SLOT TECH
MAGAZINE

July 2011

Slot Machine Technology for the International Casino & Gaming Industry

This attractive OLED button was observed on a slot machine at the Atlantis Casino in Reno Nevada. The photograph was taken on April 20, 2011. The button is apropos as the restaurants at the Atlantis Casino are all very good. And yes, I tried them all!

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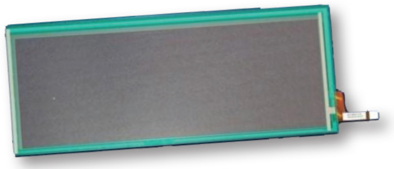

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Randy Fromm

Dear Friends of Slot Tech Magazine,

The stuff that I have thrown up on YouTube has proven to be helpful to me in a way that I hadn't anticipated (search for Randy Fromm and you'll find my channel). During a recent class, I was unable to cover all of the basic electronics topics that I wanted to present. We were concentrating on components, power supplies and LCDs in an accelerated, two-day course that left no time for the basics. However, I was able to refer them to the channel as a sort of a "homework" assignment and, in the end, it worked out really well.

If you're interested in training a lot of techs in just a couple of days, you might be interested in this new, "high-speed" class. Give me a call and we can discuss your needs. Otherwise, you are all welcome to bone up on the basics online at youtube.com.

Have a wonderful Summer.

Randy Fromm

Randy Fromm - Publisher

Randy Fromm's
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Kiesub Offers Lighting Alternatives

There has been a considerable amount of research compiled over the years about what motivates the average gambler. This naturally includes the look and feel of a slot machine as the person approaches and then sits down to play. If you talk to slot directors in casinos, you will get a plethora of opinions about what is important when it comes to the appearance of any particular machine. Much attention has been given to how the player perceives the machine even before they sit down. A burned out light or dimly lit machine tends to shy the player away from the machine, probably on a subconscious level. Lights too bright on a machine or one with some glare also might annoy the patron and cause them to move on to another machine and/ or another casino.

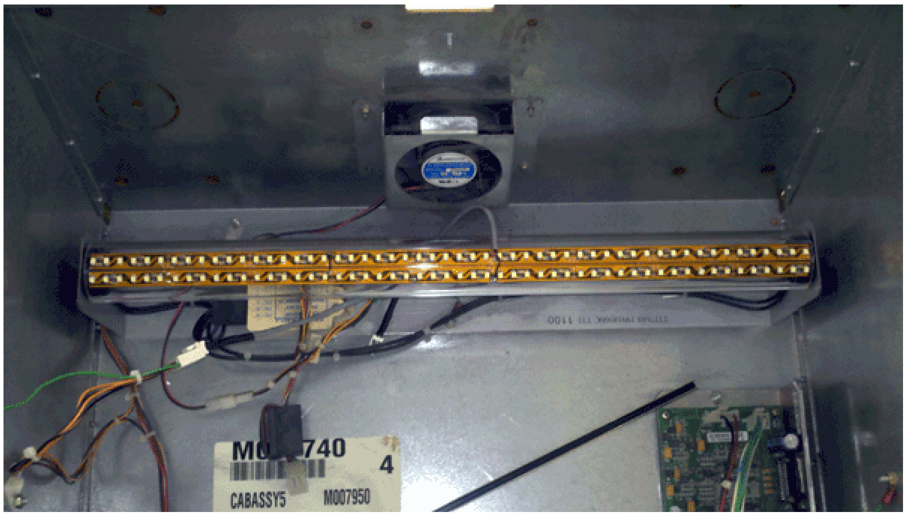
To take it still further, the mood of the patron might be affected by coloration of the light. A dimly lit machine may be too subdued making for a bored or too relaxed mood or the opposite of high anxiety with a color too bold.

The list could go on and on with other examples of perceived impression as this and this is just the tip of the iceberg when it comes to the psychological studies of players. Although these studies and their conclusions are obviously considerations valuable to all gaming properties, they may take a back seat to economic pressure to reduce costs in this challenging economy.

Perhaps you already are familiar with PrismPro LED light panels being offered by Kiesub Electronics and distributed by Suzo Happ. These panels are a striking example of how the casino industry drives innovation based on the science of players' psychology. The panels fill the glass with just the right amount of brightness, all the way to the edge so you get the full benefit of the graphics with no spotting or glare. Coloration can be fine tuned to the taste of the particular property in a way that will blend with the décor. With a five-year expected lifespan, the casino doesn't have to worry about burned out lamps.

Simply put, these panels solve all the issues we have just discussed. Well, perhaps all but one. The price.

This brings us to the newest development in Led lighting solutions for slot machines. In spring of 2011, Kiesub released a new, lower priced unit which does not replace the premium PrismPro line but performs at acceptable levels of brightness and coverage and at less than 50% of the cost for PrismPro series. Kiesub calls it the Econo line.



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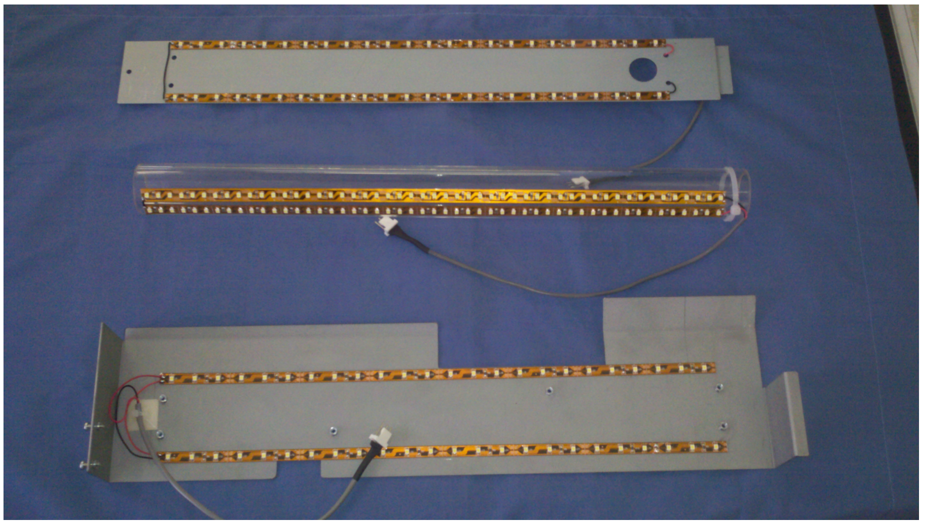

