

# SLOT TECH MAGAZINE

Slot Machine Technology for the International Gaming Industry



TechFest 12  
Nice, California  
October 11-13 2005

Understanding Video Reels  
LEDs are Lighting the Way  
WMS Power Supply Addendum  
Don't Be Mislead by Logical Thinking  
In-Circuit Electrolytic Capacitor Testing



# How many \$\$ does it take to change a light bulb?

If you're still using fluorescent tube sets in your slots, you're spending too much...for maintenance to change them, for energy to light them, and for air conditioning to cool them off.

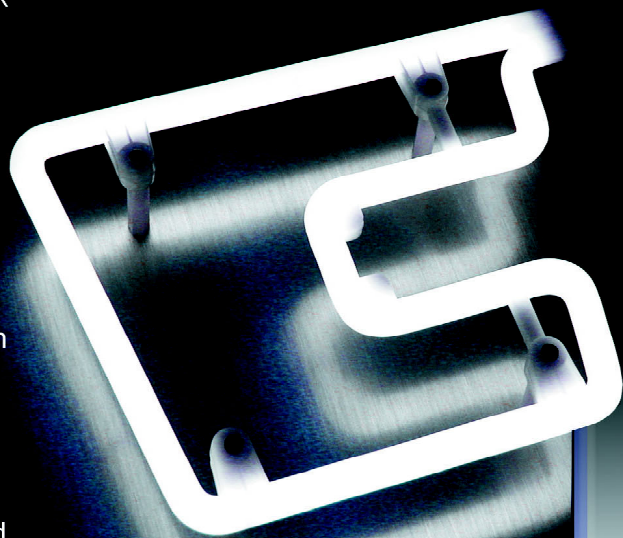
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## August 2005

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## My CapAnalyzer is here! My CapAnalyzer is here!

It finally arrived and I had a chance to use it in a test environment and for some real monitor repair.

For the past few months, we've been running advertisements for a really cool piece of test equipment that tests electrolytic capacitors. It's a microprocessor-controlled ESR meter that uses a clever and effective technique to test electrolytic capacitors in or out of circuit. The manufacturer wanted to spark interest in the device with a series

of "teasers" - pages of testimonials from satisfied users. At the top of the ad was the URL for the website. You were supposed to have been consumed by curiosity such that you would all flock to the website where you could read more about what a wonderful piece of test equipment the CapAnalyzer is (and, actually, it really IS) and buy one for the shop.

Unfortunately, the ads didn't work very well. I imagine there are a number of reasons why not. Maybe you saw the ad but didn't have the time at work to look it up. Maybe you don't have internet access at work. Maybe you grab the magazine on the way in to the personal facility and there's definitely no internet access in there. I suppose that's what happens when electronics geeks try their hand at advertising but I wanted to call your attention to this product because it works and we (in the shop) need to have an ESR meter. It is one of the few "must have" items for any slot shop that does monitor repair (and that should be everybody, as far as I am concerned).

When Slot Tech Magazine began running the CapAnalyzer advertisements, I begged the manufacturer for a sample. I was eager to try it out and see how it compared to my old Capacitor Wizard. The Capacitor Wizard is a sort of Eighties technology ESR meter that has been reviewed in the past here in Slot Tech Magazine (way back in July 2001). I also wanted to evaluate it because I would hate to advertise a bogus unit that didn't perform as advertised.

I tested the unit on a monitor chassis that I use for "hands-on" training. I have a collection of bad electrolytic capacitors that are actual failures taken from this exact model of monitor. Over the years, I have collected virtually every electrolytic capacitor that ever fails in this monitor. There are actually only eight common failures. I installed the bad caps (one at a time) and verified the symptom (sometimes electrolytic capacitors mysteriously "fix" themselves after they've been sitting around and may have to oper-



ate for a while before they exhibit symptoms. Ironically, it's usually the other way around with slightly degraded capacitors that seem to fix themselves as they warm.).

The CapAnalyzer worked perfectly well. It's easy to use and requires no specialized electronic training to use it. It had been my plan all along to write a full-blown review of the device but I don't really know what else to say other than if you don't already have a good ESR meter, this is a really nifty unit and you ought to check it out. Even if you already have a Sencore LC103, this unit is cheap enough that you might want one for its portability and as a second unit if you're doing a lot of monitor repair (and who isn't these days?). Read more about the CapAnalyzer on page 26.

BTW, our continuing series on the Tovis digital monitor will pick up again next month.

One more thing. I have a two-week slot tech school planned for August 22 - Sept 2 2005, here in San Diego at Sycuan Casino. More details are available at slot-techs.com

That's all for this month. See you at the casino.

**Randy Fromm**

**TechFest 12 will be held  
at Robinson Rancheria in  
Nice, California  
October 11-13 2005**

Randy Fromm's

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## WMS Power Supply Addendum

By Herschel Peeler

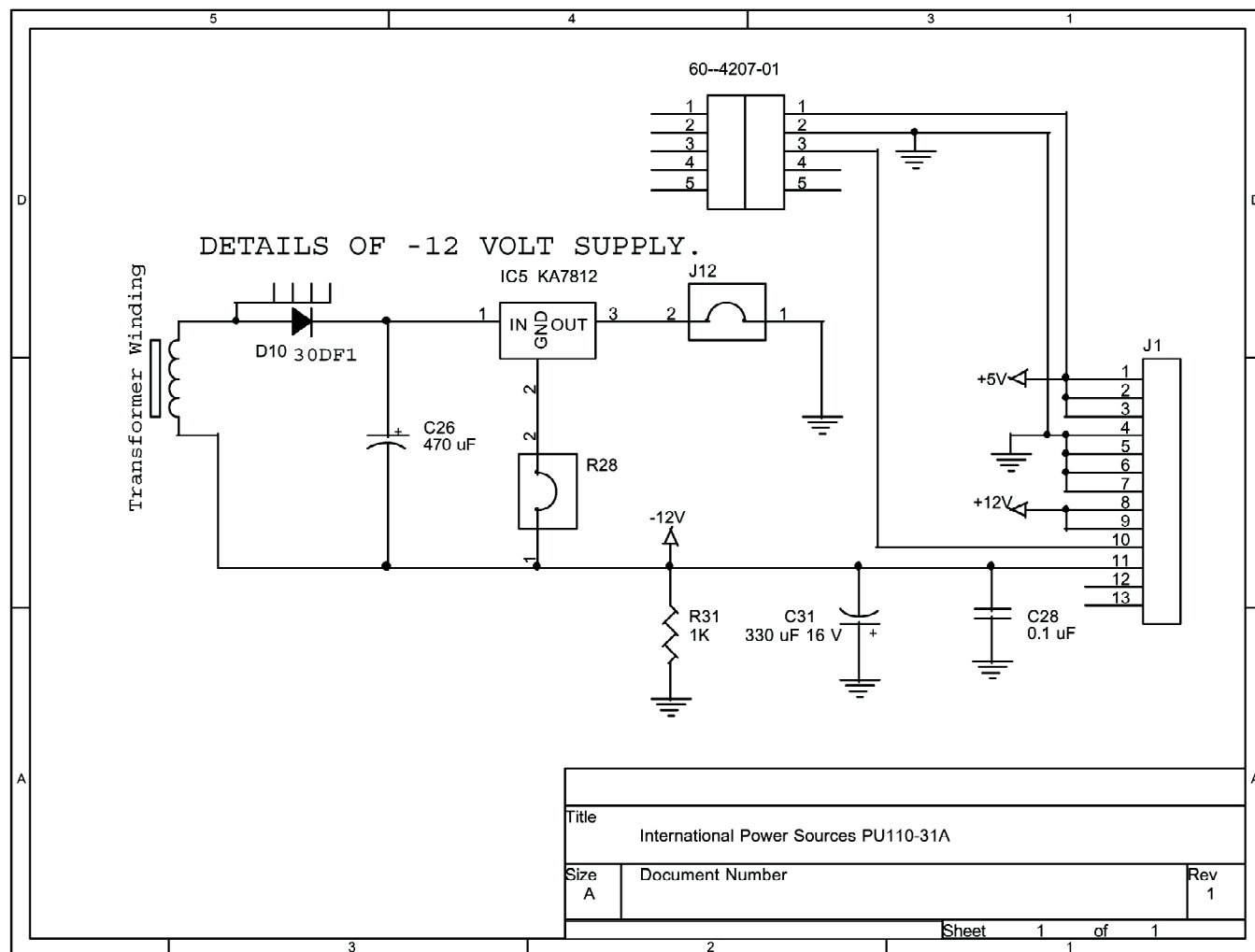
Volts, +12 Volts and -12 Volts. Most of it is a fairly straightforward design, but the -12 Volt side does something tricky.

They use a positive 12 Volt regulator (7812, TO-220 package) to generate the -12 Volts. When I first traced out this circuit for troubleshooting it was a real head-scratcher. Once I got the circuit completed and redrawn it made sense. They ground the output of the voltage regulator and take the output off of the terminal that would otherwise go to ground.

