January 2004

Right: During a recent monitor repair class in Chicago, Illinois, technicians from across the country took an early-morning tour of the Wells-Gardner monitor factory in McCook. The tour was lead by W-G's Field Service Coordinator, Chuck Hedrick. Also participating in the tour was Field Service Engineer, Chuck Rabiola.

Slot Tech Editorial

The December issue of Slot Tech Magazine carried a letter to the editor regarding service manuals and/or, at times, the lack thereof. Following publication of the December issue of Slot Tech Magazine, I received a telephone call from Wally Sa'd of Wells-Gardner Electronics. Wells-Gardner, as readers of Slot Tech Magazine know, is a monitor manufacturer. Their monitors are found in slot machines worldwide. Wally wanted to know why I hadn't mentioned W-G when I was handing out kudos to those manufacturers that support the technical community with replacement components and schematic diagrams. Here is his follow-up e-mail:

Dear Randy,

Wells-Gardner has always been committed to product support by providing detailed schematics and service manuals. Our technical support staff is experienced, knowledgeable and responsive. Product data sheets and other technical information is available on our web site.

Wally Sa'd
Vice President of National Sales
Wells Gardner Electronics Corp.
9500 W. 55th Street, Suite A
McCook, Illinois 60525-3605
Direct 708-290-2180
Fax 708-290-2203

Wally is correct, of course. Since day one, Wells-Gardner has always provided detailed schematic diagrams, complete service manuals and customer support for their products. I simply neglected to mention it in this case. I have however, declared this previously, in the August 2002 issue when I stated:

"The manufacturers have always been extremely cooperative with me when I have asked for help. In some cases, it's schematic diagrams. Wells-Gardner, for example, has supported me for the past twenty years, generously supplying my students with service manuals and schematic diagrams and even hosting my tech schools numerous times at their manufacturing plant in Chicago."


Randy Fromm

And so Wally, just to refresh your memory of my public support for W-G, this one's for you: *I, Randy Fromm, do hereby declare my long-standing appreciation of Wells-Gardner Electronics, your products and your personnel (especially Chuck Hedrick) for their outstanding assistance in the past, present and future.*

'Nuff said . . .

I wish a happy and prosperous New Year to all. To our contributing writers, thank you for all of your outstanding work. To our treasured subscribers and advertisers, thank you for your continued support of Slot Tech Magazine.

See you at the casino.

Randy Fromm

Randy Fromm - Publisher

Randy Fromm's
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Slot Technical Department

Senior and Site Technicians

By Kevin Noble

There are many departments needed to make the operation of a casino successful. Without any one of them, the casino could not exist. Every job and task performed is essential to the smooth flow of the operation. Having been lucky enough to experience working in a large commercial casino and now a smaller scaled down version, I can compare different aspects of the operations. The smaller casino allows me to interact with customers and patrons, giving what I consider to be better customer service. The interaction between all the employees brings everyone closer together. Friendships develop and at the same time, when tragedy strikes, everyone is there to pull together to help out the employee and their families. This allows us work together and attains a common goal and to be the best that we all can be.

Our Slot Attendants are an extension of our Technical Department, especially when projects are on the go and we may not always be unavailable. Our department is made up of two classifications of technicians: Senior Technicians and Site Technicians. Senior Technicians are responsible for helping co-coordinate machine moves. They also participate in the moves, conversions, upgrades, and everything to ensure the department runs smoothly.

Site Technicians have the same responsibilities as the Senior Technician when one is not present. We currently have three Seniors (two on the day shift and one on the afternoon shift) and nine Site Technicians: three on days, four on afternoons and one on grave. Unlike many casinos, we have no Technical Managers or Supervisors.

Team Work

Every casino has different policies and procedures, tasks and responsibilities to ensure all the equipment is up and running. The company cannot make a profit with games and equipment down. This is why we have different assigned tasks to make sure the equipment is running to its full capacity every morning. A minor daily chore is the checking of all yellow cards. These are minor problems that do not require a Technician's presence immediately but can be looked at when the machine is free or when a Technician becomes free.

Some of the minor problems could be burned out bulbs, handle problems, broken clips and loose buttons to name a few. Also every morning we check for BV lights out, flickering fluorescent lights and door-open codes caused by the Soft/Hard count crew.

When AGCO is scheduled at the site, we perform what we call "Randoms." A Random is when the Gaming Commission comes in, picks games at random and performs EPROM verifications, coin tests and inspections to ensure the integrity of the game, and that all procedures are maintained. The Grave Technician works on a daily preventative maintenance program for the Cage and Coin Department. Cleaning and calibrating such equipment as the wrappers, and bill counters, just to name a few. The Grave Technician also completes most of the service reports handed down from the Auditing Department. They may consist of bill testing, coin

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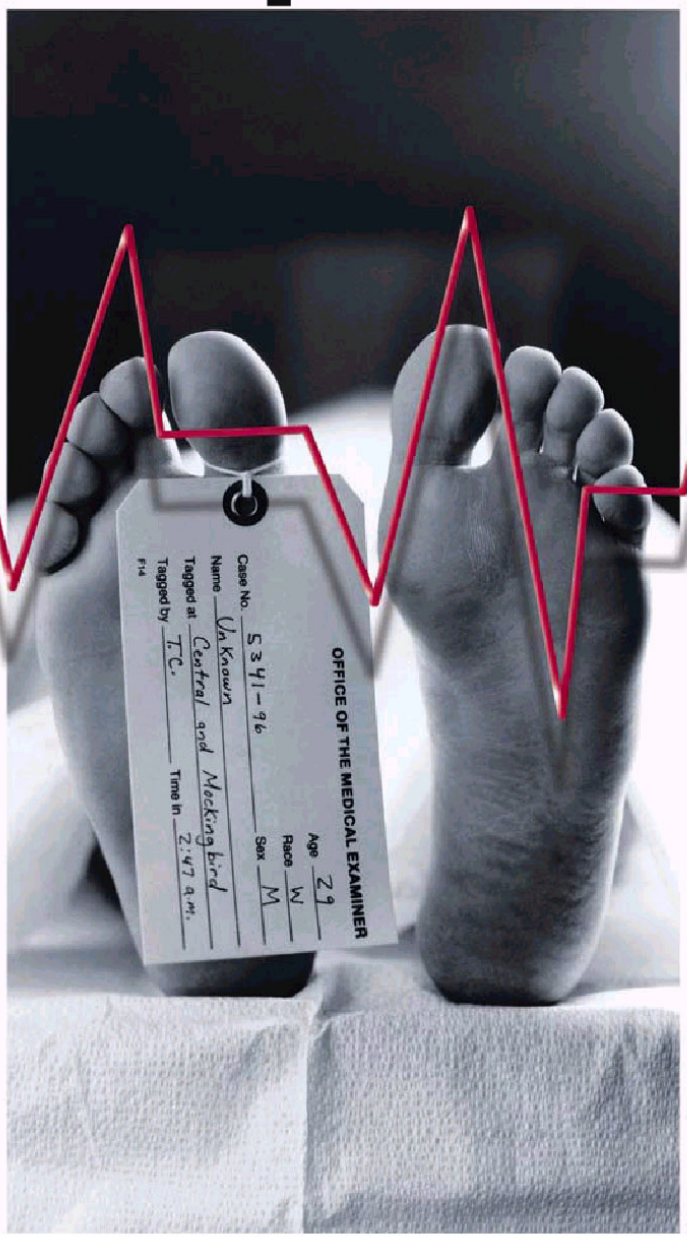

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testing and games or doors not communicating with the system. They also have the responsibility of following the drop team in case any repairs may be needed. A bi-weekly inventory program is also in place and is brought up to date and faxed to the main warehouse to ensure our inventory is up-to-date. In this manner, we do not encounter any part shortages. Monthly programs such as a Williams hopper test, ensure that the hoppers are in working order. Some of these procedures are implemented by the Ontario Gaming Commission.

Promotions

Watching some technicians come into the department and take the next step is exciting, knowing that you can move through the corporate ladder. Currently we have had three technicians become AGCO Electronic Gaming Control Officers, two technicians went on to become Slot Shift Managers, one technician departed to work on cruse ships, one technician moved over to become a regional MIS technician, and one went on to become a regional surveillance technician.

On December 4th, I lost a great technician (and good friend) Alex Tranilles to the AGCO. Alex accepted the position as an Electronic Gaming Enforcement Officer for the Toronto Area. His hard work and expertise will be missed greatly. Good luck Alex.

Responsibilities

Senior Slot Technician

The Senior Slot Technician at our site is responsible for providing leadership, training, communications with other departments, handing out job assignments, signing out sensitive parts and making decisions. Senior Technicians are responsible for all tasks including major and minor repairs, preventative maintenance, MIS room repairs, upgrades, moves and conversions. We also maintain sensitive and non-sensitive parts inventory for ordering of parts and maintaining adequate inventory levels. We also are involved with writing reports, proposals, solutions, requests and improvements both within our department and on the gaming floor.