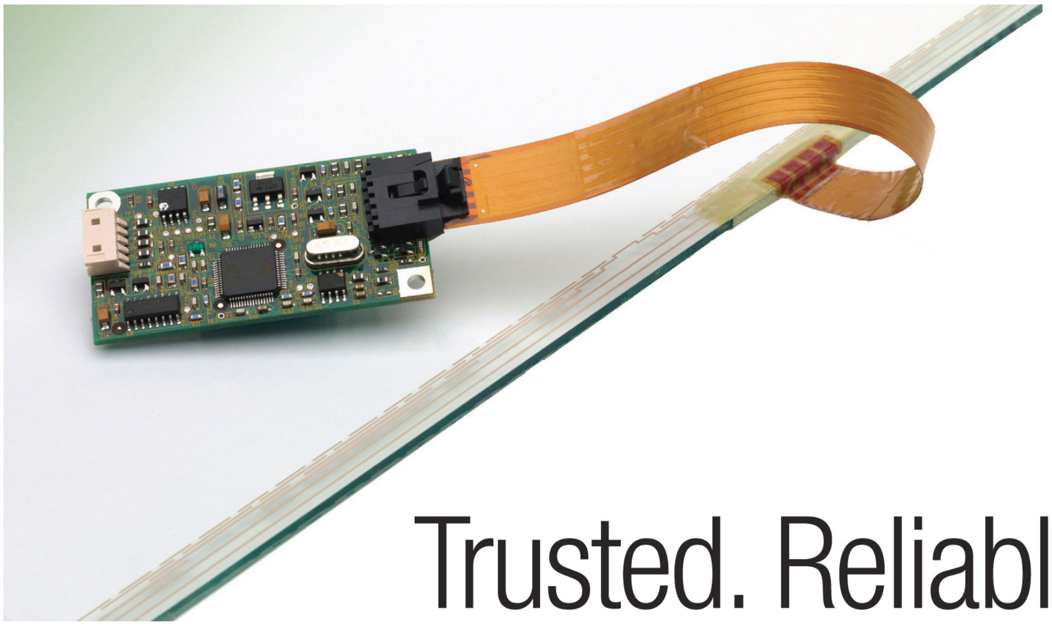

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The technology used in the Econo line is direct forward lighting utilizing flexible LED strips mounted with very simple hardware making for a quick, no modification install. Some models utilize acrylic tubes that snap into the existing fluorescent sockets where others have mounting brackets supplied.
The Econo series LED solutions will complement the high performance PrismPro line in the fulfillment needs among the broad spectrum of casinos and other operators.

Kiesub Electronics' Econo and the PrismPro line of LED products are available exclusively thru distribution at The Suzo-Happ Group.

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For more information contact:
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Kiesub Electronics Introduces New Econo Series LED Replacements for Slot Machines

Las Vegas, NV - KIESUB ELECTRONICS has released a new LED replacement for fluorescent and incandescent lamps for the slot machine industry.

"Kiesub saw the demand for a low priced alternative to LED lighting inside slot machines", says Mike Johnsen, Director of Manufacturing at Kiesub Electronics. "We designed the LED Econo Series to be an energy-efficient alternative to incandescent and fluorescent lamps while keeping the costs at a minimum. These units will make it possible for even the most budget-minded Casino properties to take advantage of energy-saving technologies.

In 2009, Kiesub designed an LED panel to replace the constantly failing lamps and bulbs in slot machines. In response to customer requests, Kiesub released a substantially lower-priced unit. This does not replace the premium PrismPro line, but performs at acceptable levels of brightness and coverage- at less than 50% of the cost for PrismPro series.

The two product lines will complement each other in the fulfillment of a broad spectrum of casino's needs.

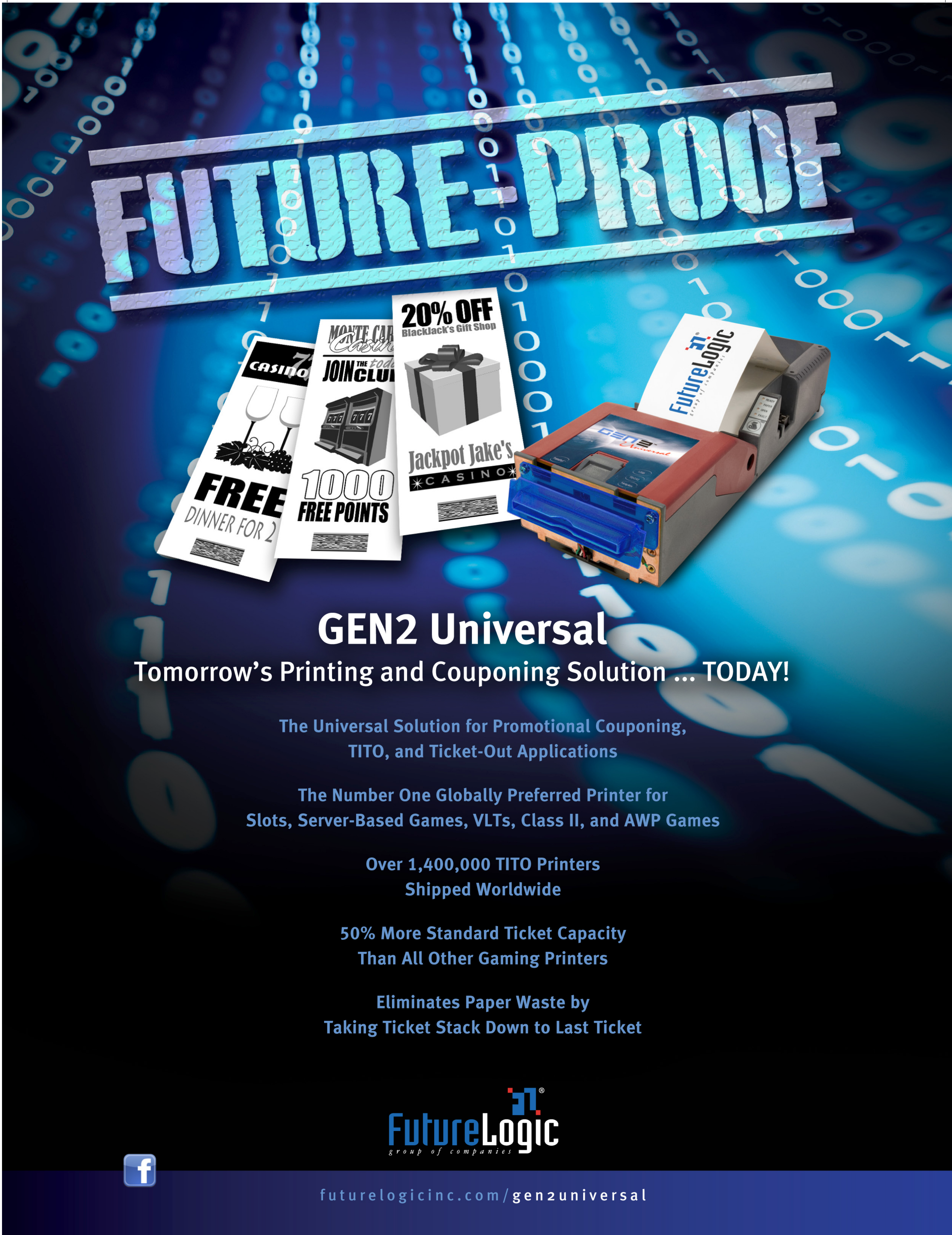
The major benefits of LED technology include lower power consumption (saves energy), longer life-up to 5 years (labor & time saver), and less heat generation (nearby components won't fail).

Kiesub has designed over 50 different products to replace the lamps in the graphics panels of the most popular slot machines, from the "Insert Bills" arrow, "$5 to $100 Face Up" arrow, to the Topper and large Belly Glass panels.

The demand has been nearly overwhelming: Over 50,000 of Kiesub's LED replacement boards and panels have been installed in Las Vegas and throughout the US. Installation of these LED panels has reduced energy consumption by enough energy to power about 12,000 homes.

Since 1995, Kiesub's manufacturing division has provided contract manufacturing and value-added assembly services. Custom cable harnesses, battery-pack assemblies, electro-mechanical assemblies, PC board stuffing, engineering and design services are just a few of the services that Kiesub provides with their fully-trained, IPC-certified staff with over 75 years of combined experience.

Kiesub Electronics, an electronics distributor and value-added/ contract manufacturer established in 1973, supplies electronic parts, equipment, batteries, accessories, cable harnesses, and electro-mechanical assemblies to the hotel/casino, industrial, commercial, OEM and government markets locally and nationwide.