This works if you realize what the voltage regulator actually does. It regulates the voltage difference between pin 3 (the +12 Volt output) and pin 2 (ground) to be 12 Volts. That's a 12 Volt difference with pin 2 being 12 volts below the pin 3 output. If we ground the output what was the ground pin is now 12 volts more negative

**P**roblem: no -12 Volts, IC5 gets hot, D10 gets hot. (International Power Sources PU110-31A)

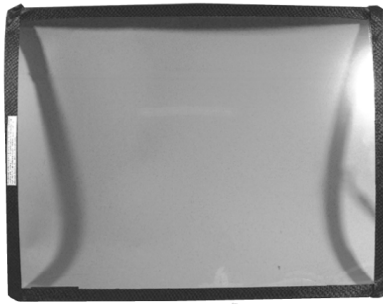
Inside the Williams main power supply is a power supply board. This board supplies the main +5



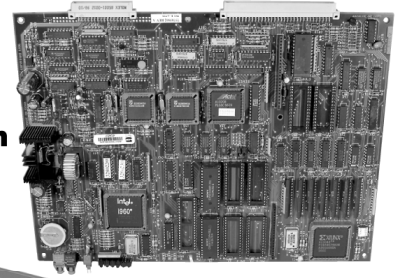


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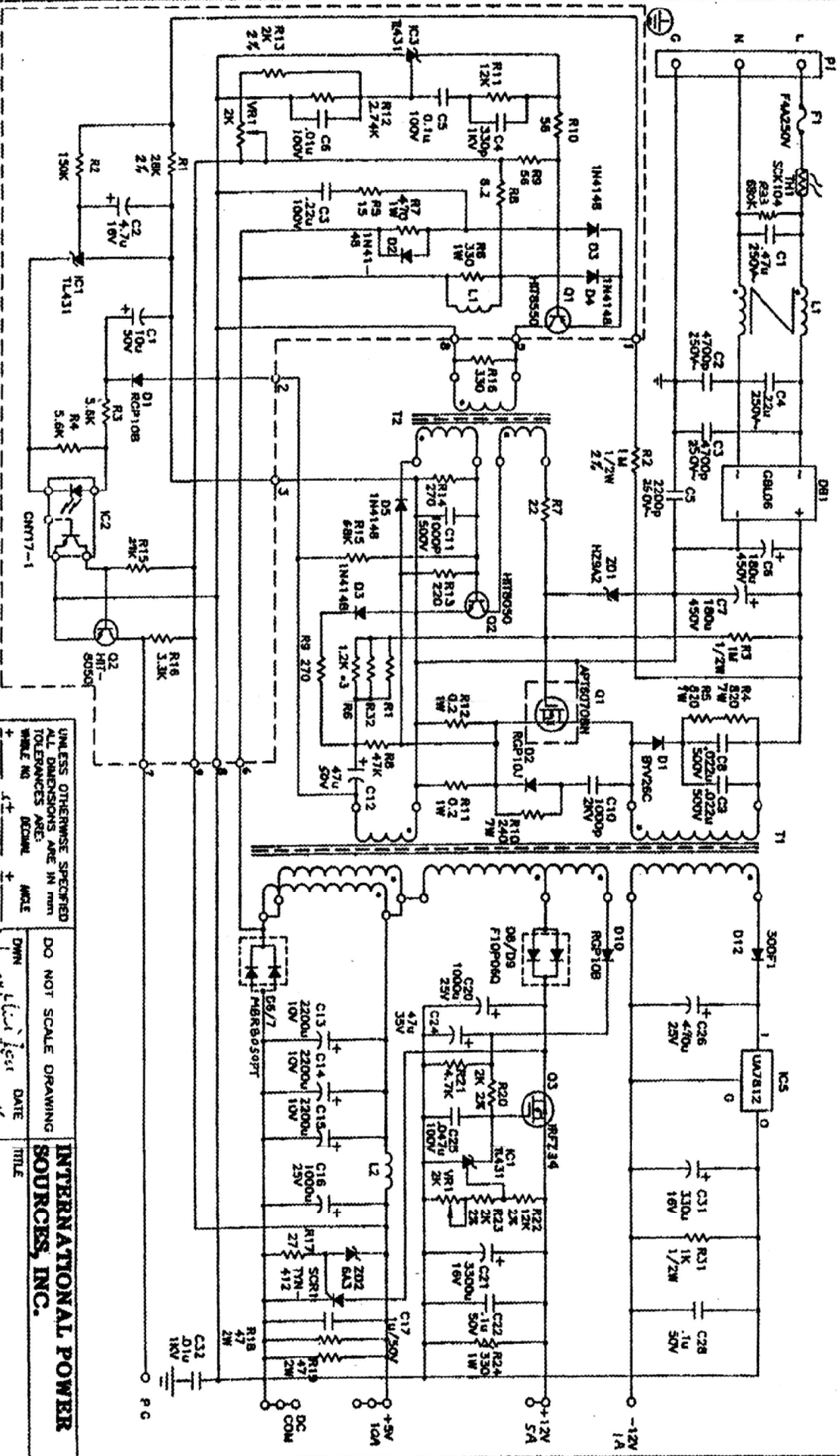
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A					100K 1/4W 5% 100K												

NOTE: UNLESS OTHERWISE SPECIFIED

1. RESISTORS ARE 1/4W. 5% VALUE IN OHMS.
2. CAPACITANCES ARE IN FARADS.

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SCHEMATIC PU110-31A

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SCALE	SHEET 1 OF 1
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than ground.

Jumpers on the board provide for alternative designs.

## Voltage Measurements

At the cathode of the rectifier (pin 1 of the voltage regulator) to ground you should measure about +4 Volts. This makes sense when you realize that the output of the voltage regulator is grounded. All we measure here is the drop across the voltage regulator.

At pin 2 of the voltage regulator you should measure -12 Volts to ground. Pin 3 (normally the output of the regulator) is ground.

Across C26 you should measure about 16 Volts DC. Across C31 you should see 12 Volts.

In my case the problem ended up being C28, a small blue Multi-Layer Ceramic capacitor that I initially overlooked on first observation. It appeared as though C31 was shorted. After taking the capacitor out and checking it with a meter I realized it wasn't my problem. I took the meter to the board and found my short was still on the board. After an hour of circuit tracing and initial confusion I found C28.

My C28 was smoked, but the smoked side was facing down and I overlooked it on my initial observation. I had to look at another board to find the proper value, 0.1  $\mu$ F ("104"). Cost of repair, \$0.10 and a bit of frustration and education. But because we took the time to de-engineer the circuit these will be quick repairs in the future.

Other problems with these boards:  
Burned traces.

There are a number of manufacturers that Williams uses for this application. International Power Sources is just one.

**"I have only come here seeking knowledge. Things they would not teach me of in college."**

You go through a couple of years of college, get out in the real world and find out you still don't know fudge. Okay, so where do you go to complete your education? College doesn't teach you anything about slot machines. IGT, Bally, Aristocrat, Williams and perhaps a few others, are good about supplying schematics but they just don't

give you complete information for board repair. Where do you go?

You go to the same sources the engineers that designed the games went to. Most manufacturers have web sites and data books that give you the complete scoop on what's inside those squares on the schematics. You know those squares with the pin numbers on them and Greek phrases like "AD0 - AD15", "NMI" and "IntReq.0" You too can go to the data books or web sites and get the same information the guys that designed the game did. Armed with a good basic education in Analog and Digital you can start from basics and work your way to the most complex microprocessors and instruction sets. Most of the web sites are easy to find. To list but a few:

[www.fairchildsemi.com](http://www.fairchildsemi.com) - Fairchild (good information on analog and digital ICs) [www.intel.com](http://www.intel.com) - Intel (we all know who they are)

[www.freescale.com](http://www.freescale.com) - Motorola (the IC fabrication plant spun off as a separate unit) [www.fujitsu.com/us/services/edevice](http://www.fujitsu.com/us/services/edevice) - Fujitsu microelectronics

[www.amp.com](http://www.amp.com) - Tyco and AMP connectors

[www.molex.com](http://www.molex.com) - Molex connectors

If you can't find the manufacturer you want with the "www.(name).com" pattern, go to [www.google.com](http://www.google.com) and search through google. Search by vendor name or even part number.

Other than the manufacturer's web sites there are also a number of general places to go.

[www.alldatasheet.com](http://www.alldatasheet.com) - This is a place to obtain data sheets on just about anything semiconductor. Diodes, Transistors, Integrated Circuits, and best of all it's free. This is another personal favorite. Even if you can't find the exact data sheet you want if you can find one that's close [alldatasheet.com](http://alldatasheet.com) will have a link to the vendors.

[www.web-ee.com](http://www.web-ee.com) - This is a good site for electronics information in general.

Distributors also often have data sheets and such at their web sites.

[www.mouser.com](http://www.mouser.com) - Mouser Electronics

[www.jameco.com](http://www.jameco.com) - Jameco Electronics (a personal favorite)

[www.digikey.com](http://www.digikey.com) - Digi-Key Electronics

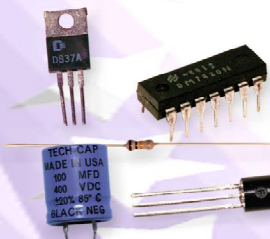




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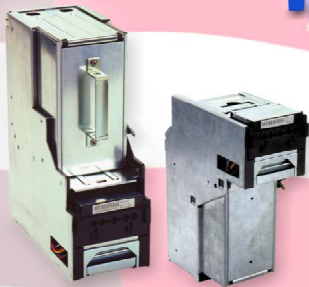


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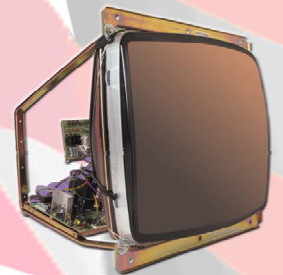
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## Books

Of course you can buy books on electronics from most bookstores or online. There are dozens of books with examples of circuits, not just textbooks. Some of these are educational. Some assume you already know and just need a few ideas. A word of warning though. A lot of these books are printed for use in the United Kingdom and the ICs referenced are not those we find in American slot machines. We do find them in Aristocrat and other brands. Buy the ones that pertain to your needs.

Data sheets tell you what the pins of the ICs do and what the inside of the IC looks like. There are also things called Application Notes that give you examples of how the IC works in various basic circuits. Most of the time you can look at the application note and see the same circuits you find in the game. For instance the oscillator section of the CC-16 series coin comparators is right out of the application notes. The application note tells you how the circuit works and gives you hints for troubleshooting the circuit.

The truth is out there. You just have to spend some time and get familiar with the world around you. The guys that designed the games didn't pull the IC and configurations out of thin air. They found the basics in books. You can too. You have access to the same information as they did.

With this in mind, The Herschel Peeler Collection has a pretty good collection of Data Sheets, Application Notes and examples of use for many of the ICs, diodes and transistors you run into in the gaming industry. Go to <http://slot-tech-ftp.serveftp.com:8080/slottechmagazineftpmirror/theHerschelPeelercollection/EagleMountainsheapofstuff/DataSheets/> or <http://tinyurl.com/aq85b> Most of the schematics have been converted to jpg or pdf files. If you run into some that were not, the schematics were created in OrCAD. The demo version is quite suitable for casual use and is also free.

