APPLICATION NOTE #113A

Ballast Test System Production and Engineering Examples

Introduction

Lighting systems used throughout the world represent a significant portion of world wide electric energy consumption. Due to their higher energy efficiency, electronic ballasts are quickly replacing magnetic ones. To verify correct operation and efficiency rating of both ballast types, several power measurements need to be made using a stable AC power source to provide the input power. The California Instruments Ballast Test System (BTS) provides a cost effective and high speed functional test solution for magnetic and electronic lighting ballasts in both production and engineering applications.

This application note provides a general overview of ballast testing requirements, and deals with the demands those tests impose on a functional ballast test system. Some typical production test and engineering applications are used to illustrate the flexibility of the BTS system.

BTS-1000 Ballast Test System

Lamp and Ballast Characteristics

Fluorescent (discharge) lamps are operated by a special version power supply, called a ballast. There are two basic ballast types, the conventional or magnetic ballast, and the newer electronic ballast. In many ways, the development of ballasts parallels the evolution of regular power supplies. The magnetic ballast is a linear device, basically consisting of a current limiting transformer, with perhaps a starter and a power factor correcting capacitor. The newer electronic ballast is in essence a high frequency switching power supply, with some extra functions added.

The input voltage range of most ballasts varies from 100 -270 Vrms at either 50 or 60 Hz. High Intensity Discharge (HID) type ballasts for big commercial applications (sports stadiums) may consume in excess of 1500 Watts, and require higher voltages. Others, mainly for public transportation, may operate from DC voltages in the range from 12 - 48 Volts. On board aircraft and ships, ballasts may be operated at a line frequency of 400 Hz.

Compact Fluorescent Lamps (CFL) are gaining popularity because of their energy savings potential and their form factor which closely resembles the traditional incandescent bulb. Power levels for CFL ballast applications range from about 7 watts to around 40 Watts. The multitude of fluorescent lamps therefore, cover a wide power range. As may be expected, there is an equally large variety in ballasts, both magnetic and electronic types. The basic functions are similar however, and a typical fluorescent lamp circuit is shown in Figure 1.

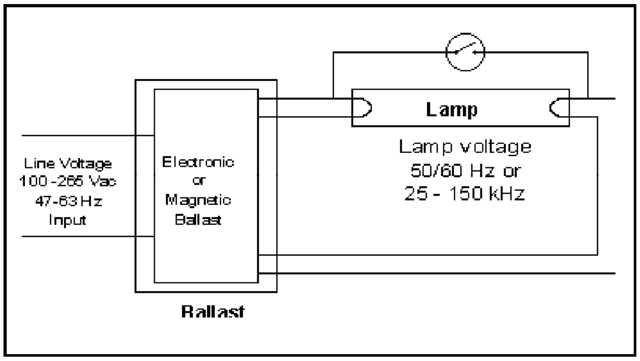

Figure 1: General fluorescent lamp circuit.

Regardless of the type, the following key tasks are performed by a ballast:

1. Line Voltage Transformer
2. Current Limiting
3. Lamp Startup

1. Line Voltage Transformation.

The ballast transforms the line voltage to the required lamp voltage (101 Volts nominal for the popular 4 ft. tube - 40 watt lamp). Depending on lamp type, the ballast may have to provide a high starting voltage (in excess of 1200 Volts for certain types).

2. Current Limiting

After a lamp "strikes", the gas inside the bulb is ionized and the lamp becomes a virtual short circuit. If the ballasts would not limit the amount of current, the lamp would rapidly self-destruct because of excessive current levels. For example, the maximum current allowed for the common 4 ft. lamp is set to 430 mA.

In the case of magnetic ballasts, the current limiting can be achieved in several ways. Simple "reactance" ballasts for low power lamps (typically < 20 Watts) utilize the high inductive reactance of a choke to limit the current. These ballasts have a low power factor, meaning that they require much higher current levels than the power rating indicates. The more expensive higher power factor ballasts typically employ a power factor correction (PFC) capacitor.

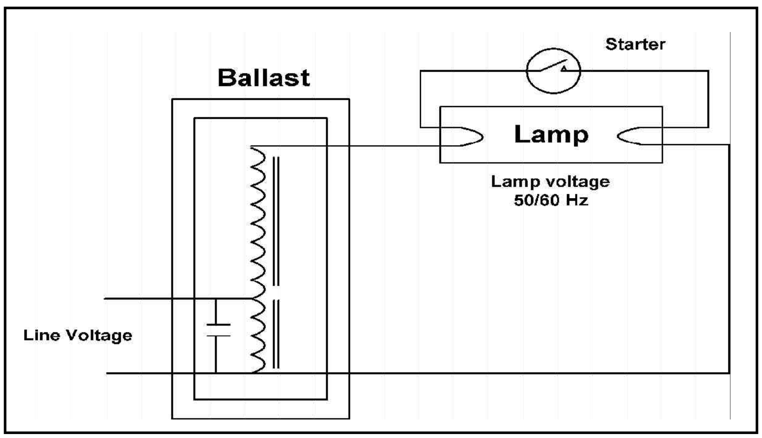

Figure 2: Basic magnetic ballast with starter.