Without having any supervisor or manager in our department, this is one of the toughest situations to be in if you are a Senior Technician. You are called upon to exercise leadership. You need to learn to listen carefully to what people are saying, not to jump to any conclusions, to make decisions, work to promote departmental teamwork, hand out assignments and learn to say "no" when necessary.

Other aspects of the job include knowing your co-workers' strengths and weaknesses, helping to correct any mistakes without be critical, making sure others understand their assignments and keeping them informed of any changes and updated technology.

We have no authority to discipline, write up, or be involved in any actions between Slot Technicians and our Management. One of the best things I enjoy is the interaction with the manufacturers' representatives, the vendors and suppliers.

Site Technician

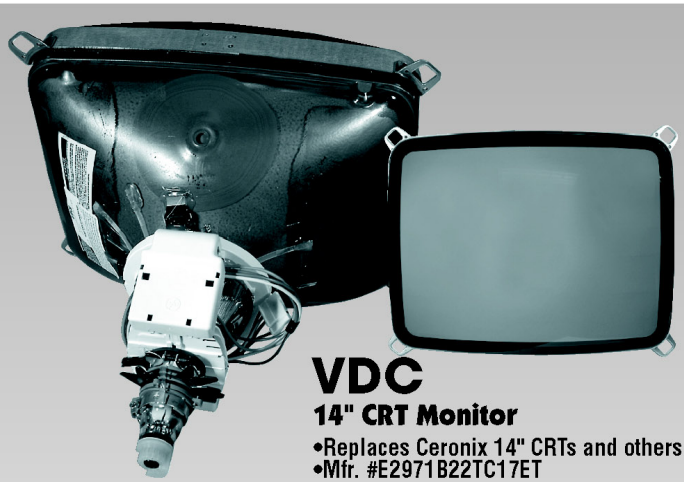
The Site Technician responds to all service requests called by the Slot Attendant Supervisor or Shift Manager. They're considered the first level of repair. When called upon, the Site Technician basically does everything a Senior Technician does when a Senior Tech is not available. The Site Technician has the ability to order parts and write shift reports. The only major difference is not having a "sensitive parts" room key on their key ring.

Tasks

There are many tasks in our department that we have to share when a Senior Technician is not present. When this happens, the Site Technician is then pressed into the role. On days, we share the workload and try to rotate different chores so we do not get stuck doing the same things every day, like working with AGCO.

Some of our common tasks are:

* Clearing all coin and bill jams
* Replacing burned out lights and bulbs
* Performing all preventative



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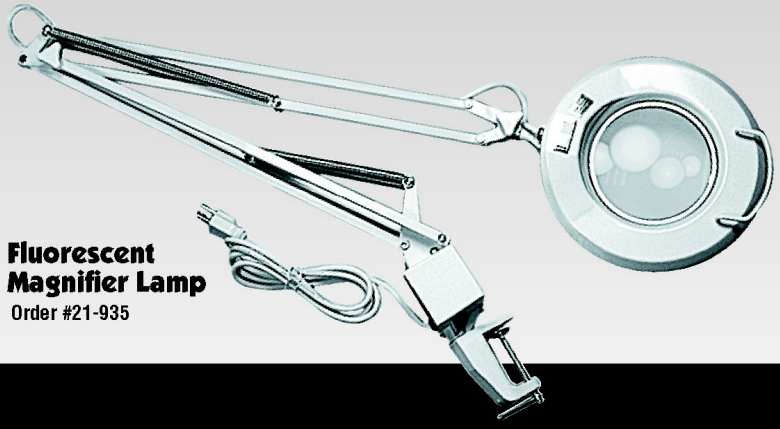

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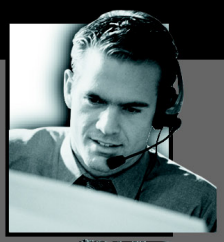

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* Mikohn System, progressive signs, hard and soft count equipment
* Writing reports, proposals, solutions, requests and floor improvements
* Training new technicians
* AGCO sealing and unsealing, random inspections, modifications, progressive testing

Paperwork

The most important paperwork involved is writing a shift report and passing on information to the next shift. Our shift report consists of floor duties for that day, any messages to pass along, parts ordered and received games that are currently down, games that were down and are now repaired, number of service calls on that shift and the number of games that were PM'ed. We also set up a log book for parts that were ordered. This book logs from which vendor we have ordered, the date it was ordered, the technician who ordered it, a description of parts ordered and a column to sign off when the complete purchase order is completed.

We also keep a slot file in the shop, sorted by location and asset numbers. This is handy for filling out service reports' game information ahead of time and finding locations for the Manual Jackpot Inspection Reports (they are handed down from Auditing by asset number).

Another log book is the Sensitive Parts Transfer Document book that holds all the sensitive parts transferred from the shop to the floor and back, transfers from the warehouse to the shop and back and what is currently in inventory.

Other log books include:
* Customer Notifications from all vendors
* Completed past projects
* Past memos

The Corkboard

The corkboard is where all the up-and-coming projects are stored. All the projects are dated, how many games for the project, the slot file for the games involved, and the type of project that is taking place. We then prep all of the meter sheets and out-of-order signs in advance and staple them to the project. On the day of the project, all the machine information is already printed on the sheet, saving us time on filling out the location, asset and serial numbers, along with the SMIB address, game type and theme. This is all done with our slot file.

Overview

Not being a front line casino employee, you do not get too much exposure in this department. There are many behind-the-scenes jobs that take place that always go unnoticed. Tracking all the sensitive parts takes time, counting and ordering inventory, game and equipment preventative maintenance, burned out lights, following the drop teams, service reports, manual jackpot reports, coin flow analysis reports, MIS room, cleaning reels and glass, BVs, and assembling office equipment just to name a few. A lot of this is done in the early morning hours when we are still closed or when the floor is slow.

This is all our routine we do most everyday including the basic floor repairs and, when scheduled, the moves, conversions, and upgrades. We receive no tips, most of the time no recognition, but work hard together as a group to accomplish all the above tasks.

- Kevin Noble
- Knoble@slot-techs.com

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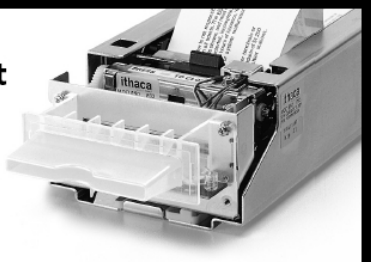

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Global's GI and GII Currency Validator

- Plus - "Condor - A Dying Breed"

By Hendrik Sidaway

Of the Bill Validators (BV) that I have had to work with here, there is only one that is not worth fixing to component level. That would be Global Payment Technology's (GPT) Generation 1 and Generation 2 (GI and GII) Currency Validator. It's not a case of it being too complex, but the cost involved in just sending the faulty boards to GPT for repairs is minimal.

The picture shows an International Back Stack (IBS) and is one of the many GPT GI and GII BV's. The ones we use are the IBS and International Down Stack (IDS).

We have a test station that one of our techs (Jako Visser) built using an old BV. It is pretty simple. Take a working spare BV and remove the following from the housing:

1. 18 Position Cable
2. Main PCB
3. Electronic Tray
4. CPU PCB
5. Stacker Harness
6. Micro PCB

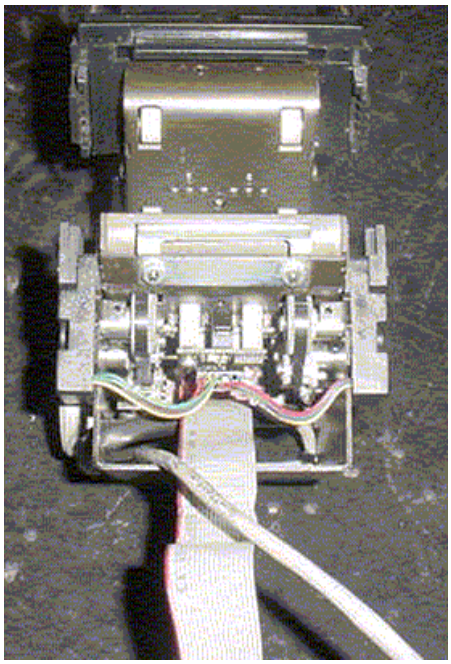
You should leave everything else inside and as with all things stripped, do not throw away any of the things you take out.

With the BV like this you can replace the CPU, Main and Micro PCB with great ease without having to take the entire BV apart. It is especially great for testing all those old boards nobody has used in about 2 months. The CPU PCB has a battery that discharges if not used and that can cause the CPU PCB having to be reprogrammed by GPT or worse, renders it useless.

What helps with this is to put the spare CPU PCB's into the test unit and let it run for about 4 to 5 hours a day. Keep doing this with all the spare CPU PCB's on an ongoing basis and the batteries should remain charged.

I haven't made any notes, a bad habit if not done properly, on any fault I have come across but have been lucky enough to have Techs (Jako again) that do. I have been able to remember 99 percent of the faults and solutions but still refer to his notes.