Go to [www.orcad.com/orcadcapture.aspx](http://www.orcad.com/orcadcapture.aspx) and look for the OrCAD Capture Demo CD.

- **Herschel Peeler**  
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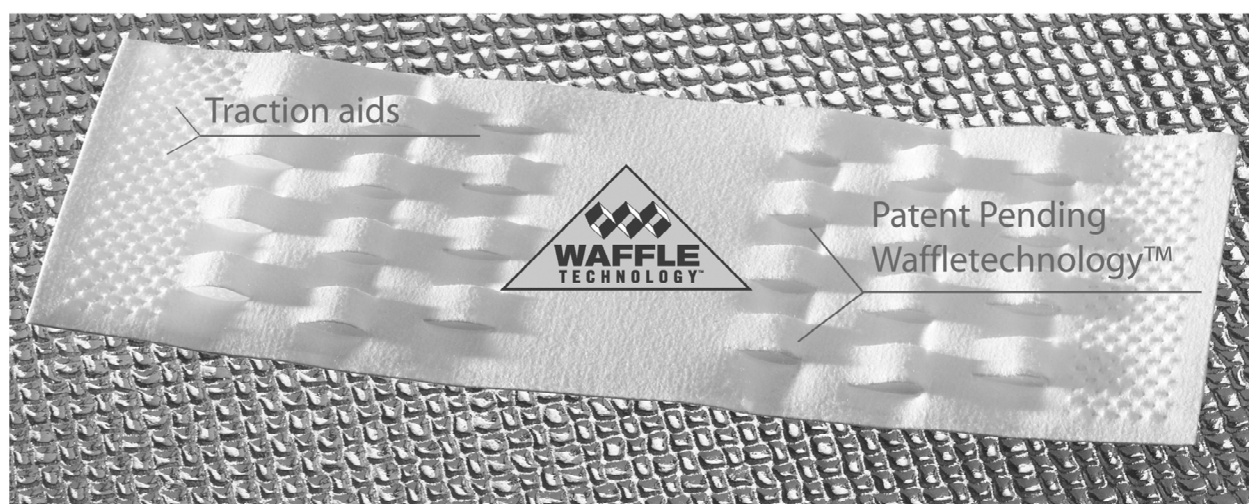


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# LEDs are Lighting the Way

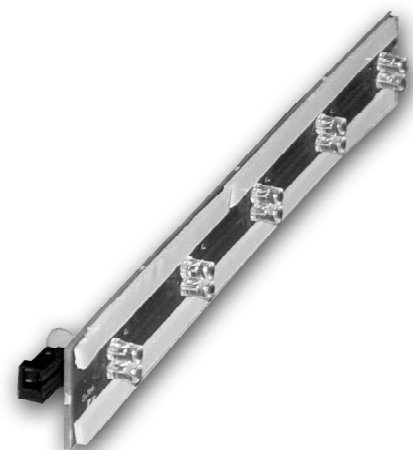
Casino operators are experiencing increased pressures to conserve energy in new and creative ways. The lighting inside slot machines and video poker machines consumes an enormous amount of power when you consider the large number of machines used in any major casino property. Many LED suppliers have emerged with products over the past couple of years but along with attempts to solve the energy crunch, they created more problems. Less than acceptable intensity, premature failure due to flawed designs, shadow problems from spot light effects, glare and coloration variations are just a few of the inherent problems with these “first generation” attempts. After several bad experiences with failures and disappointing results, many casino operators have given up and have returned to the regular, incandescent light bulbs.

The LED industry, in the mean time, has undergone huge advances in technology. These advancements are already amazing users and en-

couraging many to open their eyes to new possibilities. The driving force behind these changes is coming neither from the gaming industry nor even the LED manufacturers themselves but from our federal government. The Department of Energy has been involved in the advancements through federal grants to several major universities. Lighting applications that use light-emitting diodes are referred to as solid-state lighting (SSL). According to the U.S. Department of Energy, by 2025, SSL could displace general illumination light sources such as incandescent and fluorescent lamps, decreasing national energy consumption for lighting by 29 percent.

Commercially available white LEDs combine a light-emitting semiconductor with a phosphor (a Rare Earth compound) to produce visible white light. However, more than half of the light produced by the phosphor is diverted back toward the LED where much of it is lost due to absorption. This reduces the LED's overall light output.

Rensealer Polytechnic Institute has developed several new methods to increase the output of LED devices. SPE (scattered photon extraction) method and other new innovations will accelerate the progress of solid-state lighting and help secure our nation's energy future. Five years ago, if you asked an engineer for the life expectancy of a white LED, the response would have been, at best, around 12,000 hours or about 15 months. Today, with research from Rensealer and other universities creating advancements in the chem-

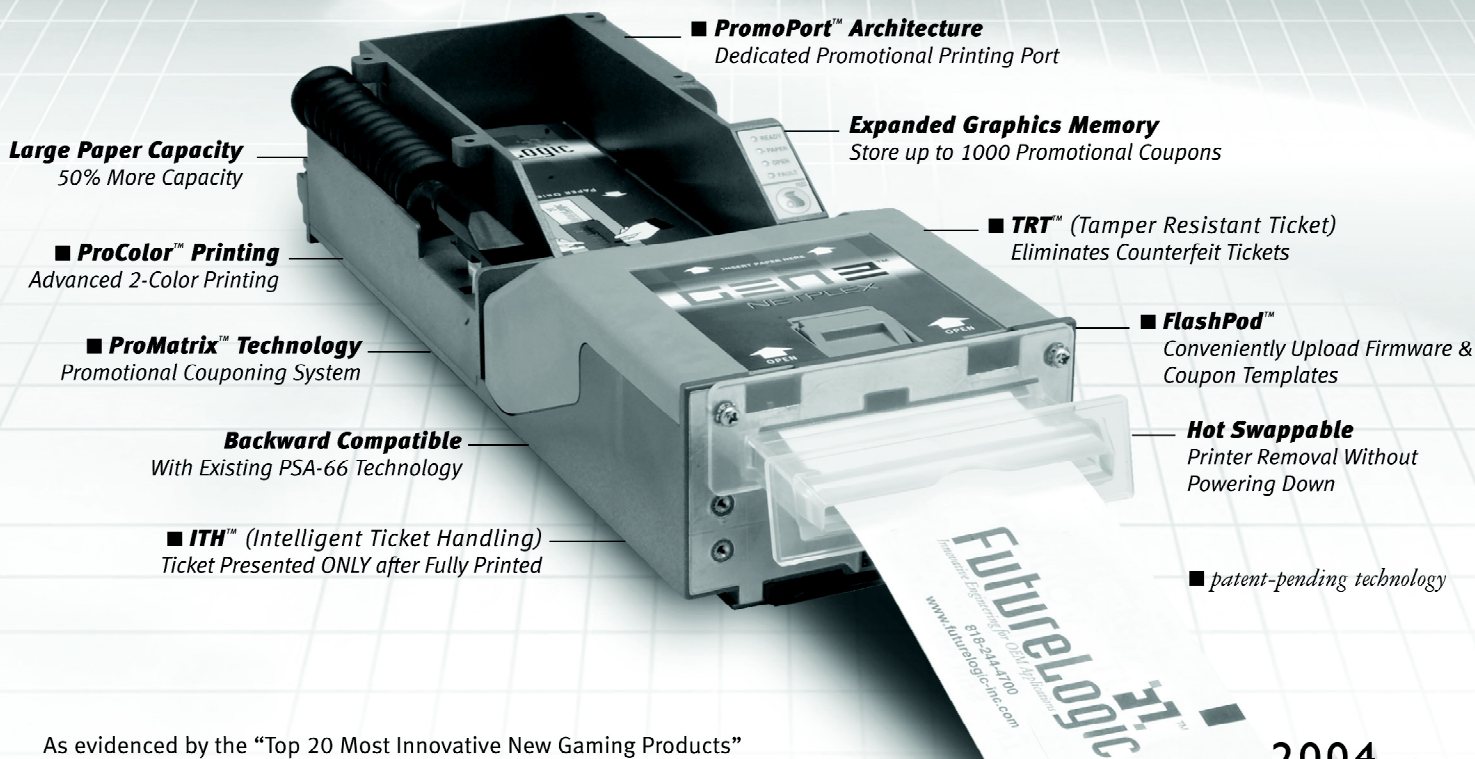


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istry and manufacturing techniques, the life has increased by more than four times to a typical lifespan of 50,000 hours or almost 6 years. The power consumption ratio to light output has also increased sevenfold to make LED lighting a viable alternative (both economically and physically) to incandescent and fluorescent devices. This improvement in life expectancy, substantial reduction in cost per unit and energy efficiency has put LED lighting at the forefront as the "best new technology" for lighting alternatives to incandescent, fluorescent and even cold cathode fluorescents.

But there is more than just increased life expectancy to consider. Those darned shadows and spots that occur with old technology LEDs are now changing with the advent of special lens formations that eliminate these problems. Inverted cone lenses, flat tops, side diffusion and frosted lenses are just a few of the solutions that can solve the shadow effect. The design of phosphor cores is also being modified to create a dispersion angle much wider than what was possible just a short time ago. Heat reduction is another factor that is greatly reduced with LEDs. Heat is a major contributor to all component failures inside a slot machine. Heat reduction has not been an easy benefit to measure but most experts regard this as a very serious consideration in prolonging the performance of the slot

machine overall.

Kiesub Electronics, a gaming supplier and manufacturer, observed the LED industry was not aggressively pursuing slot machine and video poker machines with effective solutions. Until late 2004 all LED suppliers to the gaming industry were providing LEDs that directly plugged into or replaced the individual light bulbs being used. While this concept is, on the surface, a logical one, the physical constraints of a bulb-sized device often caused overheating at the LED junction or in the load resistor and thus caused premature failures. Kiesub decided to invest research into this growing field and come up with a new and better way.

