Testing Induction Lamps using Digital Oscilloscopes

TECHNICAL BRIEF

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Summary

There are many types of lighting devices including the familiar incandescent lamp, LED (light emitting diode), HID (high intensity discharge), fluorescent, and induction lamps. All of them can convert AC power (and in some cases DC power) into light. But there are differences in efficiency, complexity of construction, lifetime, brightness and in the color of emitted light. However the testing of all of these different types of devices can be done using digital oscilloscopes. This article will discuss testing of induction lamps.

Similarities and Differences between Fluorescent Lights and Induction Lamps

In some ways, induction lamps are a subset of fluorescent lamps. The light emitted from the lamp comes by transferring the energy from ultraviolet waves (UV) to a fluorescent coating on the inside of the bulb. The fluorescent coating converts the UV into visible light and the glass wall of the bulb absorbs any remaining UV. So only the visible light is emitted. The coloration of the light depends on the types of fluorescents used to coat the inside of the bulb.

But the method of producing the UV in typical fluorescent lamps is much different than the process used by induction lamps. UV is produced by establishing an arc discharge. In the case of conventional fluorescent lamps the arc termination is at tungsten filaments (electrodes) at each end of the tube. An electrical current sustains the arc. The electrons in the arc through the lamp stimulate mercury vapor in the lamp thereby producing the UV waves that in turn excite the phosphor. Once the lamp starts up, it becomes a device with negative resistance- the more current that flows in the lamp, the lower its resistance becomes. So a ballast is required to moderate the flow of energy.

By contrast, induction lamps do not have filaments. This is also a huge difference from conventional fluorescent bulbs where the arc goes from one electrode to the other. The Induction lamp has one continuous arc, eliminating the need for the wear out electrodes. Induction lamps work on the same principle as transformers, commonly encountered by electronic design engineers in power supplies. An alternating current passing through a conductor (the “primary”) will generate a magnetic field whose strength varies with the amount of current. The time varying magnetic field will induce a current in a nearby conductor (the “secondary”).

In the case of induction lamps, the 50-60 cycle AC line current is stepped up to RF frequencies. The wire carrying the RF signal is wrapped around a ferrite core that is exterior to a bulb containing mercury gas. The wire wound core acts as the primary of a transformer and the gas is the secondary. The energy transferred by this process excites the gas and it starts to emit UV. An electronic ballast is used to control the start-up and steady state operation of the bulb. These types of lighting devices can be highly efficient and long lasting. Efficiency is rated in lumens of light output per watt of power consumed.

An Example of Testing an Induction Lamp

Both the efficiency and the longevity of an induction lamp depend crucially on the ballast used to control it. In many cases this is a microprocessor controlled circuit – and considerable design and test expertise is needed to create a reliable, low cost yet effective ballast. Typically, a lighting device needs to operate in AC circuits with voltages ranging from 108 to 270 volts and frequencies of 50-60 Hz. Figure 1 shows an example of testing on an induction lamp. In this case, the lamp ignition is having a hard time starting. The input voltage is 277 volts. This should be stepped up to about 450 volts and 200 kHz to operate the lamp. The upper half of the oscilloscope screen shows the capture of four signals over the course of one second during start up. Note the time/div in the lower right corner is 100 ms/div and there are ten horizontal divisions on the screen. The lower portion of the screen shows a zoomed detail at 20 ms/div of the four upper traces – basically, the zoom shows the portion of the signal captured in the 2nd and 3rd horizontal divisions of the upper grid. In the upper gird you can see highlighting on the early portion of the signal which indicates which piece of the signal is being shown in the zoom.

