lamp operating wattage.

Different ballast manufacturers, however, may express input watts in different ways, such as ANSI Watts, Open Fixture or Enclosed Fixture. The only repeatable measurement is ANSI Watts, since the test method is standardized for the lighting industry.

Ballast Losses refers to the wattage used by the ballast alone. If only ballast losses are specified, the total input watts equals ballast losses plus lamp



wattage. However, this calculation can be misleading as it assumes that the lamps are operated at full wattage.

## Input Voltage

Each ballast is designed to operate at the nominal voltage shown on the ballast label. Abnormal deviation from these values will result in damage to either the ballast or lamp or both. It is therefore recommended that the voltage applied to ballasts bearing the following nominal rating be maintained within the respective limits shown:

<b>NOMINAL VOLTAGE</b>	<b>APPLIED VOLTAGE LIMIT</b>
120	112 - 127
208	199 - 216
220	210 - 230
240	225 - 250
250	235 - 260
277	255 - 290
347	322 - 365
480	450 - 500

**Electronic ballasts may operate over a wider voltage limit of  $\pm 10\%$ .**

## Input Current

Input Current is the current drawn by the ballast and lamps and is generally listed for normal operation. For most ballasts, it is the only current that should be specified since it is also the maximum current. Some ballasts, like electromagnetic compact ballasts, specify operating current, starting current, and open circuit current because normal operating current is not the highest current. It is possible that either starting or open circuit current could be higher than operating current. The highest current must be listed because it is critical to the proper sizing of the lighting system circuit, circuit breakers, fuses, etc. Otherwise, nuisance outages could occur.

### a. Inrush Current

Ballasts have an input current during initial start-up several times greater than their normal operating current. This current during start-up is referred to as Inrush Current. This current during start-up typically lasts for a very short duration, about  $\frac{1}{4}$  of the 60 Hz cycle. Electronic ballasts generally have higher inrush current than electromagnetic or hybrid ballasts. Nuisance tripping of circuit breakers or fuses could occur if they are not sized to handle the inrush current from the ballast.

### b. Fuse Protection

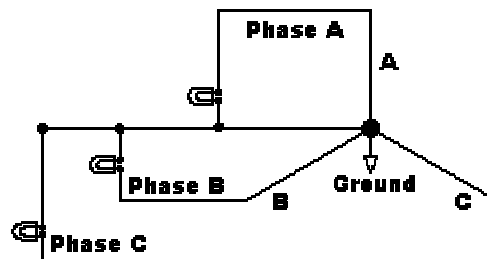
Individual fusing is sometimes considered when many fixtures operate on a single circuit and where it is desirable to isolate an inoperative fixture quickly. This helps in troubleshooting a fixture and avoids a complete circuit outage if a ballast fails shorted. If used, fuses should be of the slow-blow type and should accommodate the inrush current of the ballast. Electronic ballasts generally have higher inrush current than electromagnetic ballasts. This will not be a problem if the correct fuse is specified.

### c. Total Harmonic Distortion

Harmonics are currents or voltages which have frequencies that are integer multiples of the fundamental power frequency. Each has a name associated with the multiplying number, i.e., if the fundamental frequency is 60 Hz, then the second harmonic is 120 Hz, the third is 180 Hz, etc.

Harmonics occur whenever the current or voltage wave shape is distorted, i.e., when the wave shape varies from a pure sine wave. Electric Utilities typically generate a voltage which is very nearly a sine wave. If an end user connects a linear load such as a resistive heater, the resulting current will be a sine wave and no harmonics will be present. If, however, the load is non-linear, drawing short pulses of current within each cycle, the current wave shape will be distorted (non-sinusoidal) and harmonic currents will flow. The total current will be a combination of the fundamental plus each of the harmonics. Total Harmonic Distortion (THD) is the measurement of the magnitude of the input current harmonics compared with the amplitude of the fundamental frequency current.