3. Lamp Startup

The required lamp voltage is typically produced by an auto-transformer. The switching mechanism of the starter includes a bi-metallic strip, which initially conducts current and allows the lamp filament to preheat. Small inexpensive fluorescent lamps may employ a manual preheat switch. "Instant start" lamps don't have a starter nor preheat the cathodes. The lamp gas is ionized through a high voltage across the lamp, from about 400 up to 1000 Volts for most popular types. Figure 2 shows a basic auto-transformer ballast configuration with PFC, and a starter.

The transformer of "Rapid start" lamps has extra windings to produce a low voltage of about 3.5 Vrms to heat the cathodes. The starting voltage of rapid start types is almost 280 Volts for a standard 4 ft. lamp, which is considerably lower than the 400 to 1000 Volts of the instant start version, while the operating voltage for either type is nominally 101 Vac (for the 4 ft. lamp). Rapid start versions are the most popular, and are found in most homes and offices. The electronic ballast version for fluorescent lamps utilizes a switching power supply design to produce the desired voltages, and the current is controlled through standard current limiting techniques.

Benefits of Electronic Ballasts

Lamp life is greatly affected by the voltages and currents which occur when the lamp is started. A 25 % increase in start-up current reduces lamp life by more than 50 % ! Therefore, peak current is an important parameter to watch. Initially, electronic ballasts had poor performance in these areas, and overall reliability was poor. Newer electronic ballast designs perform better and have several major advantages over the older linear/magnetic types. Higher efficiency and smaller size are well known benefits of switching power supplies vs. linear operating types. The same is true for ballasts. For fluorescent lamps, there is another benefit. The higher switching frequency, in excess of 35 kHz for most modern designs, results in a 10 - 12 % higher light output per Watt of consumed power. Therefore, electronic ballasts offer overall efficiency improvements of 25 % or more compared to their magnetic counterparts. This higher efficiency can lead to enormous savings and, therefore, electronic ballasts are quickly displacing the older magnetic types.

Ballast Test System Applications

The California Instruments ballast test system (BTS) was designed specifically to test either type of lighting ballast. General purpose rack and stack test systems are commonly used for this purpose today. These systems rely on multiple test instruments using custom test software and represent high system integration and maintenance costs. The BTS is a dedicated, single vendor, functional test system that combines AC source voltage, measurement and switching functions into a single unit. Figure 3 shows a block diagram of the BTS hardware. All instrumentation hardware is housed in a small 3.5 inch (88.9 mm) high rack mount unit.

The PC based architecture of the BTS enables both production test and design engineering use of the same system. The following pages include sample production and engineering test screens, showing some of the measurements that can be performed by the BTS.

Production Test Sequence

For production test applications, the BTS system software implements the test sequence shown below. Each of the test steps listed has user defined PASS / FAIL

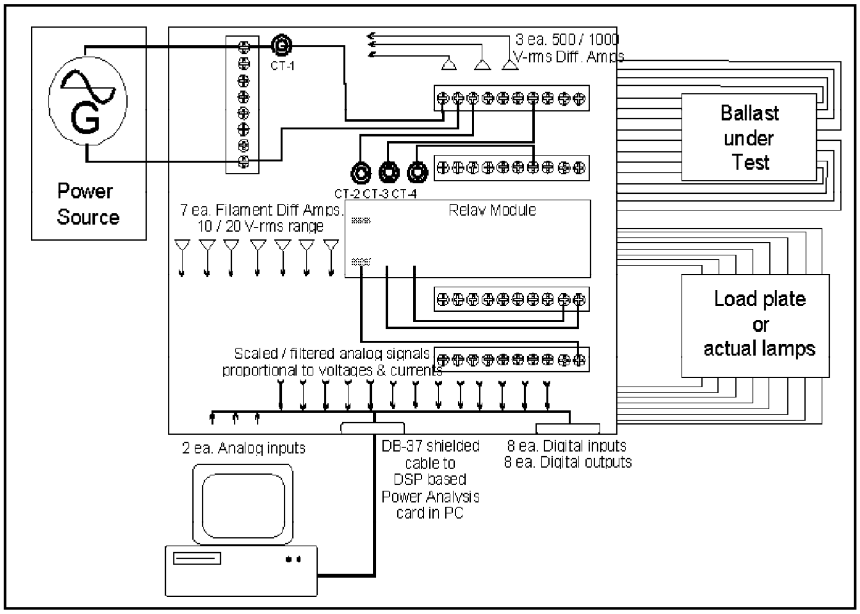

Figure 3: California Instruments Ballast Test System architecture.

criteria. If a test step fails, the remainder of the test sequence is aborted. Test data for each ballast and each test step is automatically logged to disk.