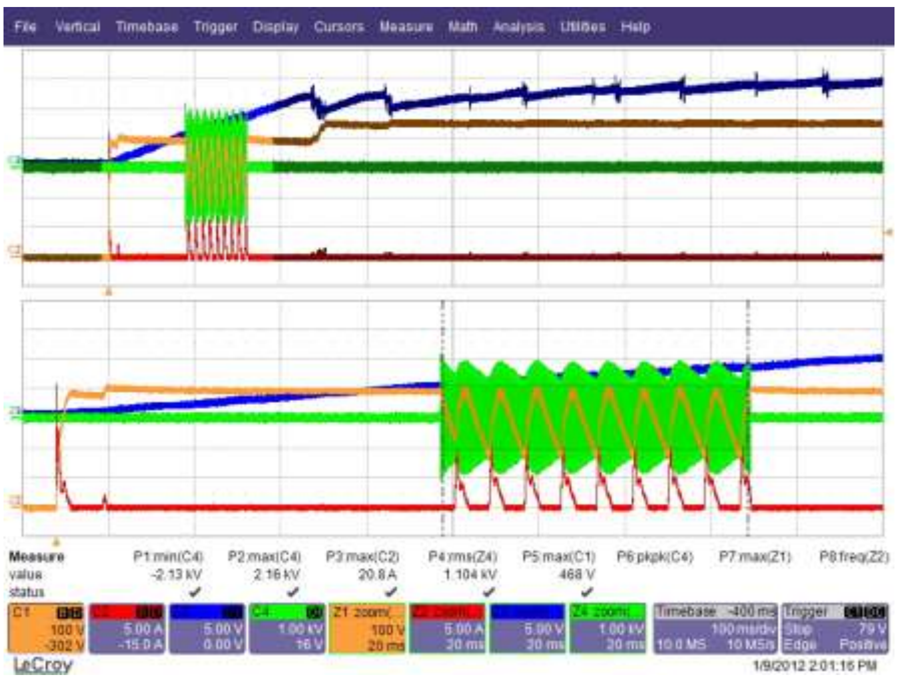

Figure 1: *Failed ignition of an induction lamp operating at 277 volts. The upper grid shows one second of capture time for four signals. The highlighted portions of those signals are shown as zoom details in the lower grid. Channel 1 (orange) is the rail voltage, Channel 2 (red) is the boost diode current, channel 3 (blue) is the bias supply voltage and channel 4 (green) is the output voltage of the lamp*

Channel 1 (orange) is the rail voltage which should be boosted to 450 volts. Note in the lower left corner of the screen the sensitivity of channel 1 is 100 Volts/div. In the highlighted portion of the lamp start up channel 1 only reaches (just barely) the fourth division, 400 volts. If you examine the upper trace you can see it reaches 450 volts about half a division later. Channel 2 (red) is the boost diode current (5 amps/div). For proper operation of the lamp, it should be running at a frequency of 100 kHz. In the zoomed detail you can see channel 2 is starting to switch current, but at a much slower rate than 100 kHz. Channel 3 (blue) is showing the charging of the internal bias supply to run the electronics (5 volts/div). It needs to be above 10 volts and though it eventually does get there (as shown in the upper trace), during the start-up portion of the signal shown in the zoom it never reaches 10 volts. Consequently, channel 4 (green) of the oscilloscope (1 kV/div) which shows the output voltage of the lamp reveals the lamp tries to start up and then fails.

Perhaps the first lesson concerning testing of induction lamps is that you need several types of probes to acquire the signals. Channel 3 is “easy”, just 5 volts/division so the typical probe supplied with the scope can handle it. For channels 1 and 4 the signals have much higher voltages so specialized voltage probes may be required. Channel 2 is a current signal, so you either need a shunt to convert the current signal to a voltage or you need to use a current probe capable of capturing AC currents at frequencies up to at least 200 kHz.

When you want to use an oscilloscope to examine multiple signals and multiple zooms or multiple math traces it is good practice to use multiple grids. The ADC (analog to digital converter) on the front end of a typical 8 bit oscilloscope has 1 part in 256 resolution to measure the amplitude of the signal. If a scope is set up to display many signals on a single grid the user “squashes” each signal to fit a small vertical portion of the grid. Since the ADC is spreading its dynamic range across the full vertical height of the grid, if a scope user places a signal to fit into one vertical division (in order to see 8 signal shapes on a single grid) the scope winds up using only one eighth of its codes, 32 counts, to digitize the signal. Essentially, the user has paid for eight bit ADCs but is only using them as 5 bit ADCs. Note in the upper grid on Figure 1 that each of the four signals is occupying about half of the vertical range of that grid – which means the four signals are each being digitized using half of the vertical range of the ADC. In an optimal case, the user would want the signals to cover near the full range of the grid, but in actual engineering practice, some headroom often needs to be left in case the signal goes higher or lower than expected. Also, in this case, no precision measurement is needed. The scope is operating more as a simple viewing tool. The shapes of the signals are enough to confirm the lamp is not operating properly.