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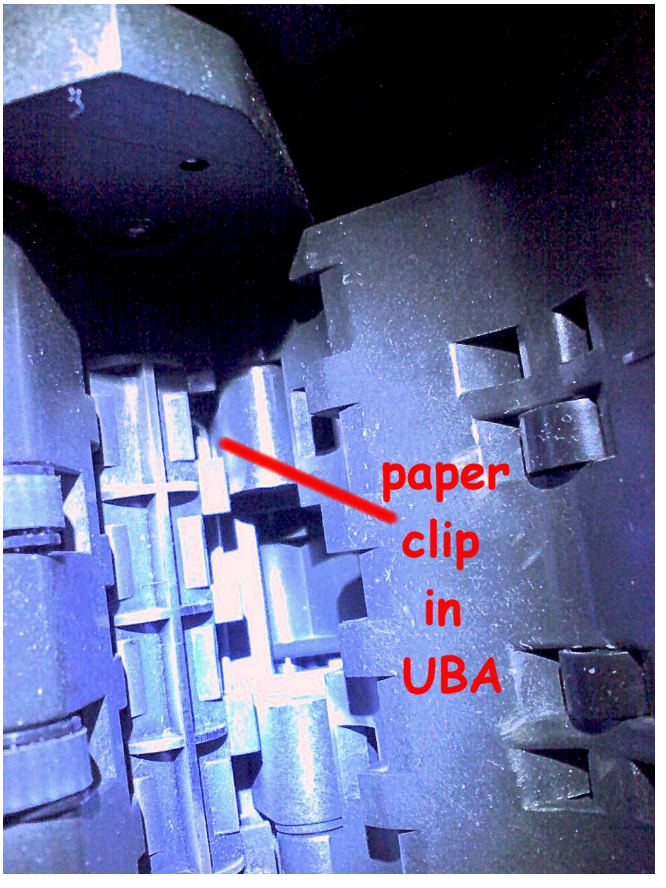
Quick Simple Repairs #76

By Pat Porath

UBA Not Working Properly

Every so often we get a call for a bill acceptor that isn't working properly. Sometimes we get numerous calls, other times only a few, per day shift. Sometimes they do not work because the bill acceptor lenses are dirty, the magnetic head is dirty, the stacker box isn't seated properly, a dip switch not set correctly, the list goes on. With this particular UBA problem it didn't "cycle" properly. In other words it didn't sound correct after it was reseated in the game. When the unit is removed and reseated into the game, a certain "cycle" or a specific certain noises will be heard. For example: the internal motors will turn and the gears will turn, the bill acceptor also uses sensors to "look" for a cash box. Anyway, the unit didn't make a complete "cycle" or "power up cycle." It started to but didn't finish. On a UBA, if it "cycles" continuously, then the stacker box may need to be reseated properly or the bill acceptor may need to be replaced. I simply look at the sensor lenses. If they look cloudy or dusty after it has cycled continuously for a bit, I swap the bill acceptor with one next door and see if the problem follows. If the problem does follow the unit, I replace it.

Back to the original problem, I reseated the stacker box a couple of times, along with reseating the bill acceptor a couple times, yet the problem remained. Next, the UBA was opened up for an internal inspection. What the? Near the back section, where the bill or ticket would exit the UBA and start to enter the cash box, was a darned paper clip that was jammed in the "anti-theft roller." This was not the first time I had seen this. After the paper clip was removed, the bill acceptor worked fine.



Older Aristocrat Rebooting Itself

I received a complaint that an older Aristocrat game was rebooting itself and wouldn't boot up all the way, so I took a look at it. The I/O board (located directly below the main board) was reseated and the main processor board was removed for inspection. Located on top of the processor chip was a cooling fan that was quite dusty. I used my finger to give it a spin to check how

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free it spun. If it spun very freely more than likely the fan was good, if not, more than likely it was bad. Well, it failed the test. The fan did not spin nice and free like it was supposed to and the area of the processor chip was quite hot. I was sure the cooling fan had failed so off to the shop in search for a new replacement. It was very simple to remove, only two plastic tabs held the unit in place and of course the connector. After a direct replacement was found (it took me a few minutes because we have quite a few small fans in stock) it was easily put on the board and the board was installed back in the game. When I turned on the main power switch for the game, the fan was checked to make sure it did in fact work and it did. The game was back online. If the game started to reboot itself again after the replacement of the fan I'm sure someone would have let me know. A bit later in the week a different Aristocrat game that was in the same bank, wouldn't boot up. Of course one of the first things I checked was the cooling fan, which was good. While taking a quick look at the main processor board to see if anything was obviously wrong, one of the boot chips was partially out of its socket. How had this happened? Maybe when the board was replaced it wasn't seated all the way or maybe the chip wasn't seated properly after a RAM clear. Hard to say. After the chip was nice and snug in its socket, the game booted up and worked perfectly.

Dead Oasis Sentinel, No COM

I recently had a Sentinel that was installed in a "Trimline" game that did not have any sign of communication at all. The Oasis display was in lower case text and the green light on the Sentinel did not flash at all. This indicated two signs of no COM. I checked the COM in and COM out cables, tried a Sentinel RAM clear, checked the COM out cable from the previous game, checked cable connections that are located in the slot base but nothing looked out of the ordinary. Maybe the Sentinel had died? I went to the shop and grabbed a spare along with a spare EPROM and a few COM chips. Before replacing the complete board, I thought I would try just a COM chip which is located at U6 next to the E-Square chip. Power was removed, the old chip taken out and a new one installed. Quite soon after power had been re-established, the green light started flashing. This indicated that the Sentinel now has some type of communication. The "global settings" were checked and in no time, the display had upper case text. My mechanic/tech card was inserted to check if there were any COM errors, that looked good too. Finally the game was communicating properly and it was back online. It had been put out of service because it was locking up for hand pays. Now it was good to go.

Ithaca 950 Printer Problem

I was told that a "Konami Advantage" game had a printer problem. Once at the game, I saw that it was an Ithaca 950. So far, this type of printers works very well for us; it was a bit unusual to run into a problem with one. As soon as I opened the printer up anyone could see that it was caked with a pile of dust. The printer was removed from the game, blown out with high pressure air from an air compressor so

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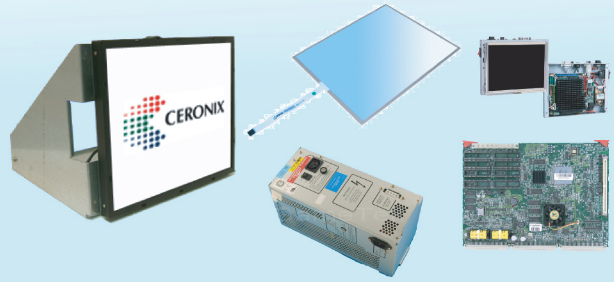

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it looked nice and clean, and the printer was put back into the game. I pressed the feed button to feed a few tickets through and it worked properly. Next, the diagnostic menu was entered on the game to access the "printer test" menu. Three test tickets printed out perfectly. Simply blowing out all of the dust with high pressure air (around 80psi give or take) fixed the problem.