1. Low voltage "short / open" test @ 20 Volts to verify that the ballast has no shorts, and that the unit is properly connected in the test fixture.
2. Full voltage OCV (open circuit voltage) test with nominal line voltage applied. The unit's OCV and no-load input current are compared against limits.
3. Low voltage "short/open" test with filament loads (if applicable) applied. Line input current is checked against user specified limits. For instant start ballasts, this test step is skipped.
4. Full voltage filament test, without lamp load. Filament voltages are checked, and the next test is performed if filament voltages are within the required range. For instant start ballasts, this test step is skipped.
5. Full load test. Nominal line voltage is applied, lamp and filament loads are applied, and all ballast parameters are compared against user defined Min/Max limits. This includes input current THD, Ballast Efficiency (or Ballast Factor), peak currents etc. The ballast sequence number is also recorded.
6. Test data files are updated, all parameters are recorded in spreadsheet compatible files. One file holds data on all tested ballasts, while the other file has only reject data. These data files permit statistical analysis, and meet all the requirements for ISO-9000 compliant manufacturing processes.

The total test time, including harmonic analysis (THD), is typically between 1.4 and 2.0 seconds, depending on ballast type. During the entire test sequence, the BTS controls the integrated AC power source (available in 1, 2, or 3 kVA versions) in order to apply the required input voltage.

BTS measurement channels

The BTS can measure a total of 7 filament voltages up to 10 Vrms. Filament channels may be reconfigured to measure up to 350 Vac (differential inputs) if required. The BTS also supports 3 high voltage measurement inputs and 4. current measurement inputs. An additional 2 inputs are allocated to measure parameters such as temperature, noise, light intensity etc. using suitable sensors. External current transformer options are available.

Production test for 4 lamp ballast.

The screen shown in Figure 4 reflects a ballast tested with resistive loads to obtain fast test times. The user can set test limits and the nominal test voltage / frequency after entering a password. Test configurations for multiple ballast types can be stored on disk for quick recall.

The typical average cycle time for a 4 lamp sign ballast with 5 filament voltages is about 1.9 seconds. This includes the low and full voltage OCV, filament test, and full load test with power analysis, THD, efficiency or ballast factor calculation etc. All the test data is written to test files. The system creates two test files, one with all the tested units, the other with just the "bad" units. Thus

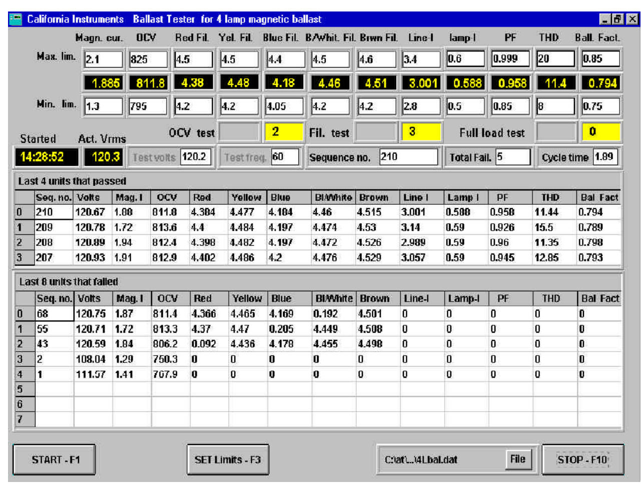

Figure 4: Sample test screen for 4 lamp ballast test.

statistical data analysis is very easy, as both files can be opened directly using a standard spreadsheet program.

The display shows the test data for the last 4 "passing" as well as the last 8 "failing" units. The latter permits the operator to label the failed units appropriately. The system also tracks the sub-totals for each test type (OCV – Filament –Full load). If required, digital I/O can interface to a PLC to accommodate automatic sorting of the failed product.

Engineering use

The PC based architecture of the BTS enables use of the same system in engineering applications as well. Additional information on ballast performance can be displayed if needed for engineering purposes.

In this mode of operation, Open Circuit Voltage test, Filament test, and full load test, are executed while displaying waveforms and harmonic spectra in real time.