The first Problem: Upright Game King machines with a denominational arrow on the side were burning out very fast and were a major energy glutton. The bulbs were socketed within a printed circuit board mounted to the door and the lamps produced an enormous amount of heat. Conventional LEDs were failing at an alarming rate. The casino operators had justified buying the LEDs on the premise of longer life and saved labor from all of the lamp changes. The casino was paying a much higher price for the LED and still replacing them every two to three months. Even though the manufacturers of these devices were honoring warranties, the beneficial expecta-

tions were not realized.

In January of 2005, Kiesub released their first solution. Kiesub engineered a new printed circuit board with 10 LEDs with inverted cone lens design, power load resistors and an MOV (metal oxide varistor) for power protection. This unit could be plugged into existing wiring with no modification to the game. A technician can typically make the conversion in less than 3 minutes. The result is a light display that looks just like the original, consumes less than half the power and will save you five years of labor changing light bulbs! For just 1000 slot machines, that translates into a total savings of \$130,000 over the life of the devices.

Kiesub has released two more innovative solutions to the gaming industry.

Any slot technician will tell you that replacing the light bulbs in slant top bill validators is a frustrating experience and could take up to five minutes, even if you are a practiced veteran to the task. Kiesub again took the whole package approach to eliminate the problem. In this case, there was also a clear need to improve the quality of the illumination. The original lamps did not light up the face clearly. Kiesub's finished product was a completely new PCB display board that lights up the bill face and with a separate set of LEDs on the other side of the board that

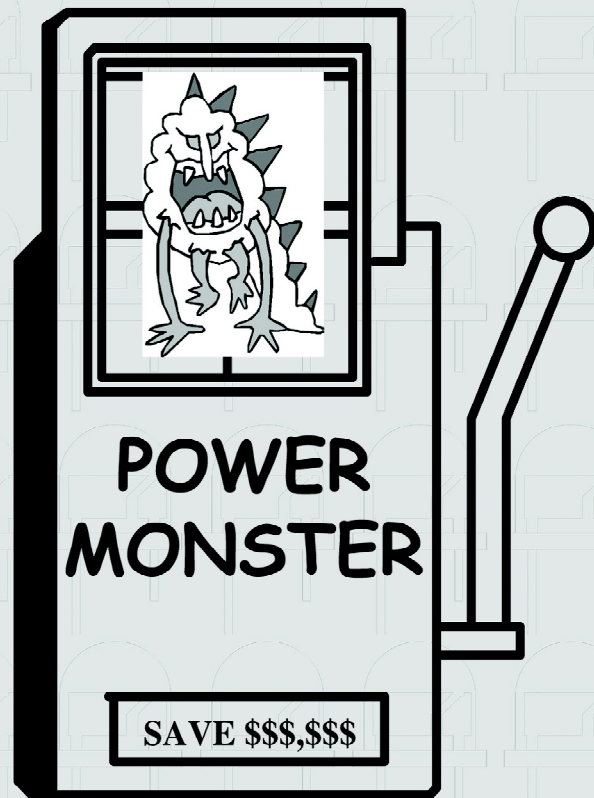


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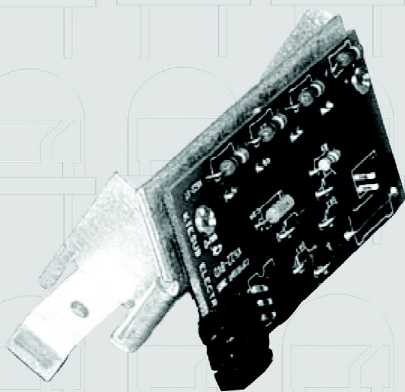
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will illuminate the yellow panel. The result is a full green display of the George Washington face (never seen before) and a very natural yellow front denom panel display. It is an easy installation that takes less than a minute with no modification or sacrifice of performance. The life expectancy of this is conservatively estimated at five years.

The other new product is also a bill validator display assembly but is used in the upright S2000 machines. The original display using incandescent lamps has a sickly yellow glow on the dollar bill face and a yellowish brown display for the yellow denom panel. With Kiesub's solution, you get a crisp dollar bill face and a much cleaner bright yellow panel. This assembly uses a completely new printed circuit board with LEDs and the components to provide the performance needed.

Kiesub continues to pursue new LED solutions which will be released this summer and early fall. A simple software program has been written to compute the savings by using these products and is available no charge from:

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Technical data sources:  
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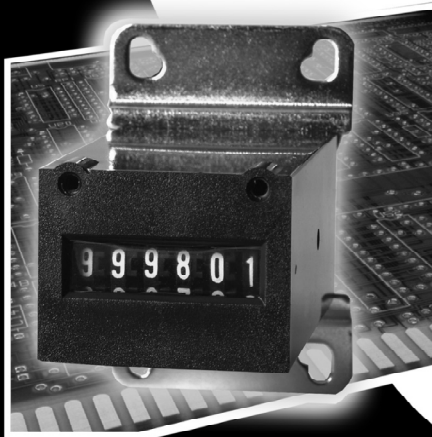
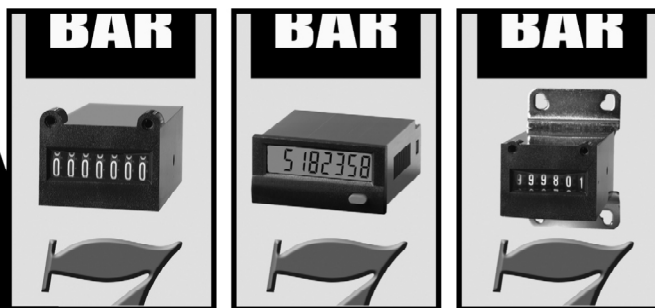
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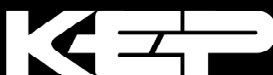
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# Don't Be Mislead by Logical Thinking

By Randy Fromm

**T**roubleshooting is only partly about using test equipment like oscilloscopes and digital multimeters to take measurements and test components. Electronics troubleshooting is mostly about logical reasoning. When you're troubleshooting something, you're mostly looking for ways to logically deduce the cause of the problem as quickly as possible and as easily as possible. In other words, if one quick test or procedure will quickly pinpoint (or eliminate) the cause of a problem, that's generally a good path to follow.

Or is it? Here is the story of a perfectly logic troubleshooting technique (one you probably use yourself on a regular basis) gone astray, tempted down the wrong path by the lure of logic.

The monitor was a Kortek KT-1703. Popular monitor. I like it because it's fun to work on. It's well laid out and the components are easy to access for replacement. The symptom was a common one: The monitor appeared completely dead. That is to say, there was no raster and no indication of high voltage (EHT). There was no static charge on the screen and you never heard the sound of the

static charge building up when the monitor was first powered up.

Of course, there are a great many things that can cause this symptom. The first thing to do is to listen for a faint ticking or chirping sound. In this case, the monitor was completely silent and in its silence, it spoke volumes. It told us that our problem was likely not a shorted horizontal output transistor or other short on the B+ power line. Experienced monitor technicians know that a shorted horizontal output transistor invariably activates the switched-mode power supply's over-current protection circuit, creating a faint but audible ticking or chirping sound that emanates from the SMPS transformer.

The next step is to hop down the SMPS outputs and see what's happening with the power supply. There are five outputs from the power supply and all but two (the 6.3 volt CRT heater voltage and the +125 volt video B+) have to be working to create the EHT that we're missing. It's easy to test all of the output voltages. Once you're familiar with where the test points are, it takes just a minute to test them all.

I generally do them in order, just to be sure that I haven't forgotten one. I started with the 6.3 VDC (used to power the CRT heater and, after regulation down to +5 VDC by a Zener diode, the sync processor circuit). It was good. The +12 VDC output (used to power the video amplifier, h/v oscillator IC and a myriad of other circuits) was only 8 VDC. Gee . . . Do you think that might have something to do with our problem (duh)? The +26 VDC output (powers the vertical output IC and drives the primary winding of the horizontal drive transformer) was good as was the B+ output (+61.5 VDC) and the +125 VDC video B+. To be technically correct in the telling of this tale, the output voltages were actually tested with the B+ output loaded with an ordinary 25 watt, incandescent light bulb. With the dummy load installed, all the SMPS output voltages were normal, with the exception of the +12 VDC, which was low. This tells us, of course, that everything on the primary side of the power supply is perfectly okay and that the flaky +12 VDC output is a logical path to follow.

There are a couple of things that can cause this low voltage situation. One is that



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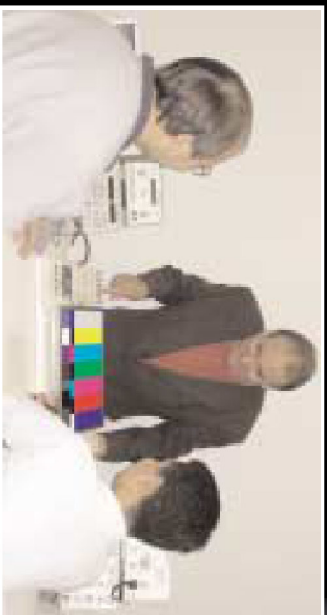
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- Understand multi-mode formats and circuit operation



- Understand analog (RGB) and digital signal formats and connectors (DVI)
- Explain the advantages and limitations of CRT vs. LCD displays
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### Hands-On LCD Monitor Troubleshooting

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## DAY 2

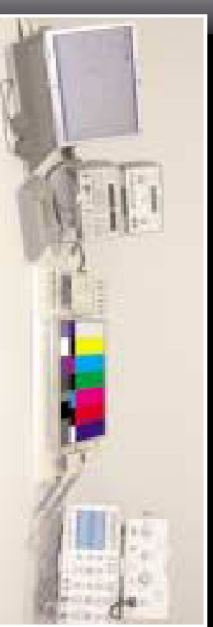
### LCD Inverter power supply and SMPS Troubleshooting

The last day of the course provides an introduction to power supplies and their uses. The students then learn how each type of SMPS and inverter power supply works by performing experiments on a working model. This course is truly a hands-on course with approximately 70% devoted to lab time performing tests utilizing an exclusive Sencore power supply trainer.