Most of the time when I have been called to a machine for bad acceptance, there are a few things that I check for first. These things would be the condition of the transport belts and the transport belt wheels. If these two things are not the cause I generally check the canister for any obstructions. Things like paperclips and folded notes.



If I am satisfied that the head itself is the cause I generally take it to the workshop for reprogramming and video levelling. In figure 1 you will find the most common problems we have encountered when trying to reprogram or test for acceptance.

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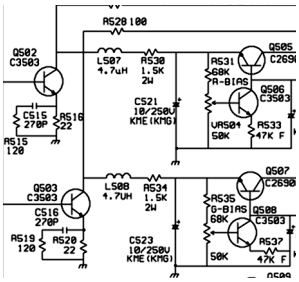
ELECTRONIC COMPONENTS

The individual components used in games are introduced. Parts such as resistors, capacitors, diodes, potentiometers and transistors are covered individually. Students learn how the components work and how to test them using the meter.

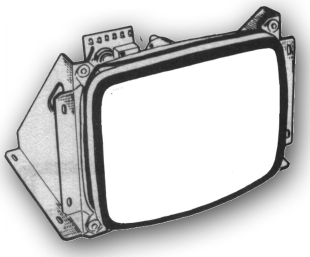
SCHEMATIC DIAGRAMS

Schematic diagrams are the "blueprints" for electronics. Learning to read schematics is easy once you know how the parts work!



POWER SUPPLIES

Power supply failure is a common complaint in many different types of systems.. Power supply failures are discussed during the class, along with shortcuts for troubleshooting and repairing them.



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BV reprograms, but doesn't sense the video levelling card.	Replace the Upper-Guide PCB.
BV reprograms, but immediately rejects the video levelling card.	Replace the Upper-Guide PCB.
BV reprograms, accept video level card, but shows "Bill Rejected Before Evaluation" error message when inserting a note.	Replace the Upper-Guide PCB.
BV reprograms, but transport motor stops after 3 or 4 clicks and Yellow and Super Blue optics **flicker** when video levelling.	Replace the Upper-Guide PCB.
BV reprograms, but transport motor stops after 3 or 4 clicks and Yellow and Super Blue optics **freeze** when video levelling.	Replace the Lower-Guide Main PCB
BV reprograms, is video levelled and connects to the RS 232 programming software. The Bezel Optical Display stays off even after changing the SRC option from active to passive mode.	Disable and then Enable the Inhibit Mode in the software. If the problem persists, replace the Micro PCB.
BV doesn't reset when Bezel opened and closed.	Replace the Micro PCB
BV doesn't connect to RS232 programming software.	Replace CPU PCB
BV reprograms, accepts video levelling but note canister doesn't cycle.	Replace CPU PCB
BV reprograms, is video levelled and connects to the RS 232 programming software. The bills keep being rejected while the BV in test mode.	Replace CPU PCB
While the BV is in the machine, the power LED doesn't flicker but stays on continuously.	Replace the Micro PCB and CPU PCB just for in case.
BV doesn't reset when Bezel opened and closed or if BV powered off and on.	Replace the Micro PCB.
BV reprograms, is video levelled and connects to the RS232 programming software. The Bezel Optical Display comes on only when Inhibit is Disabled and then Enabled again.	Save the BV settings with the SETUP button in the software.
BV reprograms, is video levelled and connects to the RS232 programming software. After the Stacker cycles the software displays "Unable To Eject Bill" error message and the BV continues to reject bills.	Replace the Upper-Guide PCB.
BV Transport motor is noisy and BV doesn't accept any notes.	Replace Micro PCB.

Figure 1 lists some of the most common problems encountered when trying to reprogram or test for acceptance.

Most of the Techs here have been trained using these guidelines and my machine down time due to BV problems have been kept to a minimal.

There are certain problems related to the stacker that I haven't mentioned at all. Sure I could go on and on but this I will keep for another time. If you feel adventurous, attempt the board repairs. As I have mentioned I haven't had the need to do so.

Condor, a Dying Breed

All of our machines use the Condor coin validator and unfortunately, the spares required to fix them are unobtainable. We have already been informed to start processing them out with the new and improved Condor Plus. Think of this as a last salute to the Condor. We will surely miss you.

I would like to share few interesting things that I have come across while working with Condors:

While moving some machines and changing the denomination on some others, we were busy reprogramming our Condors from R100 to 50c. Everything went smooth for once and it wasn't until we switched the machines on for Gaming Board testing that the problems started. I never learned a harder lesson in my life. All the Condors we stood and reprogrammed in about 2 hours wouldn't accept any coins.

The Condors belonged in the IGT S+ stepper machines we have. I didn't want to jump to conclusions so I immediately pulled one of the Condors to start faultfinding. Considering my options, it could have been one of many things. I reprogrammed it again and

BV has bad acceptance.	Check Transport Belts for wear and tear and replace if necessary.
Notes get stuck inside the BV when inserted into a machine.	Check the wheels at the back of the BV. They loose their tension and go out of position. Open the BV and bend the tension plates to increase the tension on the wheels.
BV doesn't want to accept even after reprogramming and testing okay on RS232 Programmer.	Open the Stacker to inspect the notes for bad positioning or a paperclip.

Figure 2 - Faults that are not necessarily caused by a faulty PCB.

thought that solved it. All the Condors accepted for about an hour and then the punters started playing.

One after the other, the Condors started bombing out again. It had to be a Condor fault. I was quite sure of this. I took one Condor and started again. I was obviously confused as I have done this millions of times and this has never happened. This is a technician's hell. Having a slots manager breathing down your neck, punters complaining at a 14-machine bank. Pressure I tell you.

We reprogrammed and compensated the Condor until we got the error message "Coin readings too large." We had received new 2 pence coins from the manufacturer for compensation and this was when I started comparing. They of course didn't have the same specs as the older coins. I was sure this was it. I reprogrammed again and compensated with the older 2 pence and voila! I was never happier.

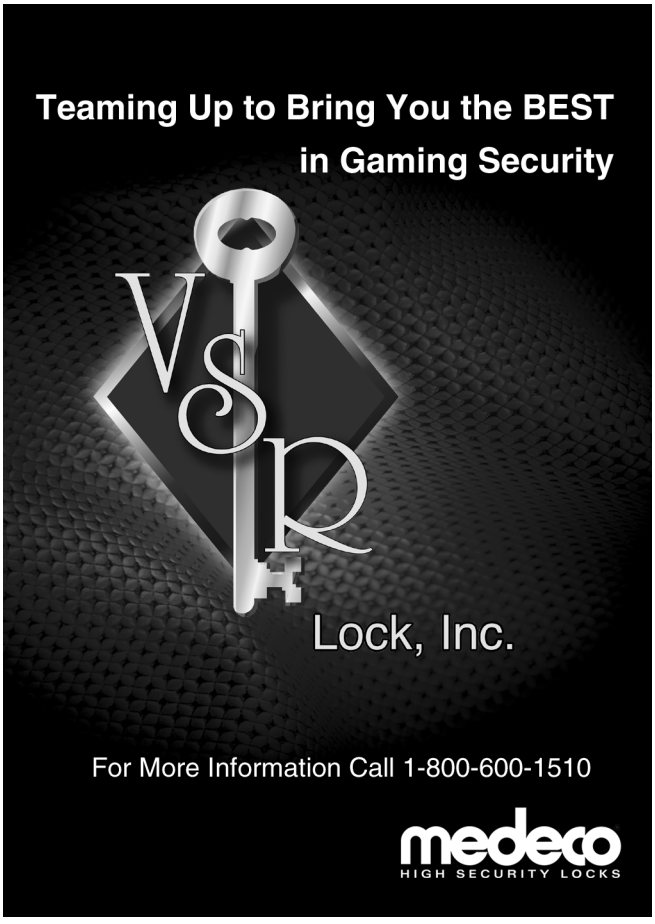
Other instances include a Condor not wanting to accept. When I plugged it into the programmer, the LED at the back was flashing red continuously. I used another Condor to get the machine up and running, allowing me to faultfind with ease. After some time (I can't remember what all I checked) I came across a loose connection on one of the optics. I just soldered the connection and yet again, I was in business.

This next error was quite mind-blowing. I sat with the problem for about 2 days. As always, I had replaced the Condor just to get the machine working. I was called to a machine that yet again had no acceptance. I took it to the workshop and reprogrammed the Condor. I did a coin acceptance test in the workshop and it was fine. The moment I put it back into the machine, it didn't want to accept. I tried compensating and yet nothing.

It wasn't until I replaced D4 that it worked. It is a GA 84, 85 or 86 diode. I know that depending on the Condor, these diodes differ. I just keep replacing them with one of the same type and it hasn't failed me yet.