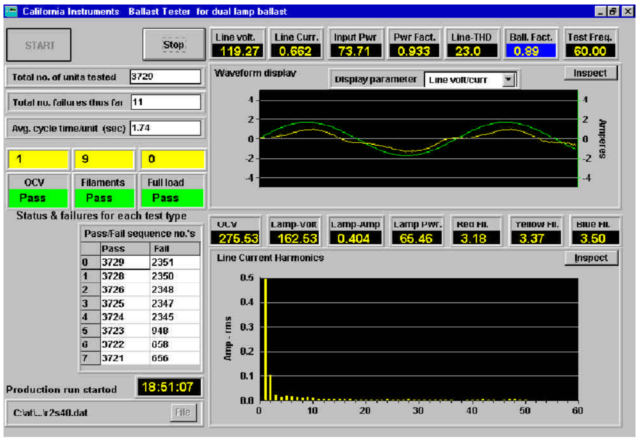

Figure 5: Engineering application screen - 2 lamp ballast.

The user may select waveform displays of various voltages and currents, and observe ballast behavior at each stage of the test. Tests can be run in a continuous loop if needed. Resistive loads are used instead of lamps to eliminate lamp induced variations.

This operating mode of the BTS is useful to establish production test limits. The user runs repeated tests on a series of known good ballasts. Test limits are adjusted to obtain "PASS" statistics that are acceptable. For example, the average test time for 3700 tests was 1.74 seconds per ballast, which included THD and efficiency calculations. Test limits for all parameters can be set by the user and are stored in the BTS configuration file. The display shows the test sequence numbers for the last 8 units that passed, and the last 8 units that failed.

Analyzing Lamp warm-up times

Rapid start ballasts pre-heat the lamp filaments before applying the strike voltage. This significantly increases the life expectancy of the lamp(s). Using the BTS, the correct startup time can be verified by measuring the actual filament temperature as a function of time. The filament resistance can be used as an indicator of temperature as filaments are typically made of tungsten which has a well defined temperature coefficient.

Figure 6 illustrates, a 5 second lamp start-up measurement cycle. All relevant parameters being displayed are written to a file at the rate of about 8 times per second. The two right hand curves display the lamp current during the warm-up cycle (top) and the filament Rh/Rc ratio. The lamp starts to conduct current after about 1.3 seconds (after 10 measurement cycles) and stabilizes within 2 seconds (within 14 readings).

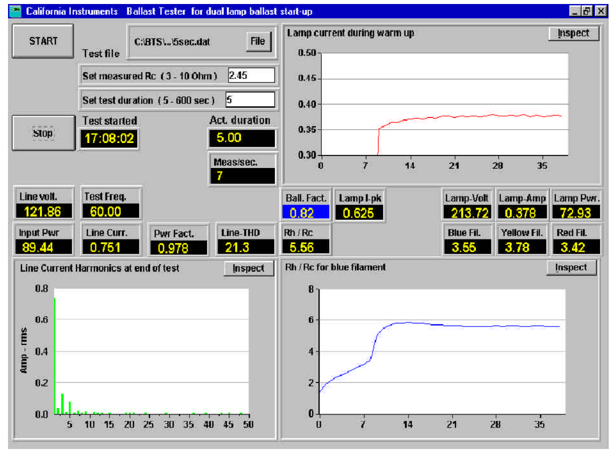

Figure 6: Rh/Rc test on standard 40 Watt lamp.

The filament resistance is calculated from rms voltage and current measurements. In this case the power factor was ignored, as it is virtually 1.00 for the filament. The filament current was obtained by running the "low voltage wire" of the blue filament through one of the BTS' current measurement channels. The lamp current is obtained in the standard fashion, i.e. running both blue filament wires through the BTS' lamp current measurement channels.

The bottom right hand curve is representative of the filament temperature (i.e. the Rhot/Rcold ratio). Note that the Rh/Rc declines slightly as the lamp current stabilizes and slightly increases over time. The BTS can perform these measurements, i.e. perform full power analysis, approximately every 125 ms. The harmonic analysis THD numbers are computed over the last measurement cycle of the 5 second test.

Summary

This application note covers only a fraction of the many possible applications of the BTS system. Additional configurations and uses are possible using the same test system. Refer to the BTS data sheet for technical specifications.

Contact California Instruments:

TEL: 858 677-9040
FAX: 858-677-0940
Email: sales@calinst.com
Web page: http://www.calinst.com

California Instruments

9689 Towne Centre Drive, San Diego, CA 92121-1964 (858) 677-9040 FAX : (858) 677-0940

Printed in the USA. APN113A 11/98