## DAY 3

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Which brings us to the other thing that can cause the +12

VIDEO INPUT

VIDEO OUTPUT

U-BLK INPUT

G1 PULSE

0F AMP PULSE

VIDEO PULSE

Horizontal Oscillator

The horizontal oscillator requires a +12 VDC power supply. Since the horizontal deflection drives the flyback transformer, a low reading of +8 VDC explains why the EHT isn't working.

3. The +12 VDC also goes to the neck PCB. Lets disconnect it!

4. With the neck board disconnected, the +12 VDC is normal and the EHT comes on.

However, neck PCB is actually okay!

1. We have no High Voltage (EHT)

2. The +12 VDC power supply measures 8 volts with DMM.

We know that the primary side of the SMPS is working because the +12 VDC output is the only one that is low.

well) and the neck board, pulling the connector is an easy way to “divide and conquer.” If the +12 VDC pops back up with the connector removed, the problem must lie on the neck board. Conversely, if the +12 VDC buss is still swamped down to +8 volts, even with the neck board disconnected, the problem can’t be in the neck board. The fault must lie on the deflection PCB.

I pulled the connector (power off, of course). When power was re-applied, not only did the +12 VDC come up to normal, the EHT started up as well. I could clearly hear the familiar sound of the static buildup and feel the hairs on the back of my hand prick up when held near the screen. The presence of continuous EHT was verified with an NE-2 Neon Lamp that glowed bright orange when held against the body of the flyback transformer. Naturally, there is no display at this time because the neck board is disconnected.

Hey! This makes perfect sense since the horizontal oscillator is also powered by +12 VDC. When the +12 was down at +8 VDC, the horizontal oscillator wouldn’t operate and, since the EHT is driven by the horizontal deflection circuit, the high voltage was nonexistent as well. When the +12 came up, so did the EHT.

Just to double-check, I reconnected the neck board. The symptom(s) returned (low +12, no EHT). When I disconnected

the neck board again, the EHT returned. That’s proof positive that the neck board is the culprit, isn’t it?

Some techs would immediately throw in a replacement neck board (either as an expedient to the repair, in order to get the monitor back on the floor as soon as possible or as the final solution, preferring to purchase replacement neck boards rather than repair them) but I figured “What the heck?” As long as I have PROVEN that the neck board is bad, I might as well go ahead and fix the thing. There isn’t too much on the PCB that’s connected to the +12 VDC line (just a capacitor for filtering and the video amplifier IC itself) so this should be a snap. I unsoldered the cap but there was no change. Next, I unsoldered the  $V_{cc}$  pins on the KA2141 IC and the monitor’s EHT fired up (+12 VDC good, etc.). Once again, I had PROVEN that the culprit was a shorted IC because when I disconnected it, the problem went away.

Funny thing though... When I used my meter to measure the resistance (power off) of the “loaded” +12 VDC buss (and, subsequently, the isolated  $V_{cc}$  pins of the video amplifier IC) I didn’t see anything that even remotely resembled a short circuit. I had thousands and thousands of ohms of resistance on the +12 VDC buss. If something was really loading down the +12 volt buss, why wasn’t I seeing it? I’ll leave that topic

for future presentation but suffice to say that there are “reasons” and leave it at that. Besides, I have already PROVEN that the neck board is to blame AND I have PROVEN that the KA2141 is to blame because when I remove power from either of them, my EHT is restored!

With a replacement IC installed on the neck board and everything reconnected, there was absolutely no change in the symptom. The monitor was completely dead, just as before.

Huh? IMPOSSIBLE! However, sure enough it was true. Maybe I was too big for my own britches. Maybe I should have swapped out the neck board. That way, I would know FOR SURE whether the problem was in the neck PCB or the deflection board. I did so but the problem remained the same. With the neck board disconnected, +12 is good and I have EHT galore. With the neck board connected, the +12 VDC is low and I have bupkis, nada, nothing!

This now seems like a complete paradox. On one hand, it simply HAS to be a bad neck board but on the other hand, the neck board has been replaced so it can’t be that. Even Mr. Spock would be scratching his head at this one.

In a rush to judgment, I made the logical (but totally incorrect) deduction that the neck board was to blame, which is really the point of this dis-



cussion. I was suckered in by the fact that pulling the neck board restored the EHT and that reconnecting it killed it. I just couldn't let go of that, despite the fact that I couldn't actually measure any shorted component anywhere.

With the neck board eliminated, that really only left one conclusion, and it's one that would have been reached immediately if I had had the use of an oscilloscope (and a hearty recommendation for the use of an oscilloscope in monitor troubleshooting once you have gained some experience). This had to be a ripple problem. Despite the fact that the filter capacitor tests perfectly good and has been replaced, this "low voltage" problem really has to be ripple.

If the capacitor itself wasn't bad, had it become disconnected somehow? Close inspection with a powerful magnifying glass revealed a tiny crack in the return path (the

negative lead) between the capacitor and ground. It was invisible to the naked eye (and a hearty recommendation for the use of "optical augmentation" when examining PCBs, especially following rework of any kind). This type of problem can be difficult to troubleshoot when your skills are limited to measuring power supply voltages and testing / replacing components. If you don't really understand how the circuits operate, it's tough to find things like broken traces.

On the other hand, it was my teammate (and student) Jimmy Hefner, apprentice slot tech from The Palace Casino, who actually located the broken trace once I had stopped leading him down the garden path of my incorrect "logical deduction." Way to go, Jimmy.

So why did the EHT come up with the neck board removed, even though there was nothing actually wrong with the

neck board? Because, with the neck board disconnected, we removed some of the load on the +12 VDC buss. As it turns out, it was enough that the only remaining electrolytic on the +12 VDC line (C301) provided sufficient filtering to operate the horizontal oscillator IC (IC301) with the neck PCB removed but not with the additional (albeit normal) load of the neck board. Pretty interesting, huh?

I suppose the real moral to the story is the thing that all good technicians know and that I have always preached: You can't test a power supply without a proper load. When I pulled the neck board, I unloaded the power supply and it began to work. When I reconnected the (normal) load, the power supply developed a lot of ripple due to lack of output filtering, not due to excessive load.

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# Fast, Accurate and Safe In-Circuit Electrolytic Capacitor Testing

By David Miga

**T**roubleshooting and locating defective electrolytic capacitors has been a thorn in the side of all technicians for many years. The CapAnalyzer 88A will help solve problems caused by electrolytic capacitors in audio, video, power supply, and system control circuits. This article will also show how to locate these bad capacitors easily without having to unsolder and test or cut up the P board and without needing the service manual, by using specialized test equipment specifically designed to make you more productive. Although you may have to unlearn some old-fashioned, slower methods, if you are progressive enough to learn these tricks, you will be able to fix slot monitors and power supplies faster and easier than you ever thought possible.

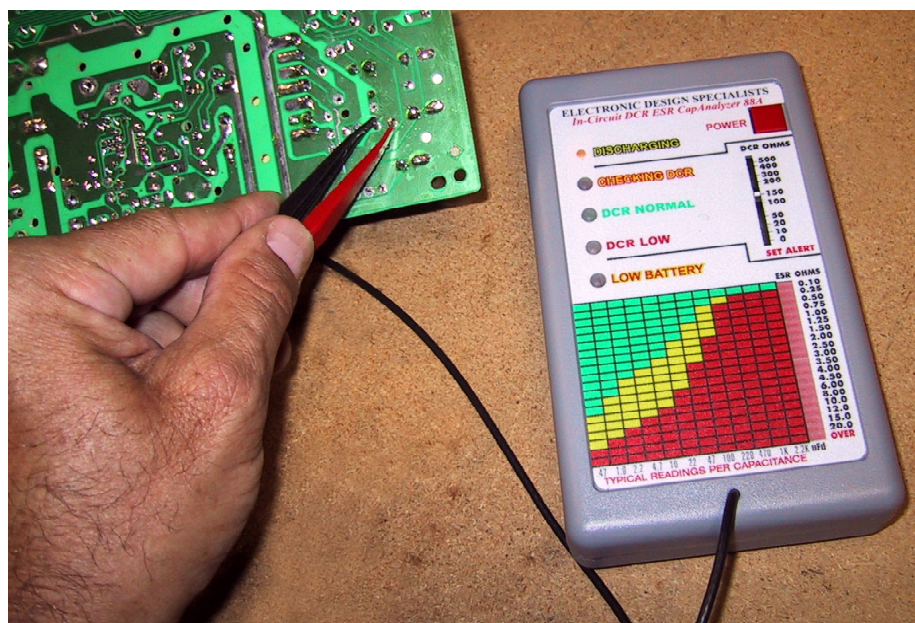
There are several ways a capacitor can fail. In slot monitors, the high temperatures inside the cabinet often cause electrolytic capacitors to dry up. In high-frequency circuits such as switched-mode power supplies, the capacitors tend to leak. In low-voltage circuits such as system control and low-voltage supplies, capacitors might short, partially or completely. Therefore, the

technician must first check all electrolytic capacitors for DC Resistance (DCR) shorts or leakage, and then check for physically leaky or dried-up capacitors by measuring high-frequency Equivalent Series Resistance (ESR). These methods will not require a soldering iron, a service manual or any cutting tools. It will require some logical reasoning, good eyesight and some specialized equipment; your \$29 DMM won't help you find the tough dogs.

### Dried and Physically Leaky Capacitors

As a capacitor dries up internally, it can become electri-

cally leaky. Most of the caps in this category will be found in monitors. As the capacitor dries up, it can cause strange problems in the particular circuit it is in. For example, in the monitor's vertical section, it can cause vertical overlap, insufficient vertical or non-linear scanning. If the capacitor is in the power supply, jail bars or "hairy" interference may ride on the video. In one popular gaming monitor, a bad filter capacitor in the 6.3 VDC power supply causes loss of horizontal sync. Go figure! In the audio section it can cause distortion or low audio. In the system control supply, it can cause intermittent functions and



Pomona "tweezer" probe makes one-handed, in-circuit testing of electrolytic capacitors fast and accurate.

microcontroller confusion, even a blank display. In the video circuits it can cause incorrect colors and/or a washed-out image.

Newer, digital monitors can also have these problems but with a different culprit: surface mounted capacitors.