- Hendrik Sidaway
hsidaway@slot-techs.com

Editor's Note: Hendrik is the Senior Slots Technician at the Emerald Casino in South Africa. Visit their website at: http://www.emeraldcasino.co.za



Bally S6000 Part 1

By Herschel Peeler

The S6000 family is one of the most popular reel games from Bally. The model number on the side of the game specifies which version you may have. If the model starts with "S63" followed by a string of letters and numbers, it is an S6300 series; or just "S6" makes it an S6000 series. By name, these are members of the "ProSlot" series machines, or "ProSlant" if it a slant top, along with the S5500 models. What defines it as an S6000 machine is the electronics package (MPU board and software). The cabinet may be an upright or slant top and still be an S6000. The top box that sits on the cabinet may take different shapes also. Features may be added for a given theme of the game built around the S6000 platform.

Game themes are not unique to a specific model. If you were to try to order a belly glass for a "Blazing Sevens" game by that description alone, the person at the other end of the phone would likely not know which one you were talking about. Trying to find it in the parts book by that description would be equally confusing. You would find perhaps a dozen pieces of glass fitting that description. Each for a different family line, cabinet style, width, or any number of other variations. Every piece of glass has a part number printed on it. Know what model your game is or order things by part number. You can't go wrong.

Operation of the game is the same for all games in the S6xxx family. Jumpers on the MPU board are mostly the same. Setting up options, bookkeeping and diagnostic are mostly the same. The only variations would be things added to the game like Progressive Displays or add-on features. Some of the options are set up by DIP switches and jumpers on the board. Others are set up in software through the Options mode. The tech manual covers these things quite well. With limited space I won't try to duplicate these things here. The manuals are not that hard to get hold of, are excellently written and quite complete.

The S6xxx family is a 16-bit machine running at about 20 MHz. This puts it on par with an IBM PC AT. That ancient 80286 based processor, three generations before the first Pentium. The processor used is a Motorola 68HC000, which probably puts it on the same level as the very first Apple Macintosh. This is not a state-of-the-art processor. It doesn't have to be. It doesn't take much processing power to play a reel game.

Many of the components used you would likely find in an early Macintosh. Most of the parts are off-the-shelf type components, available from a commercial vendor of (older) electronics components. Mostly the game is High Speed CMOS (74HCxx) devices and yes, everything on this board is sensitive to static electricity. Please handle it as such. I know you can get away without doing so sometimes but our customers come here to gamble, not us. The design of the electronics is very "straight up" with very few creative aspects. With any given microprocessor most of the circuit is a standard design. If you have learned one, the next

is easy. Worthy of note, there are a few components that would not be covered in a course on basic electronics and a few circuits worth talking about. Speaking of which, we have the following circuit descriptions:

Power Supply

The power supply assembly has an externally mounted transformer. There are at least three different transformers for different applications. In all cases, we have two secondary windings. A 21 VAC secondary is rectified and filtered for +24 VDC power to drive high power devices. AC Power Sense and AC Power Failure also use the 21 VAC line for their source. There is a 7.5 VAC secondary that is used to power player panel and various small lamps. Also inside the power supply assembly is a switching power supply module that generates +12 V, -12 V, and +5 V for the Logic circuits. AC power distribution is also provided for by the power supply assembly. The circuit breakers provide protection to the 7.5 VAC (CB1) and +24 V (CB2), CB3 and CB4 are AC Main line breakers. Logic circuits have their own fuse on the switching power supply module.

CPU Design Notes

The basic design of the CPU is much as you might expect to find built around any other 68000 style design. The CPU provides the usual Address and Data Bus as

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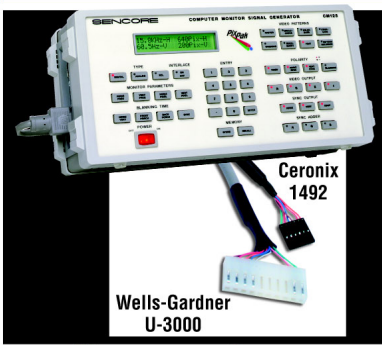

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well as Control lines. Address selection is pretty standard. One thing that may be worth noting when working with a 68000 style microprocessor is the concept of Data Transfer Acknowledge (DTACK). On synchronous bus designs, we send out Address, Data and Control lines. Along with these, we send out a Strobe line to synchronize all devices on the bus to the fact that a new machine cycle is in process. The length of each machine cycle is the same (no, not always). This is a synchronous bus design. The processor cannot run at a faster speed than the slowest device on the bus. Yes, that's a simplification. We will correct that statement later when we discuss the concept of a Wait State.

The 68000 is capable of operating with an asynchronous bus. Each bus transfer is not committed to any specific length of time associated by the strobe pulse we mentioned. When the 68000 enables the address and control lines it also sends out an Address Strobe. When a device decodes its address it sends back a signal called Transfer Acknowledge. The processor may then end that cycle at that time. This allows fast devices to respond quickly and slower devices to respond more slowly, each in their own time. Our bus cycle is not committed to be as slow as the slowest device. U62, in the lower right hand corner of page 1 handles DTACK functions.

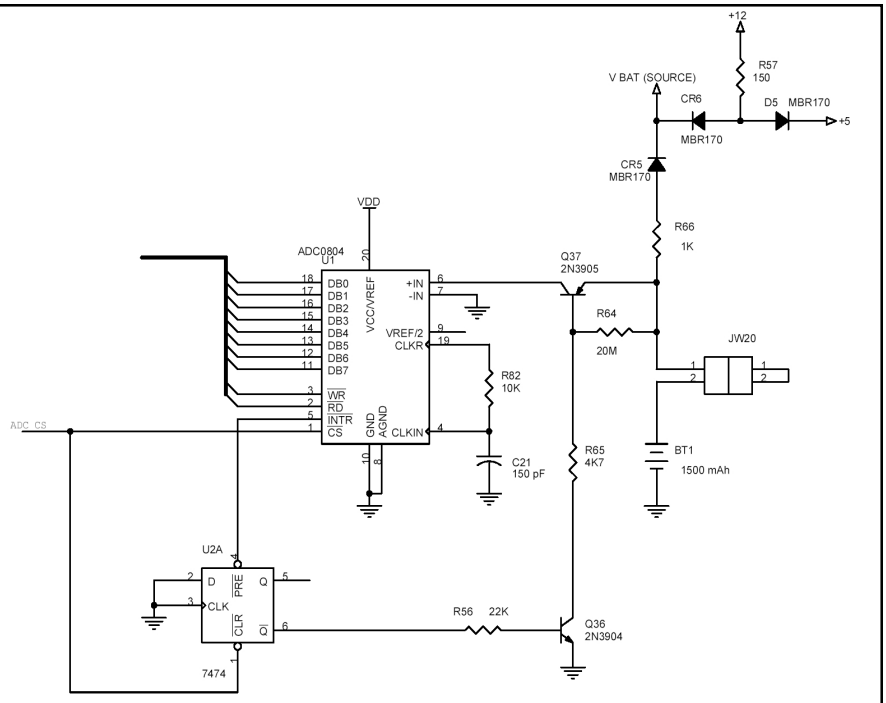

Figure 1. - The battery voltage may be read by the CPU by using the Analog to Digital Converter.

The equivalent of this in a synchronous bus design uses a Wait State. This delays the current operation the processor is doing by one more processor clock cycle or in increments of the processor clock pulse. This allows the synchronous bus to slow down for slower devices, but only in increments of the processor clock pulse.

The 68000 is capable of operating in either synchronous or asynchronous bus mode.

SafeRAM

SafeRAM is a procedure that sets the basic game parameters to default values. Since these are all just data stored in RAM, most data is safe at any given time. This does more than just clear memory. All options that are setup by software have a default value unless they are deliberately specified to be otherwise. This information is stored in the game as data in memory (RAM) with battery backed-up power. SafeRAM sets up this section of RAM to the default values. To be more specific, there are three levels of SafeRAM procedures we can do. A Partial SafeRAM clears most of the bookkeeping and error counters, but retains the options. This is the procedure you would use to clear an error condition you can't otherwise clear normally. A Complete SafeRAM resets software configured options also. This is the procedure you might use if you were converting the game to a new theme. A Complete SafeRAM clears all memory and puts the game back to a condition it had as it came from the factory. All history is erased of previous games and conditions. Normally this is only done when the game is first

put on the casino floor.

When doing a SafeRAM, the display should give the following message in the Win Paid window. Complete Clear should start out as “CH C” when started. “CL C” when finished, or “E C” for an error encountered during SafeRAM. For a Full SafeRAM you should get “CH F” and “CL F” or “E F”. For a Partial SafeRAM you should get “CH P” and “CL P” or “E P”.

Since this process uses very little of the MPUs resources, if you can not do a SafeRAM or get an error as a result you likely have a problem in the CPU chip, Address and Data Buffers, Address Selection, or Memory. Most of these chips are on sockets. Reseating the ICs may well resolve your problem. Of course, follow acceptable procedures with concerns for static electricity. The circuits at the bottom left of Page 2 on the MPU schematics control SafeRAM (U34 and U35).