#### TYPICAL ELECTRICAL SUPPLY SYSTEM FOR COMMERCIAL BUILDINGS (4 WIRE, 3 PHASE WYE CONFIGURATION)



NEUTRAL CURRENT = CURRENT ON PHASE A +  
PHASE B + PHASE C  
EACH PHASE IS 120 DEGREES OUT OF PHASE WITH  
RESPECT TO THE OTHERS

Harmonics are important because in three-phase systems, certain harmonic currents can overload neutral conductors. The troublesome harmonics, called "triplens," consist of the 3<sup>rd</sup> and odd multiples of the 3<sup>rd</sup> (i.e., 3<sup>rd</sup>, 9<sup>th</sup>, 15<sup>th</sup>, etc.). These harmonics will add rather than cancel in the neutral of a three-phase 4-wire system. Therefore, if the triplen harmonics exceed 33 1/3, more current will flow in the neutral wire than in any of the phase wires, even if the phase currents are perfectly balanced.

### Power Factor

The Power Factor of a ballast is the measurement of how efficiently it converts the voltage and current supplied from the power source into watts of usable power consumed by the ballast and lamps. Perfect utilization of

electrical current would result in a power factor of 100%. Power factor is not an indication of the ballast's ability to supply light through the lamps.

$$\text{Power Factor} = \frac{\text{Input Watts}}{\text{Line Volts} \times \text{Line Amps}}$$

Fluorescent ballasts are designated high power factor, normal (low) power factor, or power factor corrected. High power factor ballasts, which are specified for all commercial lighting applications, are those having a ratio of input watts delivered to the ballast and lamps, compared to the volt-amperes supplied, of greater than 90% (.9). High power factor ballasts employ a lower operating current than low power factor ballasts so more fixtures can be installed per branch circuit. Low power factor ballasts require about twice the current needed by high power factor ballasts. Low power factor ballasts create added wiring costs because fewer fixtures are permitted per circuit, and can load branch circuits as well as the circuits of the utility, potentially resulting in penalty charges.

#### **Advantages of High Power Factor Ballasts**

1. Avoid possible penalty charges from electric utility.
2. Wiring costs are less because normal power factor ballasts take about twice the line current of high power factor ballasts and may require heavier wire to carry the load.
3. With high power factor ballasts, more fixtures can be installed on each branch circuit.

#### Ballast Factor

Ballast Factor is the measurement of a ballast's ability to produce light from fluorescent lamps. It is the ratio of light output produced by lamps operating on a commercial ballast versus the light output of the same lamps operating on a 60 Hz laboratory reference ballast specified to ANSI standards for a given lamp type.

$$\text{Ballast Factor} = \frac{\text{Commercial ballast light output}}{\text{Laboratory reference ballast (100\% light output)}}$$

Ballast factor is multiplied by the lumen rating of the lamp, times the number of lamps, to determine the delivered lumens (actual amount of light) from this ballast and lamp system. A ballast may have different ballast factors for different lamps, e.g., an electromagnetic ballast with standard lamps has a B.F. of 95% while the same ballast with energy saving lamps has a B.F. of 88%.

#### Ballast Efficacy Factor

The Ballast Efficacy Factor is a ratio of the ballast factor (the ballast's ability to produce light) versus the watts input to the ballast. This measurement is generally used to compare the efficiencies of various ballasts with the same lamp.

$$\text{Ballast Efficacy Factor} = \frac{\text{Ballast Factor}}{\text{Ballast Watt Input}}$$

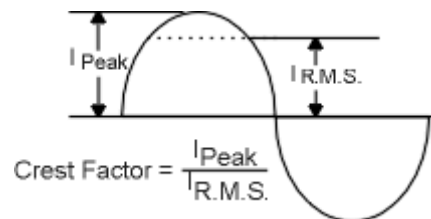
The higher the ballast efficacy factor, the more efficient the ballast. When ballast efficacy factor is multiplied by the lumen rating of the lamp and the number of lamps, a ratio of lumens per watt is created.

$$\text{Lumens Per Watt} = \text{B.E.F.} \times (\text{Rated Lamp Lumens}) \times (\text{Number of Lamps})$$

The higher the lumens per watt, the more efficient the ballast and lamp system. This measurement can be used to compare different types of ballast and lamp systems; for example, F32T8 vs. F40T12 systems.

## Crest Factor

Crest factor is one of the criteria used by lamp and ballast manufacturers to ensure fluorescent lamp life. A measurement of current supplied by the ballast to the lamp, it is basically the ratio of peak current to the root mean square or RMS (think "average") current values. Lamp manufacturers and ANSI require a crest factor of 1.7 or less on electronic ballasts in order for the lamp to be warranted properly for its rated life. Electromagnetic ballast crest factor limits are 1.7 for rapid start lamps and 1.85 for instant start lamps. Current that has a high crest factor can cause materials to be eroded from lamp electrodes prematurely shortening lamp life.