Often, the problem will be less noticeable if the unit is left on for some time. That's because a dried-up capacitor will usually decrease its ESR with higher temperature.

Most technicians already know these symptoms and have an idea where on the board to start. The first step is visual observation. Vacuum all debris off the board and look for dark areas under each cap, for bulging tops and for shrunk and/or splitting covers.

On surface mount capacitors, look for the solder connections under the capacitor to have a cloudy look. This can be easily confused with perfectly good, lead-free solder joints (which always look sort of grainy) so be sure to compare to other solder joints on the PCB.

After visual observation and replacement of the obvious offenders, it's time to measure the rest of the electrolytic capacitors. The problem of measuring each capacitor is more difficult than measuring resistors, which can be measured in circuit quite easily with any cheap DMM. That is because any circuit that encompasses an electrolytic capacitor already has some DC resistance and some capacitance from other parts of the circuit. Some "capacitor checkers" claim to work in

circuit but since they actually measure circuit capacitance and resistance, they give such erroneous readings that caps usually have to be unsoldered and re-measured out of circuit anyway. In fact, even some of the most expensive capacitor meters (over \$2000) will not always measure capacitors accurately in circuit. Some meters measure the capacitance at two different frequencies and show it as two different readings. Most ESR meters will show a partially or fully shorted capacitor as "perfect."

Speaking of "ESR" meters, their designers already know that the trick to locating bad capacitors in-circuit is not to measure capacitance at all! Years of testing by many technicians and engineers has shown that as a capacitor ages, its Equivalent Series

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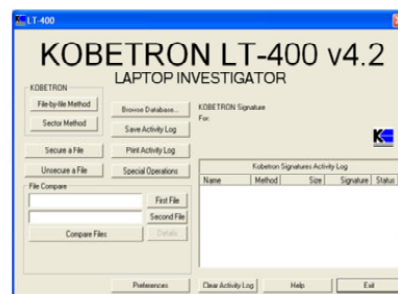
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Resistance increases. What is ESR? Without going through the math, a perfect capacitance will measure as an open circuit at DC and will show less and less resistance as the frequency across it increases. Some inexpensive capacitor meters utilize this property by measuring a capacitor's impedance (Impedance is a type of resistance measurement. It is "AC resistance") at a fixed frequency such as 1 kHz and translating the reading to capacitance. In reality, checking a capacitor at 1 kHz only works if the capacitor is being used in a circuit that also operates at 1 kHz. VGA resolution monitor video circuits use frequencies into the megahertz and in PWM power supplies, the operating frequency is pegged to the horizontal scan rate so frequencies of 31.5 kHz and higher are commonly used. It makes more sense to forget about capacitance altogether and use our knowledge that high frequency ESR increases with age and as a capacitor dries up.

Several ESR capacitor checkers have appeared throughout the years. The originator was a simple meter that used 50 kHz and a simple mechanical meter. The technology wasn't good enough at that time to measure capacitors accurately. A more recent meter is a slightly improved version, still using an old-fashioned mechanical meter, but running at a more accurate 100 kHz. However, these meters have their limi-

tations; they cannot check for leaky or shorted caps and the technician must individually discharge each capacitor before testing. Also, the cheap test probes add their own capacitance and readings varied depending on the position that the technician held the probes (and whether or not he or she was sweating!).

A more modern design for an in-circuit ESR/DCR tester is the CapAnalyzer 88A by EDS. This unique meter uses a test frequency higher than most others, automatically discharges the capacitor under test, checks for Low DCR, then checks and displays ESR on a 20 segment LED bar scale. It includes a low-capacitance, one-handed tweezer test probe, and beeps from one to five beeps depending on the ESR reading of the cap. Because it is microprocessor controlled, it has more features and is much more accurate than the older designs. Possibly its best attribute is a three-colored chart on the front panel that shows typical ESR readings of good, fair and bad caps depending on their capacitance.

The CapAnalyzer 88A claims 100% accuracy in circuit because of its testing parameters. The frequency is high enough to make the capacitor's actual capacitance insignificant, so it measures only the ESR. The high test frequency also helps isolate the capacitor under test from the rest of the circuit via the high inductance of the PC

board copper foil. This frequency is also high enough to ignore any coils over 5  $\mu$ H. ESR testing is done with a calibrated low resistance at the test point which allows it to compensate for normal circuit resistance. Both DCR and ESR measurements are under 50 millivolts so that no active devices are turned on, therefore only the component at the test point will respond. However, because it checks DCR first, it will alert the technician immediately if the capacitor or anything else in that circuit is shorted or leaky, before it checks ESR. This test parameter (DCR OHMS SET ALERT) is user adjustable from zero to 500 ohms.

#### Using the CapAnalyzer 88A to Check Electrolytic Capacitors

When the CapAnalyzer 88A is first turned on, after a second of internal calibration checks, it will briefly check all LEDs, multi-tone beeper and the battery. Then, it will flash the OVER LED slowly to indicate ready. The DCR OHMS slider set alert is normally set to about 150 ohms. To test an electrolytic, simply hold the tweezer test probe across the capacitor leads. Polarity does not matter. The CapAnalyzer will chirp once to let you know that you have a good connection and the DISCHARGING LED will turn on for a fraction of a second.

The first test is the DCR test. The CapAnalyzer will show either a NORMAL or LOW LED, depending on the set-

ting of the DCR OHMS SET ALERT slider. If the slider is set to 50 ohms, the CapAnalyzer will sound an alarm and light the DCR LOW LED if the DC resistance is lower than 50 ohms. Most circuits will never show this low normally. However, in some circuits, the circuit's resistance might be lower or higher. In these cases, you may set the slider for as low a DC resistance as you expect the circuit resistance to be normally. For example, where the supply must power a 15 ohm load, you could set the slider to 10 ohms. The CapAnalyzer would treat any DC resistance above 10 ohms as normal and warn you if measured DC resistance is lower than 10 ohms. In fact, you can set the DCR SET ALERT anywhere from a fraction of an ohm by setting the slider all the way down to 0, to as high as 500 ohms DCR.

Be advised that if you have the slider set higher than 100 ohms and try to measure a very large electrolytic, the charging time to test the electrolytic may exceed the DCR test period and you may get a false DCR LOW, or the CapAnalyzer may try testing the capacitor over and over because of conflicting test results. Therefore, use 50 ohms as a guideline when measuring most medium to large electrolytic capacitors and use the values higher than 100 ohms when measuring small tantalum and surface-

mounted capacitors. Surface-mounted tantalums can become leaky by as high as 500 ohms.

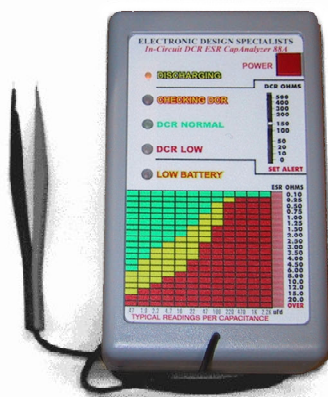
## Capacitor Testing

As you touch and hold the probe across the cap, the unit will chirp once to indicate testing has started, will pass the DCR test, then will chirp one or more times depending on the ESR of the cap. The CapAnalyzer 88A has been designed to chirp once if the ESR is less than one ohm,

two chirps from one to two ohms, three chirps from two to three ohms, four chirps from four to eight ohms and five chirps from eight to 20 ohms. The handy three-color chart on the front panel shows typical ESR readings, so if a 2.2 uF capacitor chirps three times and shows 3.00 ohms ESR, the chart shows that this is in the green, good.

As a rule, some caps can show in the yellow area and may still work adequately. It is up to the technician to make the

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- Measures DCR to 500 ohms
- Measures ESR from 0.1 to 20 ohms ESR
- Checks capacitors from 0.47 uF to 2200 uF
- Beeps one to five beeps for quality
- Color chart shows good-fair-bad readings
- One-handed tweezer test probe
- Checks through-hole and surface mount

Solving problems caused by electrolytics has never been easier, now that you can locate these bad capacitors easily without having to unsolder them, and without spending time troubleshooting, by using the CapAnalyzer 88A.

As an electrolytic cap ages, it can cause problems in the particular circuit it is in. In video monitors it can cause underscan or overscan problems or a fully scrambled picture. In audio or mp3 circuits it can cause distortion or low audio. In the syscon supply it can cause intermittent functions and mpu confusion. Tantalum capacitors can become leaky by as much as 500 ohms. Many electrolytics must have super-low ESR, or else strange problems can occur.

The trick to locating a bad capacitor in circuit is to measure its Equivalent Series Resistance (ESR) at very high frequencies, and DC Resistance (DCR) and compare readings in relation to capacitance. The CapAnalyzer 88A is the only test instrument in the world that will discharge the capacitor first, measure DCR up to 500 ohms (with adjustable warning beeper) and ESR automatically and accurately, all within 2.5 seconds, with guaranteed 100% accuracy. And you don't even have to unsolder the cap.

Beware of lookalikes. These copycat DCR/ESR meters have their limitations; they don't check DCR properly for leaky or shorted caps and most don't use a test frequency high enough to guarantee 100% accuracy.

The CapAnalyzer 88A uses a test frequency higher than the others, displays ESR on a 20 segment LED bar scale, and beeps from one to five beeps depending on the ESR condition of the cap. Both DCR and ESR measurements are under 50 millivolts.

Because it checks DCR first, it will alert the technician immediately if the cap or anything else in that circuit is shorted or leaky, before it checks ESR. Included is a low-capacitance one-handed tweezer test probe for accuracy and ease-of-use. Because it is dual-microprocessor controlled, it has more features and is much more accurate than the other meters. A three-color chart on the front panel shows typical ESR readings of good and bad caps depending on their capacitance. Portability and battery operation make it ideal for repairs on site, and an optional AC adapter is available for continuous use.

Engineers for the major TV networks ABC, NBC and CBS specify the CapAnalyzer 88A, as well as technicians at AT&T, GTE, Verizon, Comcast and Time/Warner Communications. Service technicians for professional/ commercial broadcast equipment, like Panasonic Broadcast, JVC and Sony, specify the CapAnalyzer 88A, as do service managers and thousands of technicians at consumer repair companies like Circuit City, Sears, and thousands of independent repair shops.