Battery Voltage Monitor

Referring to the schematic diagram on page 16, with the ADC0804 in the center or page 1 of the Bally Schematics, the battery voltage may be read by the CPU by using the Analog to Digital Converter, hereafter referred to as the ADC, (U59, an ADC0804) on page 1 of the MPU board schematics. This operation starts with the 74HC74, U76A. When ADC_CS (Analog to Digital Converter Chip Select) happens U76A is cleared, the Q\ output goes high turning on Q36, which turns on Q37. Q37 turning on feeds the voltage at the battery to the input of the ADC. ADC_CS also triggered the ADC (U59) and started the analog to digital conversion process. At the end of this process U59 sends out an Interrupt (ADC_INT) sets U76A back again, which makes the Q\ output go low, turning off Q36 and Q37. Q36 and Q37 are only used to isolate the ADC from the battery so the battery is not drained by the ADC circuit when the ADC is not needed. Otherwise this is a classic example of the ADC0804 in use.

Next month: Part 2

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Virtual Reels? Physical Reels?

Just the real truth

By John Wilson

There tends to be a lot of confusion over reels - virtual reels, physical reels, reels of all types. Let's examine exactly how slot machine reels work and try to simplify the subject.

First of all, the reels with the strips that you put inside the machine are called the physical reels. You can physically touch them and hold them in your hands. As you're likely well aware, if you don't put them in correctly your machine will appear to play and pay strangely.

This is the first clue that all is not as it seems. The slot machine doesn't actually care if there are any reel strips in the game at all. It will play fine without them. Apart from some angry and confused players and a visit from your local gaming commission, you don't need the reels. They are there only for the amusement of the player and to let them confirm that they did get paid for three mixed bars and to show them just how close the jackpot was when the red 7 stopped just below the pay line. I'll call these physical reels the "Player Amusement Reels" as that is their primary purpose.

Figure 1 - Old mechanical reels needed 'notches' to stop the reels from spinning.

Let's take a closer look at these player amusement reel strips. You'll notice that they have 11 symbols. The blank space around each symbol is also considered a symbol to the machine. If we wrap the strip on the reel, we can count 11 symbols and 11 blank symbols for a total of 22.

Where did this standard of using 22 symbols per reel come from? Older mechanical slot machines had numerous symbols on the reels with blank spaces between. Some machines were developed with 22 symbols without blanks being a stopping place on the reel, and others used the blanks as part of the 22 symbols. This number of symbols became an informal standard and it was easier to make new machines using the old methods so that conversions could take place, and technology in place didn't have to be changed. Figure 2 shows an old mechanical reel slot machine with 21 symbols on it, 1 of which is a blank.

The so-called standard of 22 symbols per reel had two basic limitations. First of all, using mechanical stops, there was a limit to the number of stops that could accurately be used in the reels. If you had to have a physical notch in the reel, you had to make sure that the machine could latch into this notch and stop the reel where it was supposed. With a small number of symbols, you also had a limit to the total number of combinations possible in the game. Suppose that we have three reels with 22 stops per reel. Our machine has a total of 22 x 22 x 22 or 10,648 different combinations. That means that the total coins taken in is 10,648 (assuming 1 coin per game), so the total payments must be less than this if we are to make any money. You can't

have a 20,000-coin jackpot or else you find yourself in a losing proposition.

One solution is to add more symbols to the reels. This results in the reels getting larger in order to accommodate the increase of symbols and you reach a point where not only is the reel too large to fit inside the machine, but you need a lot of energy to spin the large reel. The only other option is to make the reel symbols smaller. Player's didn't go for this idea, however. They want the 7's to be big and the cherries to be large and red. The old reel shown in figure 1 is 2 1/16" wide, whereas the new one (shown in figure 2) is 3 5/16" wide.

Of course you could add more reels to the machine to make a larger number of combinations. This did happen but it adds further technological problems. With each reel you add, you increase the potential for mechanical problems as well as making it more difficult to program the various payout and combinations. For a while it might have seemed like the slot machines had reached their peek potential.

Inge Telnaes solved this problem when he submitted an idea to the U.S. patent office on February 24, 1982. The Telnaes patent, now owned by IGT, revolutionized the slot machine industry just as much as Charles Fey did when he invented the slot machine in the first place.

The Telnaes patent describes a means of using a 'virtual' reel with an almost unlimited number of symbols and stops on the reels. In order to overcome the problems we've just discussed, he proposed a method to convert this large virtual reel into the smaller physical reel inside the machine. It was a futuristic look at slot machines made possible by the emerging technology of the day.

What, then, is a 'virtual' reel? Quite simply, it's a reel that is simulated by the computer. It only exists in the memory of the computer inside the slot machine and can't be physically seen or touched. Each reel could have thousands of symbols and stops on it and still relate to the pioneer-day reel within the slot machine. With 3 reels having 1,000 stops per reel, we would have 1,000 x 1,000 x 1,000 or 1 billion possible combinations. This allows us to not only have a large jackpot payout but to have an incredible number of varying symbols and combinations.

Today, the player amusement reels move to represent the outcome of the virtual reels through the use of stepper motors under precise computer control. The stepper motors can move the reels in any direction and by specific rotations. Most stepper motors move 1.8 degrees each time an electrical pulse is sent to them, so we have a total of 360 / 1.8 = 200 positions that a reel can step

through. Due to the accurate positioning with a stepper motor, the reels can be made to spin forwards or backwards, nudge up or down to a symbol, and could be made to spin at varying speeds as well.

Since the requirement of having reel stops directly related to game payout combinations has been removed, and the stepper motors can position the reels with great accuracy, we have overcome the two problems identified earlier. This opens the door to almost unlimited possibilities when developing reel-spinning slot machines.

If the slot machine uses this imaginary reel inside to determine what symbols appear and with what probability, how then does the machine translate this into our player amusement reel? Let's examine this next.

By examining any PAR sheet for a slot machine you will see some form of a listing showing the symbols and the probability related to each symbol. Note that some symbols occur more than once and others only once. Let's examine a fictitious reel.

Taking a quick look at the reel in Figure 4, notice that the Double Bars appear 4 times and the Single Bars only appear once under "Physical Symbol." We would assume that the Double Bars have 4x the chance of coming up. This is where the player amusement reel is separated from the virtual reel.

Each symbol in the reel is assigned a value. This value tells us how many of each symbol there are. In this case, although the Single Bars appear only once, there are actually 6 of them. The Double Bars, although they appear 4 times, only have a value of 1 each, for a total of 4. The Single Bars, therefore, appear 6 times for each 4 times the Double Bars appear. The Single Bars have a (6/4) 1.5x greater chance of being picked than a Double Bar, even though they physically appear less frequently.

Let's take this one step further. Let's examine exactly how the machine gets from our virtual reel to the physical one.

Since there are 72 stops on our virtual reel, the slot machine must pick a number at random, between 1 and 72 inclusive. Let's suppose it picked 11. It then finds the 11th symbol in the list. This isn't the 11th physical symbol, but the 11th virtual symbol. As we move down our list, we find 5 blanks, then 1 Double Bar, for a total of 6. Next come 4 more blanks, bringing the total to 10. Add in 1 more to get to 11 and we're sitting at a Single Bar. Although there are six Single Bars, we only add up until we have reached our number. In this case, the 11th symbol in our list is a Single Bar. If we look down the 3rd column of our chart, we can easily find any value. Suppose we picked the random number 45. If we look down the column, the numbers 38, 39, 40, 41, 42, 43, 44, 45 and 46 all correspond to the blank just between the Double Bar and the Cherries. That is where the physical reel would stop.

As you can see, the virtual reel can be as large as we want. It only needs to have some means of looking up a reference to the physical reel. This is exactly what the slot machine does. The player amusement reel will only have 22 stops (symbols) on it. If the virtual reel has 32, 64, 128, or 5,000 stops on it, it just gets converted to the location on the physical reel.