WMS Bluebird LCD Problem

This specific ordeal was a first for me. I was called to a Bluebird game that had been rebooted a few times and then the screen would freeze up. The game was a Bluebird upright game, with a single LCD for a monitor. Just for the heck of it I rebooted the game again ending up with the same results. All that would appear on the screen was the game theme. It didn't matter if the screen was touched or if the diagnostic button was pressed or if the jackpot reset switch was turned. An image of the game theme remained on the screen. Maybe the main processor board became a bit loose? I turned off the game once again, reseated the main board and reseated both the OS card and the game card. After the power was turned back on and the game booted up with the same result.

Now what? When I wiggled the power cable to the LCD, the picture wiggled too. I thought that this was interesting. When the cable was removed from the socket, there was a brown burn mark in the connector. I've seen a few power cables go bad before, making it look like a bad LCD when actually the cable was bad. Yes! I found the problem!

After a new cable was installed (which goes from the LCD directly to the backplane board) the game was turned on yet another time and STILL the failure remained. This time I took a closer look at the LCD connections. Why were there two video cables connected to the input section of the LCD? One was a VGA, the other a DVI. If I was correct, simply unplug the VGA cable and leave the DVI in place to see what happens. As far as I know, a Bluebird game only has one video cable going to the main LCD. I disconnected the VGA on the LCD side and rebooted the game again. This time it booted up all the way and the picture looked

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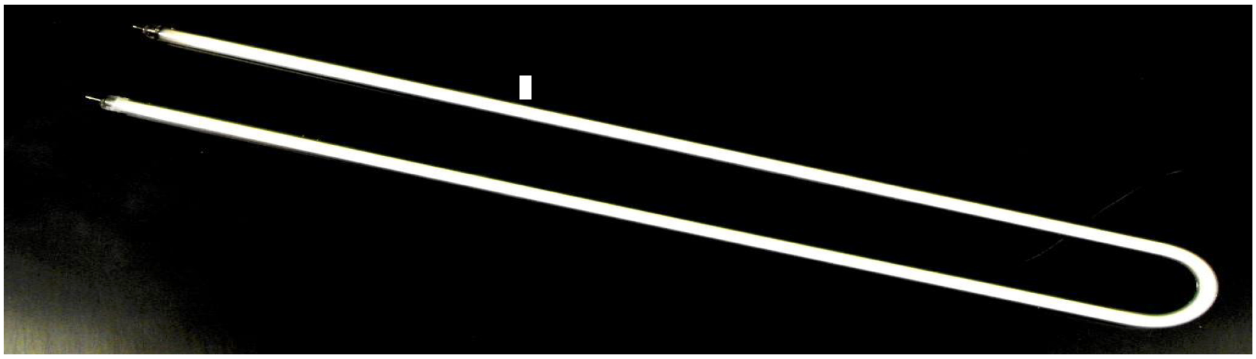

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normal. I touched the menu button (which I didn't have displayed before) and the menu screen appeared. This indicated the touch screen was working now. It also indicated that the game was normal and appeared ready for play. I closed the door and it looked great. Next, I removed the VGA cable from the game so someone wouldn't accidentally plug it in again. Finally, the game was ready to be played.

Aristocrat Viridian UBA Problem

There was an Aristocrat Viridian game that was shut down because of a bad bill acceptor and I was told we didn't have any spares. So I went to the game to check out the problem for myself. At the game, the bill acceptor wasn't even in it. The unit was sitting on the bill acceptor repair bench and next to that is the R.F.I. bill acceptors. (Ready For Installation) On this specific day we didn't have a spare UBA for a Viridian so I needed to try to get the original unit to work. Back at the game, I installed the bill acceptor then proceeded to turn on the game. It made a funny noise so I reseated the cashbox, then reseated the UBA. This time it sounded pretty normal. After the stacker door and main slot door were closed, the bill acceptor bezel light was supposed to light up showing that it was ready to accept bills or tickets but it did not. On the lower part of the game LCD a "bacc signature error" appeared. I ran across this error not that long ago. What was the cure again? I had to think for a few minutes, then it hit me. To clear the error simply open then close the logic door. Was this correct? I tried it and it worked. The bill acceptor bezel lights lit up beautiful. A blank ticket was used to make sure it would accept and reject properly and it did. Another game online.

Atronic e-motion Not-So-Simple Repair

To start off with, I thought it was a very simple case of wiping the dust off of the CD, putting it back into the game, giving it a reboot then done. That's not quite how it went. The main LCD of the game stated "CD problem" so I checked the CD to see if it had dust on it. There was. I carefully wiped off the dust with a soft cloth, from the inside outward, like you are supposed to, and put it back into the game. Shortly after the game started to boot up, the CD error appeared again. Another way to tell if the disk is or is not reading, a small light located on the disk drive will flash very rapidly when it's reading and flash slowly then stop when not reading. Maybe I didn't do a good enough job the first time, so I cleaned it again, once again without success.

Maybe the optic on the drive was dusty? I removed it from the game, used compressed air to blow it out and that didn't work either. Next, I replaced the CD drive with a new replacement, remembering to double check the small jumper located in the back part. I compared the two settings which were both on the "master" pins, then installed the drive into the game. After power was applied, the CD was inserted into the drive then the game was rebooted. Once again the CD error appeared. What in the world could it be? The CD didn't appear to be scratched very badly, the drive was brand new and all of the connections looked good. I didn't really know what else to do so I asked a co-worker to look at it. The CD was cleaned with a CD cleaning machine, it was put back into the game and still no go. Later on I did verify that it was indeed a CD problem. I was able to put in the exact same theme from the game on the same row. With a known good CD, the game booted up perfectly. This told me that the original CD was bad. A replacement was ordered and installed but why was the game still turned off? After I turned the power on I found out. Now the top LCD was black and the back VGA plug on the video board was snug in place. Note: Atronic e-motion video card, front VGA plug is for the bottom LCD, and the back is for the top LCD. I reseated the video connector on the board without a thing showing up on the screen. To me this indicated a bad LCD. A co-worker repaired or replaced it and the game was finally back online after a new CD, CD drive (not actually bad), and a different upper LCD was installed.

- Pat Porath
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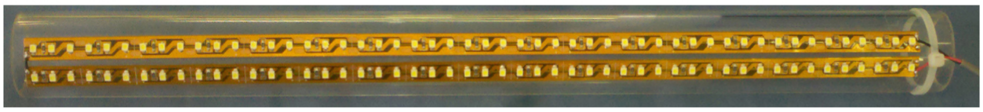

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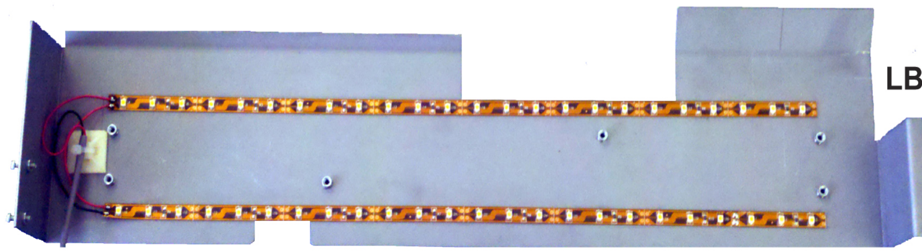

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Power Supplies. Build or Buy?

By Herschel Peeler

Powering up assemblies at the bench for testing requires some source of power similar to that provided by the game. You can buy a general-purpose power supply or build one that fits your specific needs. Two questions to ask yourself here are: 1) What are your needs? 2) What do you have to work with?