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Boca Raton, FL 33428  
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decision on whether to replace these questionable caps or not. However, any caps that show ESR in the red areas are out of spec and must be replaced.

Note that if an electrolytic capacitor is in such bad condition to be over 20 ohms ESR, the CapAnalyzer will treat it as an open circuit and will not even try to test it. The OVER indicator will continue to flash. Replace these caps, as they are bad, no matter what their capacitance is. If you wish to double-check the test probe at any time, simply short the probe contacts together and the CapAnalyzer will do a self-test. You can also check calibration at any time with a 10 ohm resistor: set the DCR OHMS alert to zero and measure across the resistor; the 10 ohm ESR LED should illuminate.

In some cases, you may find capacitors that are physically leaking, yet they check as perfect. Although the capacitor is leaking, it has not leaked enough electrolyte to render it defective and will still operate perfectly in the circuit . . . for a while. If you wish to avoid callbacks, replace them anyway.

**NOTE:** Although the CapAnalyzer automatically discharges capacitors before testing, remember that there are limits. If the capacitor is large enough and there is enough voltage stored to blow the ends off of the test probes,

you will have to replace the probes as well as the resistors in the discharging circuit of the instrument. Therefore, use common sense when measuring electrolytic capacitors that may have a serious charge stored. If you damage the unit, it will appear to try to test a capacitor as soon as it is turned on. You can easily repair it yourself. See the website for instructions.

### **Quick ESR Test**

Normally, the CapAnalyzer discharges the cap, then tests for DCR, then measures ESR. In many cases, you might know for sure that there are no shorted capacitors and might wish to save some time by eliminating the full test and just want to quickly check the ESR. To put the CapAnalyzer 88A in this special Quick ESR test, turn the unit on while shorting the probe ends together. Instead of the multi-tone song, the CapAnalyzer will only beep twice and be ready for testing. Keep in mind that a shorted capacitor will show a low ESR, so it is recommended to use only the full test. This feature also uses less power and will result in longer battery life.

### **Low Battery Warning**

The CapAnalyzer 88A uses four alkaline AAA batteries (6 VDC). Although continuous operating time is several hours, most users will only need to replace the batteries

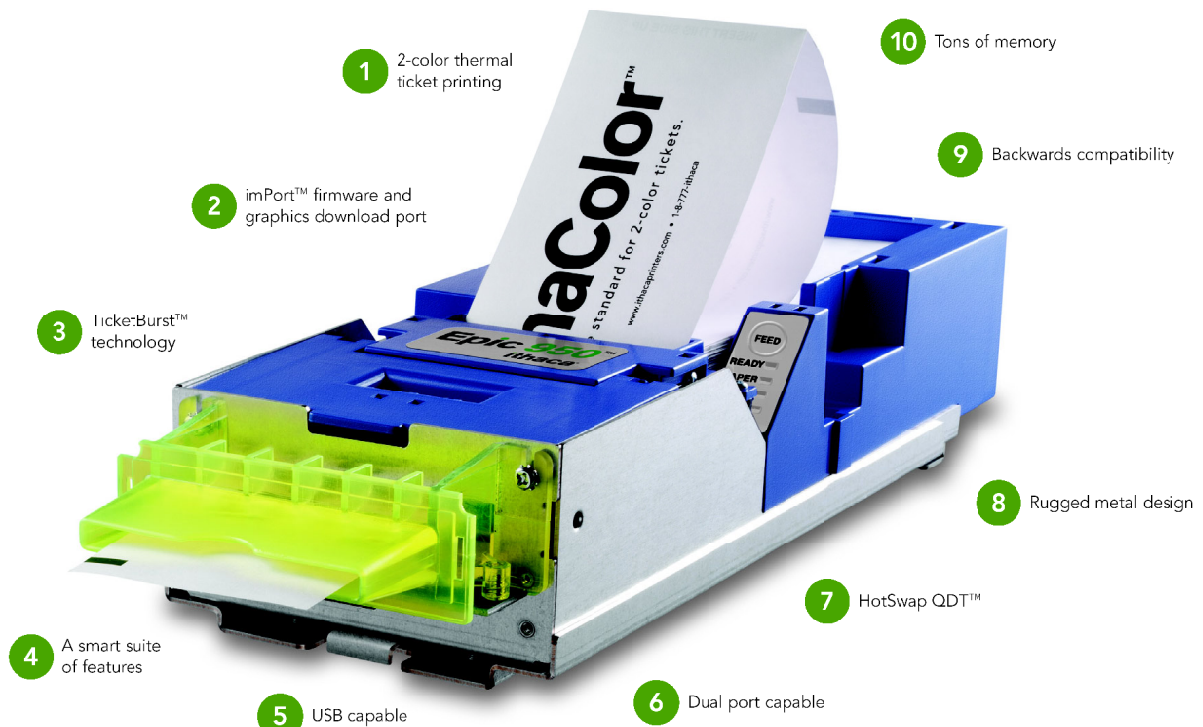
at three to six month periods. We advise to measure a few capacitors, and then turn off the CapAnalyzer when you find and replace the bad cap. If left on without being used, a three-minute warning timer will chirp three times every three minutes.

At 5.1 volts, the LOW BATTERY indicator will illuminate. The unit will still operate for some time on a low battery, until voltage falls to 4.9 volts, with a slight reduction in accuracy. Below 4.9 volts, the unit may ignore shorted capacitors, so a good test if you are not sure is to short the probe tips and see if the DCR LOW LED comes on and the alert sounds, as it should.

Do not attempt to use any external voltage source more than 6VDC. If you need to keep the CapAnalyzer on continuously, you may send your unit to EDS with a \$29 check, and a power jack and specially modified external adapter will be supplied. Alternatively, you can install the AC adapter easily yourself with a drill and soldering iron; the adapter kit is \$19.

For further information, contact:  
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# Understanding Video Reels

By John Wolson

decision, especially when it comes to video slot machines.

Video slot machines employ the same basic mathematical principals as the stepper-motor or spinning-reel slot machines. With extra reels, more symbols and complex bonus games however, determining your projected hold is no simple chore. What are the differences between the stepper slots and the video slots? How do hybrids fit into this mould? Hybrid games consisting of both spinning-reel and video reels and/or video bonus rounds offer the best of both worlds to players, but further complicate the job of casino staff. As slot machines become increasingly complex, an understanding of the underlying slot math becomes increasingly important. Imperative, in fact!

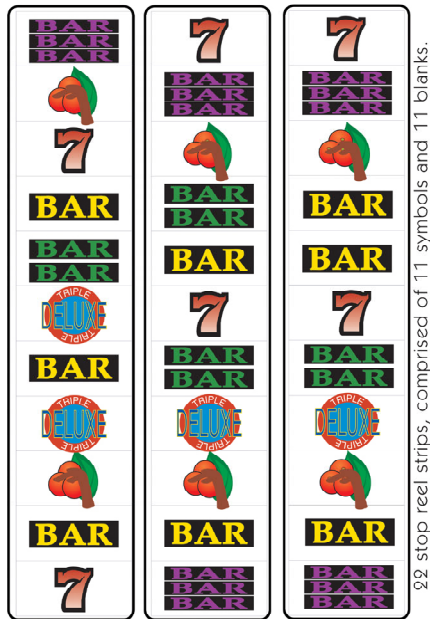
## Types of Reels

First of all, let's examine the various types of reels that we have available in our slot machines. You

can recall from our discussion on virtual reels and physical reels [Slot Tech Magazine, January 2004] that the reels the players see are quite different from the reels the slot machine works with. Recall that these physical reels are really for the amusement of the players I often refer to them as "player amusement reels." Physical limitations of these reels make slot design increasingly difficult. The reels can only be so large if they are going to fit inside your machine and you can only stuff so many symbols on these reels. The virtual reels, under the definition of the Telnaes patent, have a direct relationship to the physical reels. With the invention of virtual reels, the mathematical representation of the slot reels can be larger than the player amusement reels. While there may be 22 symbols and blanks on a particular reel strip, the same reel can exist inside the machine with many more blanks or symbols. Consider the following illustration (right):

**T**here is no denying that the gaming industry has changed dramatically during the past few years. As technology continues to advance rapidly, your casino floor changes along with it. No longer are table games the mainstay of the North American casino. Your slot machines are becoming more complicated, making your casino floor a dynamic place where the perfect mix of machines remains just out of reach. As denominations decrease and game complexity increases, it is more important that slot technicians, supervisors and management have a good knowledge of slot math. Deciding what machines will work on your floor doesn't have to be a trial-and-error exercise. It is, however, a very difficult

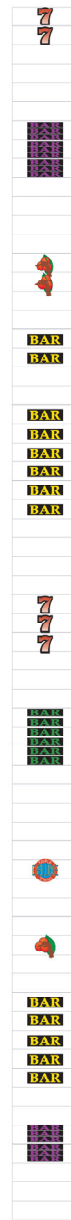
## Sample Physical Reel Strips "Player Amusement Strips"



## Sample Virtual Reel

This physical strip  
can be used to represent

this virtual strip.

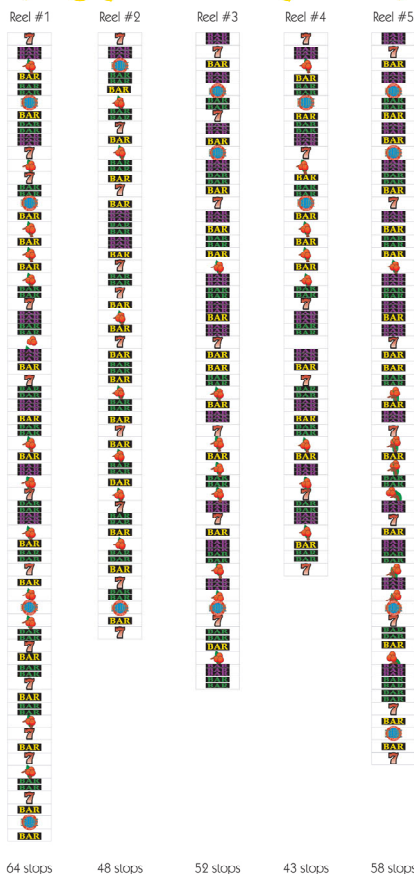


The virtual reel strip has a direct relationship to the physical reel strip.  
In this example, there are 64 stops on the virtual reel.