Physical Symbol	# of Stops	Stop Positions
Blank	5	1-5
Double Bar	1	6
Blank	4	7-10
Single Bar	6	11-16
Blank	3	17-19
Triple Bar	1	20
Blank	3	21-23
Red 7	2	24-25
Blank	5	26-30
Double Bar	1	31
Blank	5	32-36
Double Bar	1	37
Blank	9	38-46
Cherries	3	47-49
Blank	4	50-53
Triple Bar	1	54
Blank	4	55-58
Double Diamond	2	59-60
Blank	4	61-64
Double Bar	1	65
Blank	6	66-71
Triple Bar	1	72
22 Symbols	**72 Stops**	**72 Stops**

Figure 4 - Our sample 'Virtual Reel'

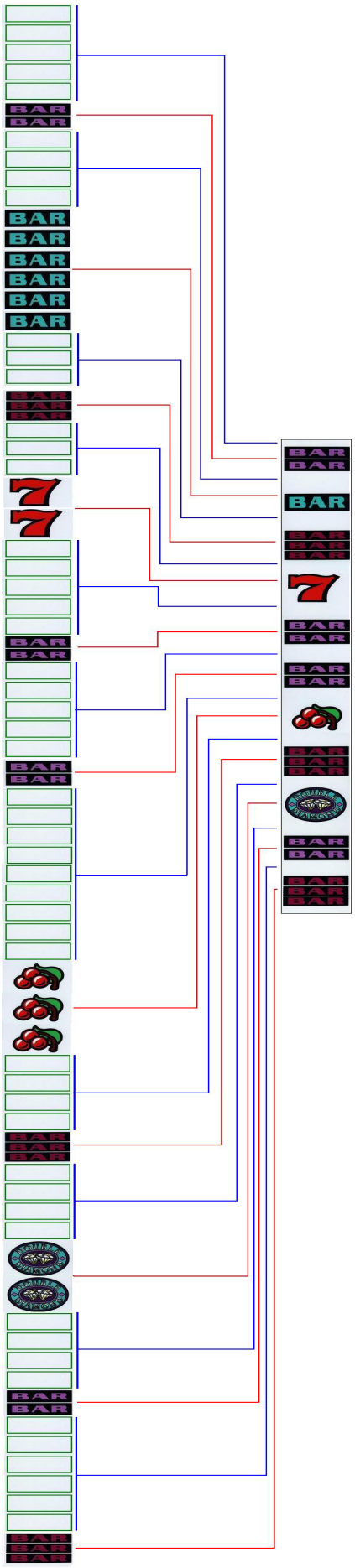

Figure 5 - Relationship between Virtual Reel (left) and Physical Reel (right)

Figure 5 shows a representation of what our sample virtual reel looks like. Blanks are shown by small rectangles for ease of recognition. The virtual reel then 'maps' onto the smaller player amusement reel, as shown in the illustration. In this example, the first five blanks correspond to the one blank before the first symbol on the actual reel. The one double bar corresponds to a double bar on the actual reel. The next four blanks map to a single blank on the actual reel, and so forth. As long as this 'map' is in place, which it is in all machines, the virtual reel can be as large as we wish.

From a player's perspective the physical reel strip certainly gives you the impression that you will have the bar symbols appearing quite frequently. Look at the virtual reel however, and it becomes overwhelmingly clear that you will have blanks showing up most of the time.

Another example of the differences between the virtual reel and the physical reel can be found by careful examination of the reel strips on an IGT Sizzling 7s machine. The '7' symbols (Red 7 or Sizzling 7) are almost always beside a bar symbol. With this design the 7's will be either on the pay line or slightly above or below it most of the time. While this gives them the illusion that the 7's have almost line up on the pay line, it's the virtual reel that tells the truth.

The only remaining step is for the slot machine to actually move the player amusement reel into position. Take a look at one of the reel hubs and you will notice a small plastic tab sticking out of the side. The tab passes through a small optical sensor (Figure 6). This allows the slot machine to know when the start of the reel is in position. By checking this sensor the computer knows the reel is aligned at the beginning and can then continue moving the reel the desired number of positions. For example, let's say that it wants to move to our Single Bar symbol, which is the 4th symbol on the physical player amusement reel strip.

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We know that there are 360 degrees in a circle, and that there are 22 symbols on our reel. Each symbol then takes up 360 / 22 or 16.36 degrees of the total circle. One important item must be mentioned here. On an actual slot machine, the size of the blanks is not always the same as the size of the symbols. In order to make our calculations as simple as possible, let's assume that the symbols and blanks are all the same size. Once we find the start of the reel (by checking the sensor as we spin the reel) we have to move 16.36 degrees to move to each symbol. The 4th symbol is 16.36 x 4 = 65.45 degrees away from the start of the reel. If the stepper motor moves 1.8 degrees per move, then 65.45 degrees divided by 1.8 degrees equals 36 steps of the motor to move the symbol into place. The numbers don't work out quite evenly (there is a small fraction remaining) because we have simplified things a little bit.

This reel strip had the blanks removed between the Triple and Double Bar symbols. They were replaced with a Single Bar symbol.

In reality, the process works the same with some minor changes to take into account where the center of the symbol is and the fact that blanks are not always as large as the visible symbols are.

To examine this from another angle, let's consider the reel indexing error (eg: 41 on an IGT = reel 1 error). As the computer spins the reel using the stepper motor, it knows that once it reaches the start of the reel, it should be back at the start of the reel after moving the motor 200 steps. If it's not, then something has gone awry with the motor, and it doesn't know for sure where the reel is. It could wait until it finds the sensor mark again, but the reel isn't spinning properly. If the machine stops the reel where it should, the symbol may not be lined up on the pay line or it might show a different symbol altogether. Should the machine arbitrarily stop the spinning reels to show the error, there is no way to predict what symbols will appear. Perhaps three Jackpot symbols will happen to land on the payline. To solve problems of players claiming the machine stopped with 3 jackpot symbols showing but not paying the jackpot, the machine will put the reels into a slow-spin and show the fault code. Then a technician can check the machine and perform some diagnostics to determine what is wrong with the reel.

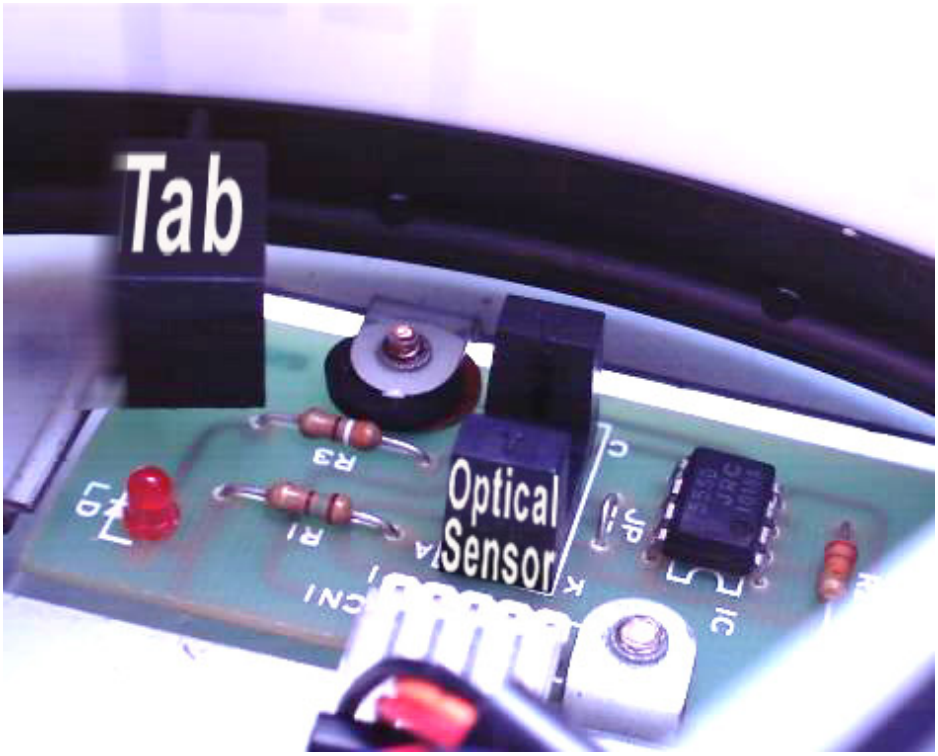

Figure 6 - 'Start of Reel' tab moving towards optical sensor

Hopefully this has cleared up the relationship between virtual reels and the physical (or player amusement) reels.

It's not hard to see that the virtual reel, which the slot machine uses, can vary quite differently from the physical reel.

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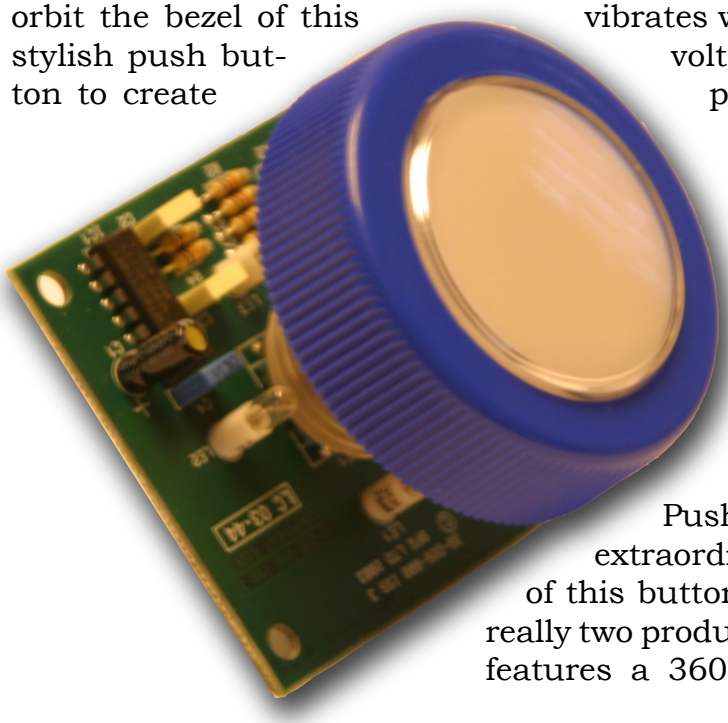
Gamesman Specialty Push Button Products

Gamesman Brand Products by Coin Mechanisms Inc.