Second Example of Induction Lamp Testing

A second example of testing the same induction lamp is shown in Figure 2. This time the basic operating conditions are 208 volts and 60 Hz. The ignition sequence is better than in Figure 1 but still not sufficient to get the lamp started during the one second of time captured by the oscilloscope. The four traces (and the four zooms) are all the same signals as in Figure 1, the horizontal time base of the acquisition and the zoom are the same and the vertical sensitivities (volts/div and current/div) are also the same as in Figure 1. The highlighted area of the upper traces is now the 4^{th} and 5^{th} horizontal divisions of the upper grid. You can see the orange trace on channel 1, the rail voltage, reaches 300 volts near the end of the first horizontal division on the upper grid and eventually gets to the targeted 450 volts near the end of the zoom portion. But during the crucial time where the lamp is starting up (as shown in the green trace on channel 4) the rail voltage oscillates at around 300 volts. Channel 2, in red, shows the boost diode current attains a much higher frequency than in Figure 1. In the zoom you can see a comb shape of quickly changing diode current. Channel 3 (blue), attains the 10 volts desired for the bias supply charging voltage shortly after the third division on the upper grid. But as the light starts to turn on (channel 4, the green trace) the bias voltage is disrupted. You can see bursts of noise on channel 3 which line up with the bursts of current on channel 2. The lamp fails to stay on and all four signal collapse back to steady states.

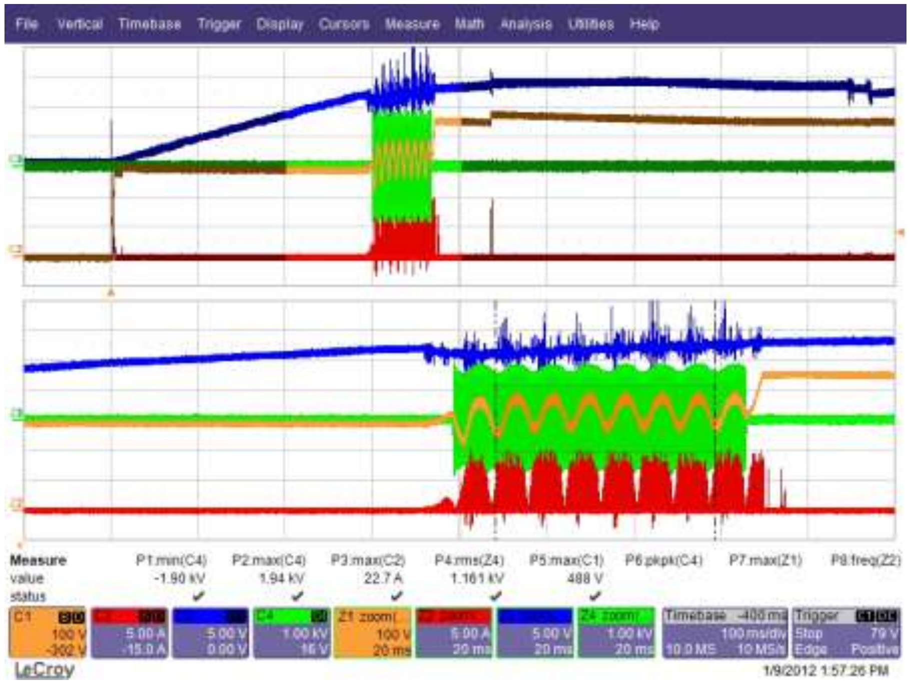

Figure 2: *The same test setup as Figure 1 but this time the input voltage is 208 volts rather than 277 volts*