There are general-purpose power supplies in the one hundred to two hundred dollar range that produce up to 50 Volts at 5 Amps. They have variable output voltage and adjustable current limiting. Most of these have metered outputs for monitoring voltage and current. They range from 15 Volts at 3 Amps for around one hundred dollars to 50 Volts at 5 Amps for about two hundred dollars. These are good for major assemblies like LCD monitors, ticket printers and bill validators. Yes, such supplies can be built for a bit less but consider the quality a factor also.

General Purpose vs. Laboratory Quality

Some supplies are billed as Laboratory Grade. To give you an example of what that means consider putting a meter on the output and compare it to what the meter on the power supply reads. Laboratory grade power supplies are more likely to be within one percent. General-purpose supplies are more likely to be within about five percent. Do you need the accuracy?

Of course you can also question the accuracy of your multimeter you are using to make the measurement? How close is it to being calibrated?

Resolution vs. Accuracy

If the 20 Volt scale on your meter can display the difference between 15.0 Volts and 15.1 Volts it has a resolution of 0.1 Volt on the 20 Volt scale. But that doesn't imply that a reading of 15.1 Volts is necessarily accurate to within 0.1 Volts. Try measuring a voltage with different meters and see what your result is. It would be a well-run shop that has all their equipment calibrated to a traceable standard. Most of the time it just isn't needed. When looking for a problem we are seldom looking for a small difference in a voltage. Five percent accuracy is acceptable. That $1.98 meter you bought at the wholesale tool warehouse works just as good as the one you spent fifty dollars for with a brand name.

Powering Smaller Test Fixtures

One frame of thought would hold that it is cheaper to have just one good general purpose power supply for all assemblies and test fixtures. The down side of that is you can only have one test fixture running at a time and if that power supply goes out the whole bench is out of service. Smaller test fixtures may only need a specific voltage and draw a few hundred milliamps. It is overkill to tie

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up a two hundred dollar power supply for such a purpose when it is relatively cheap to build a power supply for that specific purpose. I keep a supply of “wall wart” power supplies around for such things. I pick them up at yard sales and second hand stores for a dollar or less. For a few bucks I can add a voltage regulator with current limiting. I can throw a power supply together for only a few bucks for most projects below 24 Volts at 1 Amp. These are designed and built using the same parts I use in game repairs so seldom is there any need to buy anything special for this purpose.

Analog vs. Digital Meters (or none at all)

Analog meters cost about ten dollars each. A two-meter power supply adds twenty dollars to the cost of my five-dollar power supply. Digital meters can run a bit more. There is little difference technically to choose one over the other. There are a few alternatives to putting a meter on the power supply. Using a general-purpose multimeter is okay but time consuming. If a unit I am testing is malfunctioning I would prefer to know it right away and not have my hands tied up using a meter. Putting a simple LED on the output is the cheapest idea for monitoring outputs. The LED lights at just about any current through it and all it tells you is that there is some kind of voltage present. A Window Comparator using three LEDs to monitor “Good,” “High” or “Low” can be thrown together for a equal small change and give an immediate indication of a malfunction. You can even design the power supply to turn itself off on an Over Current or Voltage Out of Range condition. Again most of these are simple circuits you can probably build with parts already on hand.

Using Adjustable Current Limiting

Most bench grade power supplies have adjustable current limiting. Those who have not been techs for very long too often ignore this feature. If you know how much current the assembly you are testing should draw you can set the current limiting to a value just above that value. With the assembly under test not connected set the voltage where you want it then adjust the current setting to the point you want it to trip at. Some power supplies have a switch you can push to do this automatically. The process may vary depending on specifically what power supply you are using but it’s a good idea to get familiar with the process on your power supply.

For specific use power supplies I build, I can set the current at a specific level by selecting a resistor. Manufacturing doesn’t really need such a feature but it is the nature of doing bench repairs that we expect the device we are testing to have a problem. Current limiting is just a good idea.

There are various ways to implement this in a power supply design. Each has advantages and disadvantages but that would perhaps make a good subject for a future article instead of going into it here.

Use What You Have

Don’t overlook what you already have available. Power supplies out of a game are obviously suitable to power things at the bench as far as voltage and current capabilities go. They don’t have any metering on their outputs and current limiting is set far above the needs of specific assemblies. Twelve volts at 5 or 10 Amps is typical. This can result in 60 to 120 Watts of smoke and flame in the unit you are testing before the power supply shuts down.

24 V and 12 V vs. 25 V and 13 V

IGT assemblies are designed to run on 25 Volts or 13 Volts. Believe it or not they also run just fine at 24 Volts and 12 Volts so you don’t really have to build a special supply just for IGT assemblies. I guess you could build one that output 24.5 Volts and 12.5 Volts and consider it excellent for either use.

-Herschel Peeler
-hpeeler@slot-techs.com

Casino School Goes Hollywood

One of the common "issues" I run into while training is the problem of what to do with the slot floor while the slot techs are in training. Sometimes, there are enough slot techs that scheduling isn't a problem. At casinos with thousands of machines, I simply take 15 (or fewer) techs at a time, leaving the balance of the staff to cover the floor. But at smaller casinos, it can be problematic. Sometimes, management attempts to handle service, often with mixed results. In some cases, an out-of-order sign is hung on the game until the slot techs can get around to looking at it.

In this case, Steven Houle, Slot Technical Director for Hollywood Casino at Penn National Race Course in Grantville, PA had another idea for training his twenty-or-so slot techs. He tasked me with taking my four-day program, distilling it down to two days and repeating the program twice in order to train his entire staff.

Yow! Normally, my class runs apace but this was definitely running on overdrive! Remarkably, I was able to squeeze in almost everything I normally cover (I had to leave a few components for them to review on my YouTube channel and I had to ride herd on keeping breaks to a ten-minute maximum) and we even were able to squeeze in a few of the "hands-on" labs that make the class a lot of fun.

The reason I mention this is to offer this new class to others in the same situation. I cannot say that I am totally at ease with leaving some things unsaid and limiting the hands-on stuff (which is, argueably, the most entertaining part of the class) but Mr. Houle was pleased with the class, as were the folks that attended.

If you have more than 15 slot techs and you'd like to run them through the class so that they can repair power supplies and LCD monitors, this dual, two-day class might be an option for you. Contact Randy Fromm to discuss your training requirements. editor@slot-techs.com or give me a call at 619.593.6131.

Attending were Andrew Davis, Frank Shade, Ryan Cale, Gerald Gluchowski, David Parrott, Brad Lindenmuth, Al Bair, Kim Dean, Sarah Lou Platt, Will Patton, Brad Shomper, Al Kipp, Darren Lay, Lance Brown, Bryan Good, Mike Sullivan, Mark Durbin, Mike Kelly, and Thomas Stehman

Backlight Inverters

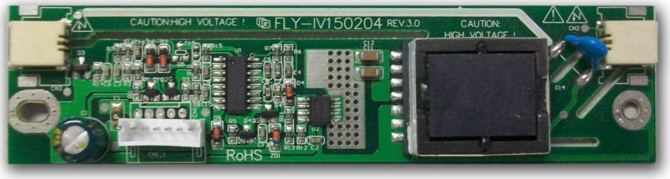
By John Peterson and Scott Barney

Although many casinos consider inverters to be a disposable sub-assembly, they are actually quite repairable. Mostly, it's just a matter of replacing a MOSFET or two (along with the SMD fuse that will often blow as a result of the MOSFET failure) and/or one or more electrolytic capacitors. Generally, most casinos will toss the bad inverters in a box and when the collection gets big enough, someone will sit down, slap in some replacement parts and get most of them up and running again. The few that aren't fixed this way (in 5-10 minutes) aren't worth the investment in time it would likely take to troubleshoot them.