## Class P Thermal Protection

All indoor fluorescent fixtures must incorporate ballast thermal protection in accordance with the National Electrical Code to limit the case temperature of the ballast to a safe level if the ballast overheats. (Fixtures employing a simple reactive type ballast for linear lamps are excepted.) Ballasts meeting the standard are designated "Class P" by Underwriters' Laboratories, Inc.

Advance Class P Magnetic and Hybrid ballasts utilize a thermal protector (TP) as part of their design within the ballast case. If the ballast gets too hot, the TP will open, disconnecting the ballast from the power line allowing it to cool down. Once cool, the TP automatically closes and reconnects power to the ballast. All Advance Electronic ballasts are Class P rated. Some incorporate the TP in their design but many do not. These latter ballasts by their design limit their case temperature below the Class P limits and are designated as "Inherently Thermal Protected".

Advance Class P ballasts also help protect against excessive line voltage, internal ballast short circuiting, inadequate lamp maintenance and improper fixture application. They also eliminate the need for individual fixture fusing. When replacing Class P or non-Class P ballasts be sure to use an exact equivalent. (For instance, nuisance tripping may occur if a non-Class P is replaced with a Class P ballast.)

## EMI/RFI (Electromagnetic Interference/Radio Frequency Interference)

Radio and TV interference, or static, is caused by the action of the arc at the lamp electrodes which creates a series of radio waves. This energy may

interfere with radio reception and the operation of other communications equipment.

*Types of interference:*

1. Direct radiation from the fluorescent lamp to the antenna circuit.
2. Line feedback from the lamp/ballast through the power line to the radio.
3. Direct radiation from the electric supply line to the antenna circuit.

To correct the first cause, it is recommended that the radio and its antenna circuit be separated at least 10 feet from the fluorescent lamp and the radio provided with a positive ground.

The second and third causes can be corrected in lighting systems that generate objectionable radio interference by additional filtering. Generally this can be accomplished by the addition of an external capacitor-reactor filter. It is also desirable for the radio and fluorescent lamp fixture to be provided with a supply voltage from separate branch circuits.

Electronic ballasts which operate the lamp at high frequency may also affect the operation of infrared, power line carrier and communications equipment. There may be no correction possible for some of these interference problems, short of changing the ballasts to a low frequency type, so care must be taken when specifying a lighting installation.

## Ballast Sound

The slight hum present in fluorescent lighting installation originates from vibration caused by the inherent magnetic action in the core & coil assembly of the ballasts. There are three possible ways this sound may be amplified:

1. Method of mounting the ballast in the fixture.
2. Loose parts in the fixture.
3. Ceilings, walls, floors and furniture.

The choice of fluorescent lamp ballasts should be made on the basis of selecting the one rated quietest for a specific location. Ballasts are assigned a sound rating, Class A through F, based on the amount of noise produced. Because electronic ballasts lack vibrating parts, and have higher operating frequencies, they generally produce less noise and achieve a lower sound rating.

To make the best selection, the application needs must be considered. It is obvious that consideration of ballast sound is more important in a private office than in a busy store. See chart for assistance in selecting the proper sound rated ballast.

### SOUND RATINGS

<b>FOR INSTALLATION IN:</b>	<b>AVERAGE AMBIENT NOISE LEVEL</b>	<b>SOUND LEVEL RATING*</b>
TV or Radio Station, Library, Reception or Reading Room, Church, School	20 - 24 Decibels	A

Study Hall		
Residence, Quiet Office, Night School Classroom	25 - 30 Decibels	B
General Office Area, Commercial Building, Storeroom	31 - 36 Decibels	C
Manufacturing Facility, Retail Store, Noisy Office	37 - 42 Decibels	D
<b>*These sound ratings are based on measurements of Average Ambient noise levels during conditions of normal occupancy. Audible ballast hum may appear amplified during exceptionally quiet periods and at times when area is unoccupied.</b>		

NOTE: In planning a lighting installation, careful consideration must be given to the selection of the ballast, the lighting fixture and the room components in the early planning stages to ensure the quietest lighting installation possible.