In addition to the oscilloscope usage lessons discussed above in the first example there are a few new points that arise. In Figure 1 the activity of the boost diode current could be clearly seen as nine fairly slow peaks of roughly triangular shape. But in Figure 2 the same signal has much faster activity. This could be viewed more clearly if channel 2 was zoomed to a faster time base. Some oscilloscopes only allow one common timebase for all zoom traces, as is shown in both figures. But in many real world test situations there are both slow signals and faster ones. So it can be desirable to have multiple zoom timebases. Many LeCroy oscilloscopes have this capability. You can even have a zoom of a zoom – perhaps turning on a 3rd and 4th grid that showed just the green and red traces on faster timebases than the existing zoom. That is a useful tool for viewing details of multiple signals. And there is a useful technique for measurements in this situation. Is the boost diode current running at its desired 200 kHz ? You can't tell from Figure 2. But if the scope was set up to show the boost diode current on a third grid, at a faster zoom display timebase you could visually ascertain the frequency , you could do an FFT of the faster zoom trace or apply a parameter measurement to that trace. Using a zoom to select of portion of a waveform for measurement is a good technique. If you want to ignore a portion of a signal and just do math or parameter measurements on a piece of the signal, you can activate a zoom to select the interesting portion of the signal, then apply math or parameters to the zoom trace (only).

A similar sort of capability with respect to measuring parameter values on just a portion of the signal can be accomplished using a feature called a "measure gate." Oscilloscopes with this feature (including many LeCroy oscilloscopes) allow the user to turn on two vertical cursors and use them to define the piece of the signal to use in making parameter measurements. The measure gate can be placed on the original acquisition channels or it can be placed on a zoom. In both Figure 1 and Figure 2 the user has placed a measure gate on the lower grid.

In Figure 1 the vertical dashed, black lines can be seen to line up with the start and end of the burst of activity on the green trace (the lamp output voltage). In Figure 2 the measure gate is noticeably inside the envelope of lamp activity. The oscilloscope user can even move the measure gate to see if parameter values are different on various portions of the signal. Is the diode switching frequency (red trace) the same in the first burst of activity as 2^{nd}, 3^{rd}, etc?

There is one final point. Suppose you have the lamp shown in Figures 1 and 2 – and when you flip a switch it turns on? Certainly the view shown of the signals during one second of acquisition time does not look good. But maybe after the circuit has a few aborted tries it starts to work and the ballast regulates the light. What you might need is an oscilloscope with a longer acquisition memory in order to record the complete action of the lamp. If you look at rectangle near the lower right corner of both Figure 1 and 2 you can see the oscilloscope is capturing "10.0 MS" which means ten million samples of data on each of the four input channels. You can also see the sampling rate is "10 MS/s" – 10 million samples per second. This sample rate is clearly a good one for capturing the sort of details in this application. Let's suppose you could keep the sampling rate the same, but instead of capturing one second of data you would like to capture for three seconds. You would need 30 million sample points. There are a couple of ways to do this. Some oscilloscopes have very long memory and you can simply go into the horizontal setup menu and tell the oscilloscope to use more. In other cases, you can sacrifice the number of input channels acquiring data in order to have longer memory available for the channels that are in use. An example is the WaveSurfer MXs-B from LeCroy (though there are also many other types of scopes with this capability). If you use all four channels of this type of scope, there are 16 Mpts of memory per channel. But the scope can also be told to operate in 2 channel mode and apply 32 Mpts of memory to each channel. So you could capture 3.2 seconds of data on 2 channels at 10 MS/s sampling rate. In order to test the operation of your lamp, maybe you only really need to see channel one and channel two of the two previous examples. Or, if desired, you could capture two signals, save them to internal memory in the scope, then capture two more signals. So you could even have all four signals – but use two acquisitions to acquire them.

Summary

There are many different types of interesting and useful lighting devices. To obtain longer lasting and more efficient lighting, good R&D engineering and careful testing are needed. This necessitates a wide variety of probes and can be enhanced by a knowledge of how to use the measurement capabilities of oscilloscopes.