That having been said, the more we know about something, the more comfortable we are working on it so let's take a sort of a detailed look at CCFLs and inverters once again, this time with a look at the often difficult world of testing and measurement.

Cold Cathode Fluorescent Lamp Parameters

Starting or Discharge Voltage is the minimum voltage required to "start" or ignite a cold-cathode fluorescent lamp (CCFL). This is generally expressed as a minimum rms voltage at some ambient temperature (generally the minimum temperature for the display or lamp).



The starting voltage is the primary parameter which determines "end of life" for the tube and therefore the usefulness of the LCD module. If a voltage less than the minimum starting voltage is applied to the tube it will not light. The starting voltage of most CCFLs is both time and temperature dependent. The older and colder the tube, the higher the starting voltage. Generally the minimum starting voltage specification is tied (directly or indirectly) to a life specification for the CCFLs and the LCD module.

The output voltage of the inverter, measured at the CCFL, must be equal to or greater than the minimum starting or discharge voltage specified at cold temperature and maximum life of the CCFL. The starting voltage required by the CCFL increases with time. The starting voltage of an aged CCFL can be more than 50% higher than a new CCFL.

Tube current is the prime mover in converting electrical power into brightness. The brightness of any given CCFL is directly proportional to the rms tube current. The tube current as specified by the tube or display manufacturer provides a benchmark for determining acceptable display brightness and indirectly the usable tube life. A general rule of thumb which is commonly used is: tube life is a square of the tube current (above nominal). If the tube current is increased to 20% above nominal then the tube's useful life could decrease by 40% (reference to the stated tube life at nominal tube current). However, greatly exceeding the nominal or maximum tube current can produce nonlinear and unpredictable life characteristics. Also exceeding the recommended tube current can produce excess heating which can cause discoloration of the display around the location of tube, affecting the overall appearance of the display.

Monitoring the current through the tube(s) can provide a useful indication of the approximate tube brightness and can be very useful in "closed loop" dc to ac inverters.

Operating voltage is the voltage across the tube after the tube has been lit. Generally the operating voltage is generated not applied. Electrically the tube looks similar to an ac zener diode dropping a predetermined voltage (determined by the length and diameter of the CCFL) with the actual voltage dropped across the tube decreasing slightly as the current through the tube is increased.

Frequency generally has no effect on the brightness, efficiency or life of the CCFL, however the frequency of the voltage and current applied to and through the tube can have a major factor in the compatibly between the tube and the display, graphic engine and graphic information displayed on the LCD module. The operating frequency of the inverter should be completely compatible with the LCD module and graphic material used and displayed in the system.

Waveform, both current and voltage, can not only affect the performance of the tube but can generate unacceptable radiated electrical noise which might have adverse effects on the rest of the systems and be very costly to fix or remove for agency approvals and certifications. A properly designed and selected inverter can minimize the waveform distortion created by the dynamic nature of the tube and provide an inverter CCFL combination with minimum impact to the system and the surrounding environment. Although the dc to ac inverter produces a pure sine-wave, the dynamic nature of the CCFL distorts both the output current and output voltage. A typical CCFL, inverter driven, waveform is illustrated in figure 1.

General Application Information

Dimming

There are two basic methods for dimming the CCFLs used to backlight LCD modules. The first is an analog approach which simply reduces the current through the tube(s) by directly or indirectly reducing the input voltage to the inverter. The second, more of a digital approach, is pulse width modulation. Pulse width modulation controls the brightness of the tube(s) by turning the inverter (and therefore the tubes) on and off very fast and governing the brightness by the controlling the on time with respect to the off time (duty cycle).

Analog dimming by reducing the tube current can be very effective when applied over a fairly narrow brightness range. Two primary areas of concern are guaranteeing proper starting voltage upon power up and maintaining minimum tube current through the tubes.

Any technique used to reduce the tube current by directly or indirectly reducing the input voltage of the inverter must insure the input starts at nominal for a sufficient amount of time during power up to light the tube at minimum temperature and maximum tube life . This can be accomplished very nicely using a closed loop system that adjusts the input voltage after