The three physical reels or reel strips are known to all slot technicians. You've seen hundreds of them in machines and have no doubt installed countless reel strips. The virtual reels, however, remain shrouded in mystery. Video slot reels are quite different from the physical spinning reels. They are virtual, by definition of the term. Virtual refers to "being such in essence or effect though not in actual fact". In other words, these virtual reels exist in the slot machine, but you can't touch or feel them. In a video slot machine, they take on quite a different representation.

They aren't virtual reels like Telnaes defines them but virtual because they really don't physically exist. There is no physical reel strip in a video slot machine. The player only sees a small portion which represents the virtual reel.

## Sample Video Configuration (Using symbols from Physical Reel)



But look what we  
can do with video  
reels!

This configuration has a cycle of 398,401,536 games.  
There are 192 jackpot combinations, occurring once every 2,075,08 games.

Traditionally, physical slot reels have 22 positions or stops on them. The Telnaes patent specifically refers to 22-position reels. The virtual reels have more stops, commonly 32, 64, or 72. WMS Gaming's early stepper slots didn't use a virtual mapping so the physical reel strips were exactly what the machine used in



the mathematical calculations. Traditional virtual-reel machines also use the same number of stops for each of the three reels. If a Diamond 7 machine had 72 virtual stops, then each reel would have 72 virtual stops. In recent times, the virtual stops on the reels have changed considerably. Not only are more stops being added to the virtual reels, but each reel is created with a different number of stops. The old 262,144 cycle game with three reels of 64 stops is being changed.

With the addition of new bonus symbols and multipliers, a 4th reel is found on many new games. This 4th reel frequently has a much larger virtual stop count. This is done to make the extra, larger payouts viable while still maintaining the overall look & feel of the game. The first three reels may have 64 or 72 stops each, but the number of virtual stops on the 4th reel may be significantly more - perhaps upwards to 1000 stops.

### **Hit Frequency**

Players love a game with a high hit-frequency. Stepper slots generally have hit frequencies from 5% to 35%. Video slots usually have hit frequencies above 50%. This is part of the

appeal of video slots - the players win more frequently.

With spinning-reel games using multipliers, there is a general rule of thumb. The larger the multiplier amount, the lower the hit frequency. A 10x payout machine will payout a lower hit frequency because of 10x and 100x payout amounts. In this aspect, the game designers are not just trying to fit in various payout amounts. They also have to consider each payout multiplied by 10 and 100. A 500 credit payout can also be a 5,000 and 50,000 credit payout when it involves one or two 10x multipliers. It's hard to implement multiplier awards and still maintain a reasonable frequency of wins. As a result you don't see very many machines with large multipliers. Numerous machines have a doubling (2x) multiplier. Fewer have 10x multipliers or larger. In video slots, higher multipliers are infrequent. In many cases, the payout for a doubling multiplier doesn't pay more if numerous symbols are on the payline. On spinning reels, one 2x pays double, two 2x pays quadruple (4x). On video slots, the payout often states "One or more 2x symbols pays twice the payout amount". Part of the rea-

son for this is the use of five reels. On a 5-reel game, four 2x symbols would multiply the win by 16x. Add in a 10x symbol, and four of them would multiply by 10,000 times. Obviously, the math for this becomes very complicated! With video slots, the use of multiplier symbols is less frequent than on spinning reel slots.

### **Minimum Payout**

On stepper reel slots, payout is almost always more than the player wagers. In some cases, the wagered amount is returned as a minimum payout. For a two-coin wager, three blanks may pay two credits. It is highly unusual to see a payout less than the wagered amount. For example, a three-coin wager with three blank symbols generally will not pay a one credit win. Once again, video slots are an entirely different beast. Here the player will frequently win less than their wagered amount. The interesting point for gaming personnel is the philosophy of the players. How many times have you seen a player bet 15 lines with one credit per line and win nine credits? In reality, their game lost six credits. Inevitably, however, they say "I wish I had played five credits!" That would mean they would

# A SIMPLE 10-STOP SLOT MACHINE

7	7	7
BAR	BAR	BAR
BAR	BAR	BAR
BAR	BAR	BAR
7	7	7
BAR	BAR	BAR

# PAYTABLE AND FREQUENCY OF HITS

7 7 7	50
$2 \times 2 \times 2 = 8$ COMBINATIONS	
BAR BAR BAR BAR BAR BAR	20
$1 \times 1 \times 1 = 1$ COMBINATION	
BAR BAR BAR	10
$2 \times 2 \times 2 = 8$ COMBINATIONS	
ANY 3 MIXED BAR BAR BAR BAR	5
$3 \times 3 \times 3 = 27$ COMBINATIONS Less Natural Double BAR -1 Less Natural BAR -0 = 10 COMBINATIONS	
THREE BLANKS	1

have lost 30 credits. For many players, a win is frequently more important than the amount of the win. Even if they end up losing money, they want to have numerous small wins. This brings us back to the point that players like to win frequently, even if they don't win much each time.

## Physical Reels and the Virtual Evolution

For a game using 22 stop reels there would be  $22 \times 22 \times 22$  or 10,648 possible combinations. This means that if the machine will only take in 10,648 coins per cycle (based upon one coin play). Allowing more coins per game doesn't increase your percentage hold. It does increase your total revenue as more coins are played each game. If you pay out 10,000 coins per cycle, then your payout percentage is  $10,000 / 10,648$  or 93.9%.

Your hold is 6.1% (100 - 93.9). If you allow the player to wager five coins per game, you still only hold 6.1%. What you do is take in more coins, giving you more revenue, faster. There is a limit to the number of coins that a player is willing to wager on any one game, however. With spinning reel slots, it seems that six coins are the maximum people are willing to part with for one game.

Virtual reels allow significantly more stops without changing the outward appearance of the game. For the 64-stop game, there would be  $64 \times 64 \times 64 = 262,144$  possible combinations. This allows much larger payouts to be made. Let's consider how. First we will create a very simple game with few combinations.

The Liberty Belle, created by Charles Fey in 1895, is credited with being the first slot machine. There were three reels with

ten symbols on each. That provided a total of 1,000 combinations. Let's create our own simple machine with 1,000 combinations.

Next we need to determine the number of combinations available. We simply add up each of the symbols per reel and multiply them together.

That gives us 660 winning combinations. There are 1,000 stops on the reel; what happened to the other 340? These are combinations of symbols and blanks, or non-paying symbols (like 7 BAR BAR) that we won't pay anything for. They are the 'losing' combinations!

At one coin play, we take in 1,000 coins per cycle. How much can we pay out? Let's start with five coins for mixed bars: 18 combinations x five coins = 90 coins paid out for mixed bars.

Single Bar? How about ten coins? Eight combinations \* ten coins = 80 paid out for single bar payments. Double Bar? How about 20 coins? One combination \* 20 = 20 paid out. Seven? Can we pay 50 coins? Eight combinations \* 50 = 400 paid out for sevens. For three blanks, let's pay out one coin. 625 combinations \* One = 625 paid out.

With this payable, the total payout per cycle is 1,125. That's more than we take in, so we have to change our payout. If we remove the payout for blanks the total paid becomes 500. The total hold is  $1000 - 500 = 500$  coins. That's pretty good. We pay out 50% and hold 50%. What about hit frequency? We don't pay for blanks, so the total number of winning combinations is 35 and 35 out of 1000 gives us a 3.5% hit frequency. This is pretty low. Will players like it? Probably not. The hit frequency is low and the payout amounts are also low. The largest win is only 50 credits. This is hardly a life-changing jackpot.

Can we make this game more appealing to the players? What if we increase the jackpot payout to 200 coins for three 7 symbols? Eight combinations x 200 coins = 1600 paid out. That alone is more than our 1,000 coins we take in. The highest we could go would be 100. That would give us  $8 \times 100 = 800$  coins paid for sevens, with the total payout now 990 coins. Hit frequency stays the same, hold % is  $10/1000 = 1\%$ , payout 99%. The 7s pay once every 125 games. Not too bad, but we can't do too much more than that. We're very limited in our

payout. Also, if we want to, we could add one more symbol - change one of the single bars to triple. However, the most that we can have is five symbols on each reel. I think you're starting to see that a game with few stops on each reel is a game with few players.

That being said, it's pretty easy to calculate the payout, probability and everything about the inner workings on this slot machine.

## Problems?

As you can see, our simple game offers few symbols, few combinations of winning symbols, a very short cycle which means that only small awards can be paid, and then fairly infrequently. In order to increase revenue, we can offer the player the chance to wager more coins per game, but this isn't a real solution.

Next month: Part two of our look at Video slot math.

- John Wilson  
[jwilson@slot-techs.com](mailto:jwilson@slot-techs.com)

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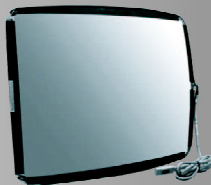
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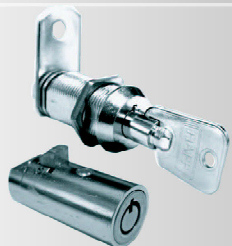
**MONITORS &  
TOUCH SCREENS**



**CLEANING &  
MAINTENANCE**



**TOOLS**



**CUSTOM LOCKS**



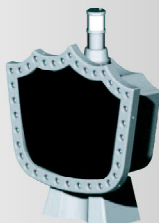
**PUSHBUTTONS**



**MATERIAL HANDLING**



**GAMING PARTS**



**ACCESSORIES**



**BATTERIES**



**LIGHTING**



**SECURITY**

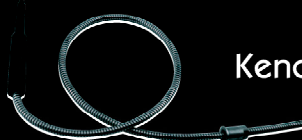
## HAPP® Service Center



**JCM Validator Repair**



**Monitor Repair**



**Keno Pen Exchange**



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