Coin Mechanisms Inc. has announced the release of the Gamesman Brand of Specialty Push Button products. The Specialty Push Button line is comprised of the GPB 430 L.E.D. Disco Button, the Vibrating Push Button and the Rotary Push Button.

The GPB 430 L.E.D. Disco Button expands the possibilities of game design further by enabling special light effects to use as an attract mode or as an integral part of a bonus play round. Tri-colored Light Emitting Diodes orbit the bezel of this stylish push button to create a wonderful visual effect and interesting play opportunities.



Another groundbreaking product in the Gamesman Brand product line, the Vibrating Button adds a totally new dimension to push button technology. This novel addition to the range will add a shock to any application and yet remains discreetly hidden from the player to create a genuine surprise. Utilizing the same small vibration device used on cell phones, the Vibrating Button's lens cap buzzes and vibrates when a 2 to 4 volt power supply is activated on its power line.

Yet another new innovation in push button technology is the Rotary Push Button. The extraordinary design of this button is that it is really two products in one. It features a 360-degree, free rotating outer bezel (allowing it to perform the function of a joystick) and a central actuation push button. This dual function specialty button will add an entirely new dimension in player control to a game feature. It is available in a variety of either solid or translucent colors.

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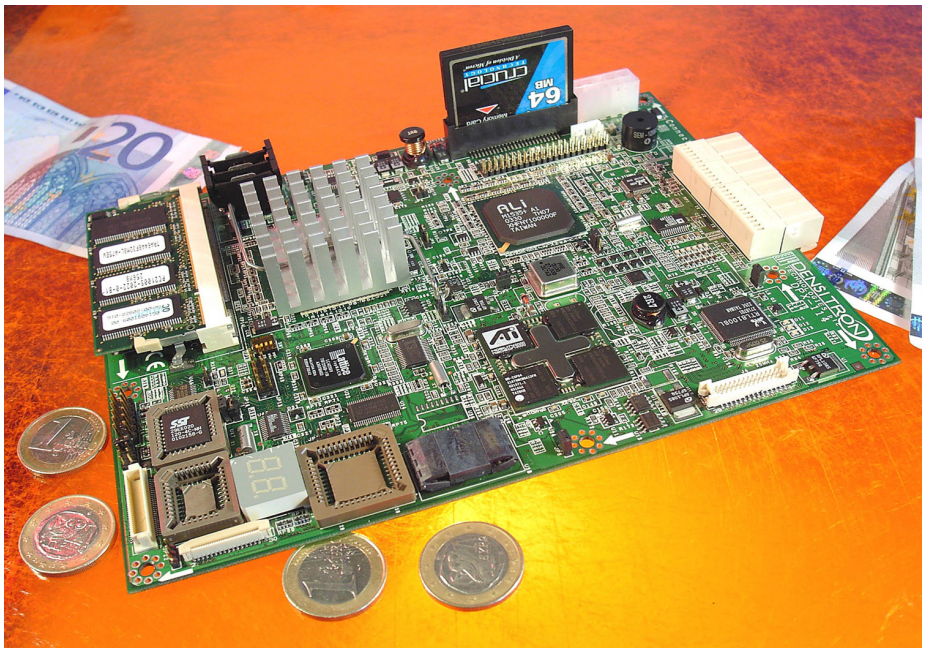
Densitron became the first company, with their DPX-80 gaming board, to bring PC-based computing in a reliable, industry tailored form to Las Vegas. Now the new ConnectBus(r)-II platform, draws on the company's 6 year's experience in the market combined with feedback from customers to deliver a complete hardware platform based on two new highly-integrated motherboards designed for the very specific needs of the gaming industry.



At the heart of the new platform is a choice of two new CPU boards, the DPX-114 and the DPX-115 which offer an unrivalled range of performance from the exceedingly low power consumption of the DPX-114 (which can run without a CPU fan) up to the very latest Intel Pentium 4 of the DPX-115. Graphics performance is also astounding, breaking new ground for embedded computing. Both the DPX-114 and the DPX-115 use the Mobility(r) Radeon(r) series graphics processors from ATI Technologies, a household name and recognized leader in graphics technology.

For the gaming OEM the new platform provides much more than a high performance embedded computer board. ConnectBus(r) II offers the same simple and accurate installation and serviceability that were key to the success and reliability of the original ConnectBus(r) products, but expands this to offer a complete solution covering all the input/output requirements, as well as security needs of a typical gaming device.
Several security features against software piracy are included to help ensure that a game will only run on specific hardware, and the hardware will only run valid game code.

The ConnectBus(r) II platform has been designed for a maximum product life to ensure that the gaming OEM is not subjected to the typical 6-month product lifecycle of standard PC motherboards and graphics cards. Densitron products have a typical lifespan of 3 to 5 years, giving the customer the confidence and stability they require from a hardware supplier.

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Computer-Based Communication and Training System

In most jurisdictions, casinos are 24-hour-a-day operations. They also often have large workforces with corporate offices and various properties in different states. Given the size of the workforce, the operating hours, and the different locations, the casino operator is presented with the challenge of effectively managing their employees. So when it comes to keeping up with their organization's training and communications needs, are there any products or systems out there that will smooth all of these wrinkles out?

Well, as it turns out, there is. It's called QTMS™ (Quality Training Management System. This is a software application that integrates a fully automated, user-friendly interface with communication and training tools designed by gaming industry experts. From the ground up, the QTMS™ has been designed for quick and easy use by any casino employee, whether they are a bartender, a slot technician, or the Vice President of Marketing. The interface is all web-based, so no special software is needed on any employee's computer.

The QTMS™ has many features to make it easy to communicate with any other person in the company, regardless of what shift they work or where they're working. For urgent memos, managers can track when communications were read and by whom, so it can be known that important information was disseminated properly. All of this can happen within seconds.

In addition to all of these abilities, the QTMS™ has other communications tools built in as well. There is an electronic logbook known as Q-Log that provides employees with the ability to add and read entries in their own departmental logbook. All of these entries are then archived in an easy-to-use repository for quick access by management.

For general communications, Q-mail allows anyone within the organization to send and receive messages to and from other employees, managers or entire departments without the need for an e-mail address. A related feature is Q-Discussion, which is a discussion board that allows threaded asynchronous communication between different employees or teams. There is an archiving system, called Q-Repository, which is where all of this data is archived for easy access by authorized personnel.

The QTMS™ even has the functionality to accept online job applications and customer satisfaction surveys, all customized to meet the casino operator's unique requirements.

In addition to all of the communications features, the QTMS™ also contains a robust, scalable and fully automated Learning Management System (LMS). This contains an extensive library of training courses designed especially for casinos by experts in the gaming industry. The courses that are currently available in the QTMS™ library fall into seven categories: Business Fundamentals, Business Skills, Computer Training, Customer Service, Employee Relations, Gaming Violation Prevention, and Industry Specific. There

are three additional categories that will be added to the library in 2004: Language (Spanish, English, and American Sign Language) Supervisory Certification for Casino Employees, and Customer Focus. Most courses take employees from eight to fifteen minutes to complete successfully, which includes taking a post-test. A feature called Q-Roster can automatically track all classroom training that is successfully completed (on-site or off-site) by casino employees. It is even possible to request a course or a number of courses be developed to cover specific subjects. Once developed, the courses will then be added to the library, in many cases at no cost to the operator. Any existing internal training materials (videos or web-based courses) can be integrated into the QTMS™ as well.

Though the QTMS™ has great communication and training features, the most important feature of the application is that it can be customized to meet any casino's unique requirements. This QTMS™ application allows for all internal forms to be integrated into the application and can be accessed from any desktop computer or training station. These forms can be job applications, Security Incident Reports, forms for the company 401k program, and even employee suggestions. The forms integrated into the QTMS™ may also be viewed in English or Spanish depending on the casino's requirements. Integrating internal forms into the QTMS™ will save the casino operator an enormous amount of money and time. Once an employee submits a form, it is automatically sent to the appropriate party within the organization while also being archived in the Q-Repository.

To give some better illustrations of how QTMS™ works, let's go over some example situations where it would be used:

The most important uses of QTMS™ are in cases where employees have to be given new information, such as an important gaming regulation change. A manager can assign a memo to be read by all of his or her employees, to the entire casino, or even to employees spread across multiple properties and shifts. Now, when employees read this message, they acknowledge that the message was read, thereby notifying the manager that the information was properly communicated. The same can be done with training courses the manager deems necessary for their employees' development. This is all automated and is accomplished within seconds, no matter the size of the organization.

Communication for planning major events at the casino is also well within the scope of QTMS™, because the QTMS™ makes it easy for employees on different shifts (and even different properties) to get any and all information needed to each other. So if your casino is planning, for example, a slot tournament, the Vice President of Marketing can asynchronously stay in touch with the managers and other employees that are pulling the event together via Q-Discussion. This makes it much easier for everyone to know what everyone else is doing so no effort gets duplicated and, even better, nothing important gets missed.