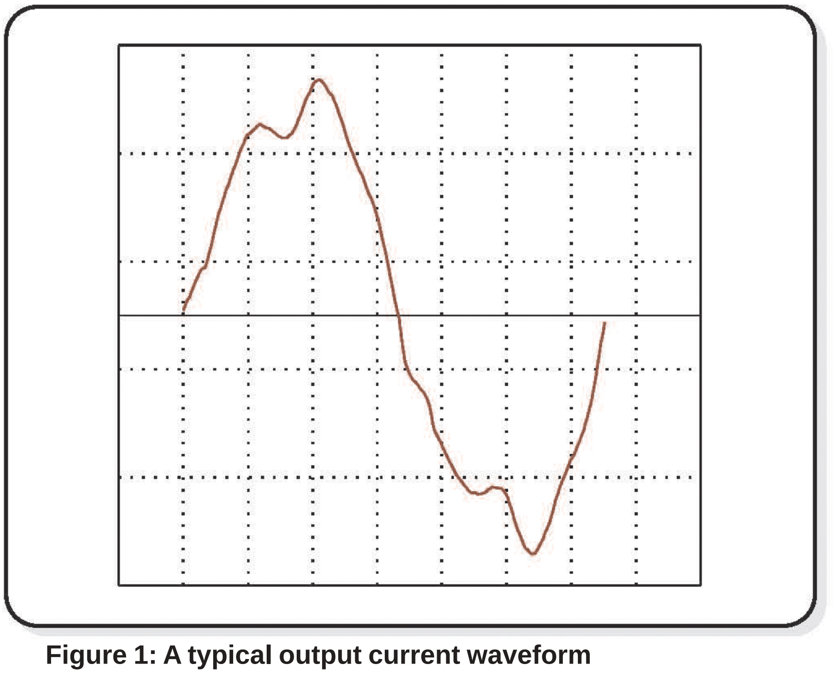


Figure 1: A typical output current waveform

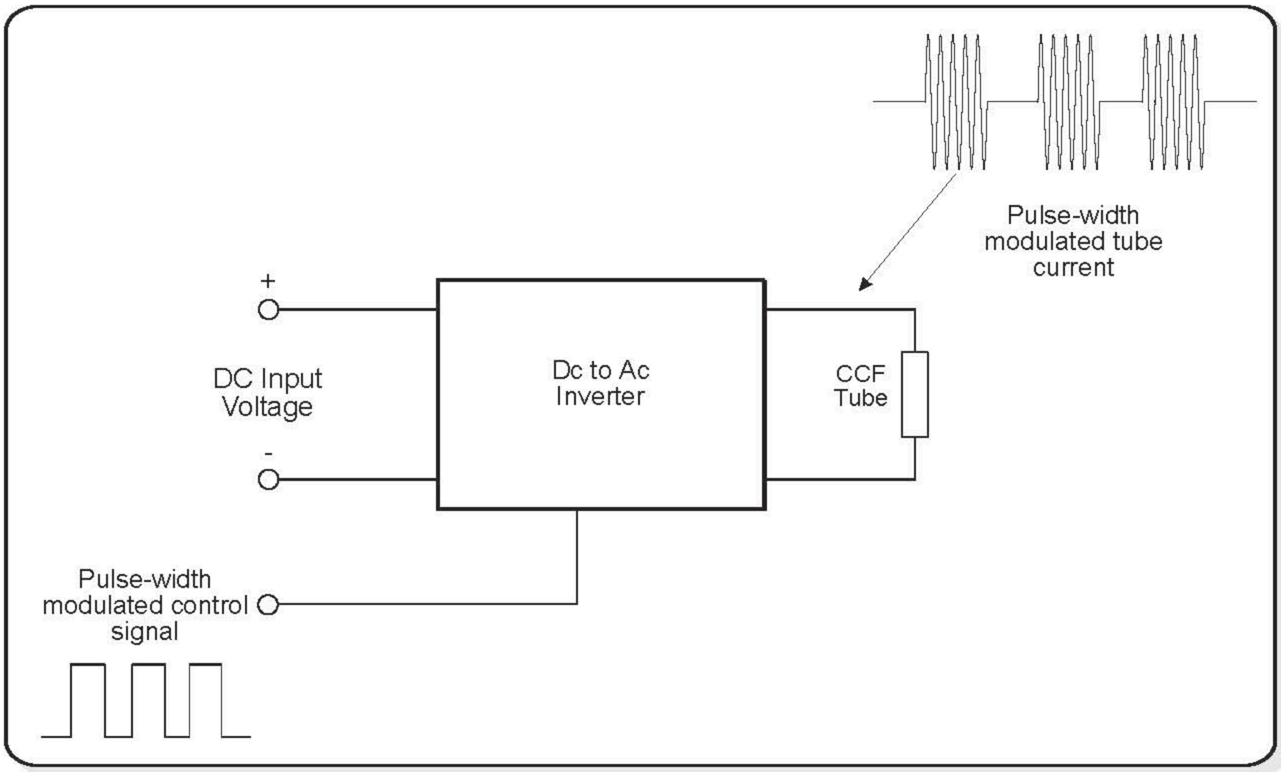


Figure 2: Simplified diagram of a pulse width modulated dc to ac inverter

sensing the tube current. CCFLs have a minimum tube current which must be maintained for proper operation. If the tube is operated well below this minimum the tube can light unpredictably or permanent damage can occur to the electrodes in the tube. This can shorten the useful life of the tube.

Pulse width modulation is a very straight forward method for controlling the brightness of CCFL(s). The inverter is turned on and off (using the input or an enable/disable line) to control the brightness. The "on" duty cycle is increased to increase the brightness and is decreased to decrease the brightness. One of the major advantages of pulse width modulation is the tube is always fully "on" or fully "off" and full starting voltage is always applied to the tube(s) (assuming nominal input voltage is present at the input of the inverter).

The frequency of the pulse width modulation signal (usually faster than the frame rate of the LCD, and generally less than 1 kHz) is selected to avoid any optical interference with the LCD module and the software or graphics being generated. In a similar way, the clock frequency of a touchscreen can be modified in case of any interference with the system itself.

Since the brightness is now controlled by a digital pulse stream with an adjustable pulse width, interfacing the inverter to the system's microcontroller is simple and straightforward, eliminating the need for "electronic" potentiometers and/or D to A converters. Also since the inverter is always operated at full load and nominal input voltage the efficiency of the entire systems can be quite high under any dimming condition.

Interconnection Pitfalls

Generally the CCFLs are placed in a low voltage, low power environment and often the high voltage and high frequency requirements of the CCFLs are overlooked. Following are some common packaging reminders that help to avoid some problems down the road:

High Voltage. A CCFL needs high voltage. The starting voltage is generally over 1,000 volts and the operating voltage is generally 500 volts rms or higher for larger displays. Even if proper spacing is not being dictated by agency approvals care should be used in the selection of wiring and connectors. A good rule of thumb is to match the spacing that came on the LCD module. Usually this spacing is adequate for agency approvals and is certainly enough for proper operation.

High Frequency. The operating frequency for the CCFL can be fairly high and the general make up of the inverter circuit can make the wiring between the inverter output and the LCD module tricky. In series with the inverters output (internally) is usually a small capacitor (15 pf - 39 pf) (see figure 3). This capacitance becomes a fairly high impedance which is always in series with the tube. Any stray capacitance produced by the inverter-to-display wiring can reduce the starting voltage applied to the tubes and reduce the life and brightness of the tubes. The inverter should be located as close as possible to the CCFLs. The wiring used should produce low capacitance. Generally the thick walled wire which is used on most LCD modules is used to produce low capacitance not high voltage protection. Operating the inverter in a non-isolated configuration can add to the stray capacitance on the output therefore reducing the starting voltage applied to the CCFLs. If this is done for noise reduction purposes, it must be taken into account in the design so adequate starting voltage is maintained.

Circuit Operation

Most CCFL dc to ac inverters are tuned switchers designed to produce a specific voltage, frequency and output current when a specified tube is connected to the output. The classic current-fed two-transistor inverter has a tuned resonating output, tuned resonating input and inductive dc input that allow excellent power transfer and high operating efficiency.

This type of circuit inherently produces a pure sine-wave output but the voltage and current waveforms are both distorted when they are applied to a CCFL, which is a highly nonlinear device.

The transition from starting voltage to operating voltage in this circuit is implemented by a small internal series output capacitor which serves as the ballast, providing impedance and allowing proper tube current after the tube has ignited. This high series internal impedance is responsible for a "constant current" output which is typical in this type of circuit. As a result, this circuit produces its nominal design output current under almost any load condition - from a very high impedance to a "dead" short circuit.

Since the output of this type of circuit is an "ac constant current source" the output will supply its nominal output current into a short circuit. Under a short circuit condition, the input current drops dramatically since the input power into the inverter is now just supplying the inverter losses which are generally very small when compared to the nominal input power.

Meaningful Measurements

Trying to measure the operating condition of a functioning cold-cathode fluorescent tube can be an interesting experience. The combination of high voltage, low current, and high frequency makes conventional test equipment and methods almost useless. Any external resistance, impedance, or ground loop can dramatically alter the operation of the dc to ac inverter and distort the measurements being observed.

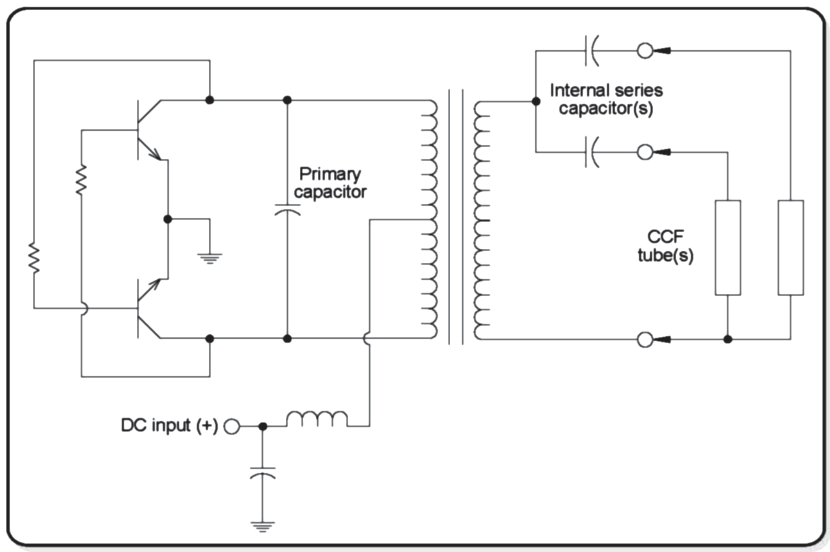


Figure 3: A basic diagram of the classic current-fed two transistor dc to ac inverter

Let's look at some specifics. The impedance of a typical 2.5 Watt 6 inch CCFL is 50,000 to 70,000 ohms. The small internal capacitor usually found in series with each output of the inverter offers an impedance that is typically three times that of the CCFL to which it is connected. Even a voltmeter with a 10 Megohm input impedance can load the output enough to render the reading meaningless. An oscilloscope can be even worse. The approximately 20 picofarads of 'scope probe capacitance presents a relatively low 250 Kohm of impedance at 30 kHz.

There are straight forward methods for measuring the voltage, frequency and current of an operating CCFL. One method is to measure the true rms current trough the CCFL using a broadband current probe (such as the Tektronix CT-2) that magnetically detects the ac current without appreciable circuit interaction. The probe's output can be fed into a appropriate true-rms voltmeter or digital oscilloscope capable of calculating true rms at the nominal current frequency.

The output voltage to the tube can be measured with a dual-channel oscilloscope and two low-capacitance (< 2.5 pf) scope probes. The oscilloscope should be connected differentially, with the probe grounds connected and floating. Channel A should be added to the inverse of channel B to produce the complete waveform on the oscilloscope (see figure 4). The rms voltage value can be calculated by the digital oscilloscope or measured with a true rms voltmeter connected to the oscilloscope's vertical-signal output jack (if available). Although this method loads the CCFL and inverter minimally, there may still be enough loading to change the operating voltage slightly, especially in higher frequency inverters. Even a slight change in the brightness of the tube is an indication of some interaction between the inverter or tube and the measuring equipment.

The no-load, starting voltage of the inverter is the most difficult parameter to measure accurately. The slightest external impedance can reduce the inverter's no-load output voltage. Nonetheless, the setup used to measure the operating voltage can be used to measure the no-load output voltage fairly accurately. The length of the test leads and wires should be minimized to reduce stray capacitance. Monitoring relative differences in the input current with and without the measuring equipment connected indicates the relative magnitude of effects of the external equipment.

For more information about inverters, contact: Endicott Research Group, Inc. 2601 Wayne St. Endicott, NY 13760 607-754-9187 Fax 607-754-9255

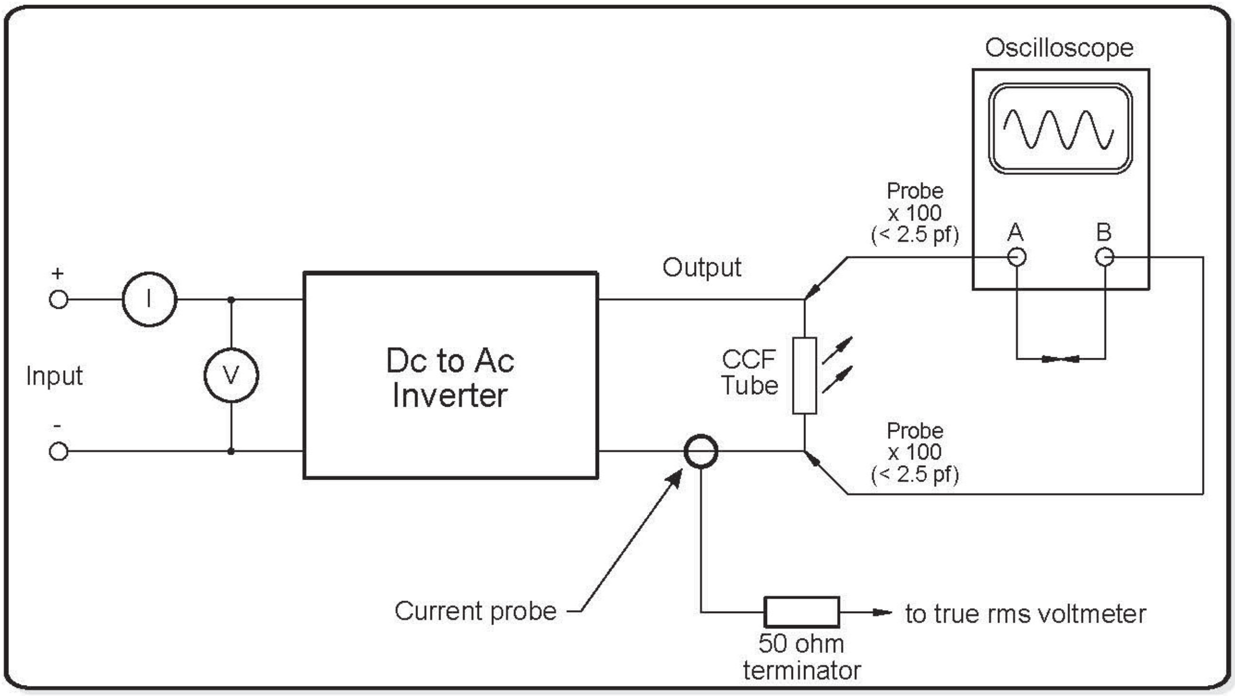


Figure 4: Basic test setup for measuring the output voltages

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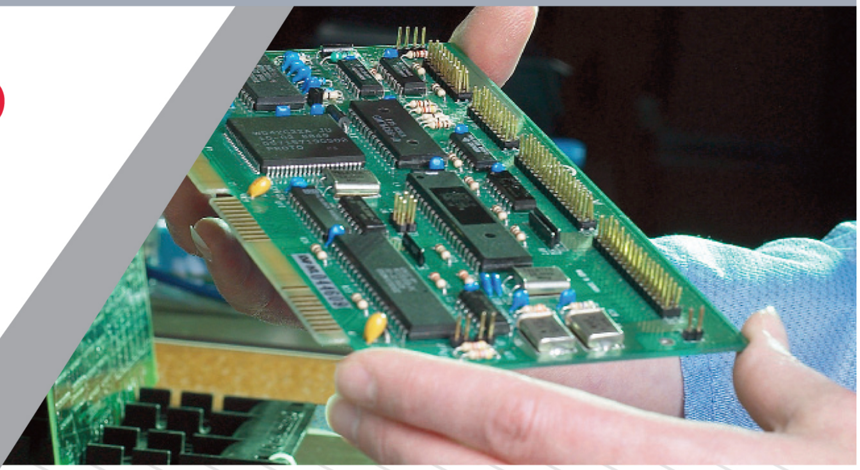

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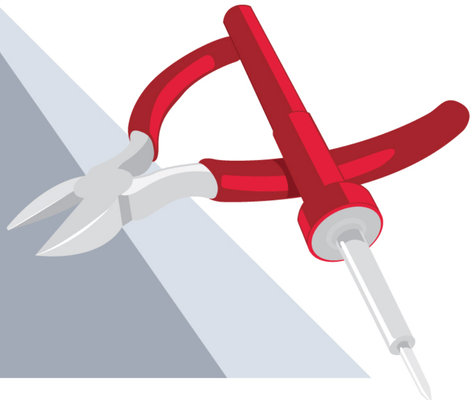

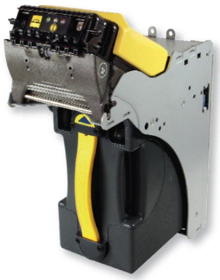

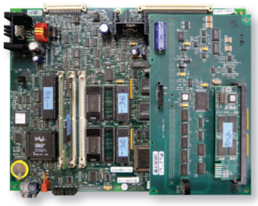

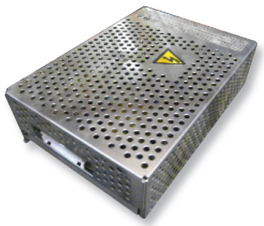

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