Really, the possibilities are endless. From effectively training casino employees or to communicating urgent information to planning out major events, the QTMS™ gives casino operators the power to take control of all of their internal communications and training.

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It's H.O.T. Understanding the Horizontal Output Transistor

It's one of the most commonly replaced semiconductors in monitors. I would probably not be going out too far on a limb to say that it is the most common semiconductor failure in monitors. From my personal experience, I know this to be true, anyway. At a recent slot tech training class at Table Mountain Casino we went through more than a dozen of them!

By way of review, let's take another quick peek at the horizontal deflection circuit. To be specific, let's concentrate on the horizontal output circuit since that's where the horizontal output transistor does its thing. In fact, in this case, we don't even need to consider the horizontal deflection coils in the deflection yoke or their associated collection of capacitors and inductors. Let's just look at the relationship between the B+ power supply, the flyback transformer and the horizontal output transistor itself.

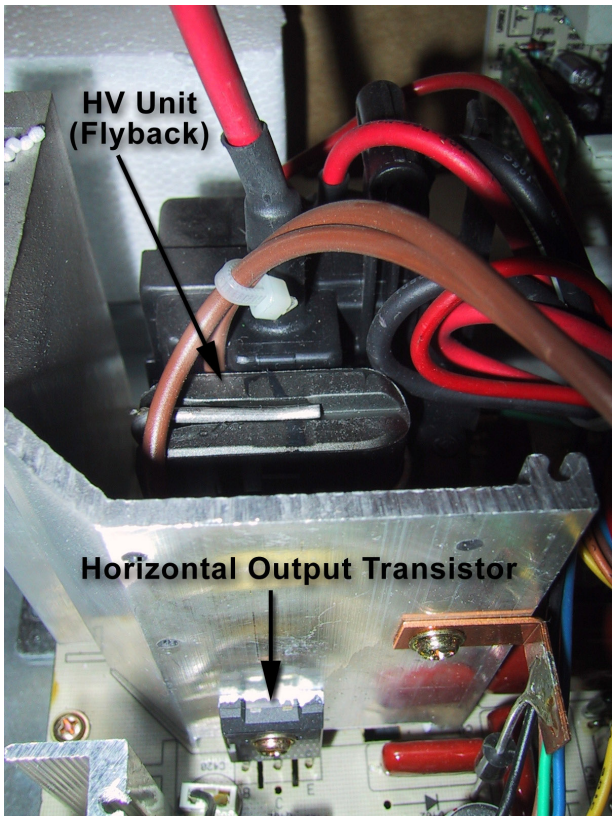
The switched-mode power supply (SMPS) creates the B+. This power supply will vary between manufacturers and models but is generally somewhere in the range of +77 VDC to +136 VDC.

The B+ is connected to one end of the primary winding of the flyback transformer. The other end on the flyback's primary winding is connected to the collector of the horizontal output transistor. It's easy to identify the horizontal output transistor in any monitor. It is always the largest transistor, closest to the flyback transformer. In a modern monitor, this is typically a TO-218 package, sometimes referred to as a TO-3P ("P" for "plastic") package as well.

The horizontal output transistor is always an NPN transistor. The emitter of the horizontal output transistor is always grounded. The horizontal output transistor is simply a "ground switch," a topic that we have covered previously here in Slot Tech Magazine.

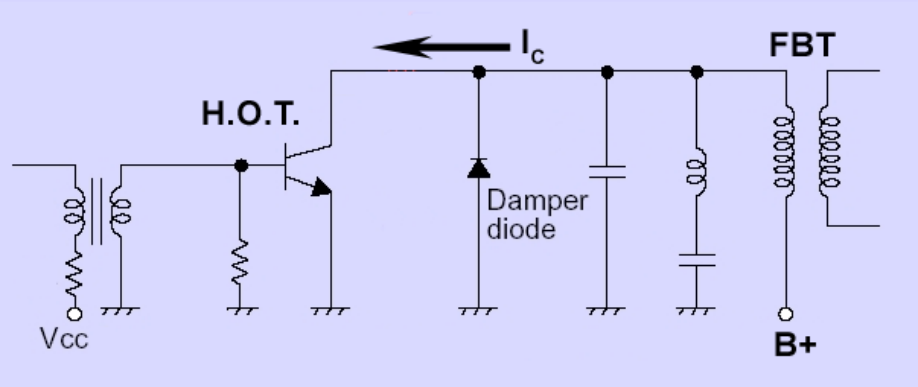
When the horizontal output transistor is turned on, the B+ current flows from the power supply, through the primary winding of the flyback transformer, through the horizontal output transistor (from collector to emitter) to ground. This builds up a nice big magnetic field in the flyback. When the transistor is turned off, the magnetic field surrounding the flyback transformer collapses. As the magnetic field expands and collapses, electric current is forced to flow through the secondary windings, creating all of the voltages that the flyback is supposed to create: the EHT, the focus voltage, the screen voltage and, in many cases, the CRT heater voltage as well. See the January 2002 issue of Slot Tech Magazine (available online at slot-tech.com) if you need to learn more about flyback derived power supplies.

The collector current flowing through the horizontal output transistor is the single highest current flow in the entire monitor. It's the James Brown of the monitor, the



It's easy to identify the horizontal output transistor in any monitor. It is always the largest transistor, closest to the flyback transformer.

hardest-working transistor in show business. When the horizontal output transistor fails, it almost always goes in a big way. Not with a shower of sparks, flame and smoke but with a dead short between the collector and the emitter. Not too surprising of course, since that's where all the current is flowing. It doesn't look bad when it fails. It's just shorted.



When the horizontal output transistor is turned on, the B+ current flows from the power supply, through the primary winding of the flyback transformer, through the horizontal output transistor (from collector to emitter) to ground.

So, What's Up With All the Different Part Numbers?

If all horizontal output transistors in all monitors are all more-or-less the same shape and size and they're all connected the same way and all performing the same function and all doing the same thing, why is it that there are so many different part numbers for the darned things? Every time you look at a new make or model of monitor, there's a different part number for the horizontal output transistor.

Well, first of all, there are hundreds, thousands of transistors that can be interchanged with one another and will function properly. In a way, it's kind of like the battery in your car. It doesn't matter what brand of battery you use but Delco and Diehard batteries will have different part numbers, regardless of the fact that their specifications might be identical or nearly so.

Consider too the fact that, although your vehicle might call for a battery that can provide 400 amps, if you replace it with a 450 amp battery, you're cool, right? You may never use the extra 50 amp capacity but it's not hurting anything either. As long as the size of the battery (the "package") is the same, it fits and it works.

	V_{CBO} = 1500 V			V_{CBO} = 1700 V			V_{CBO} = 2000 V		
Package	TO-3P(H)IS		TO-3P(LH)	TO-3P(H)IS		TO-3P(LH)	TO-3P(H)IS		TO-3P(LH)
Pc max	40 to 75 W		180 to 220 W	40 to 75 W		180 to 220 W	40 to 75W		180 to 220 W
** $I_{C(sat)}$	Built-in damper	Not built-in damper	Not built-in damper	Built-in damper	Not built-in damper	Not built-in damper	Built-in damper	Not built-in damper	Not built-in damper
3 A	2SD2599			2SD2550					
3.5 A	2SD2586								
4 A	2SD2499	2SD2498		2SD2551					
4.5 A	S2055N	S2000N							
5 A	2SD2539 2SC5339								
5.5 A				2SD2638					
6 A	2SC5280 2SD2559	2SC5386 2SD2500		2SC5716 2SD2553					
7 A		2SC5404							
8 A	* S3H58	2SC5387 2SC5855					* S3H60		
11 A		2SC5411 2SC5856	2SC5421			2SC5422		* 2SC5997	
12 A				* S3G18	2SC5588	2SC5590			2SC5748
14 A		2SC5587 * S3G90	2SC5589			2SC5446			
15 A			2SC5445						
17 A		2SC5717	2SC5695		2SC5857	2SC5858			2SC5612
18 A						2SC5859			
22 A						2SC5570			

It's kind of the same way with horizontal output transistors. It's really just a matter of specifications and, in the case of horizontal output transistors, there are four or five that you need to consider when selecting a replacement device.

Specifications

I_c - Collector Current This is the maximum current (measured in amperes) that can be controlled by the transistor. Naturally, large transistors can handle more current that small transistors, just as thick wire can handle more current than thin wire. The largest size transistor we commonly use in games is the TO-218 package.

V_{CEO} or BV_{CEO} - Collector-to-Emitter Voltage This is the maximum voltage that the transistor can handle as measured between the collector and the emitter when the base lead is open (not connected.) This is when the transistor is completely turned off and must block the current from flowing between the collector and emitter of the transistor.

V_{CBO} or BV_{CBO}- Collector-to-Base Voltage This is the maximum voltage that the transistor can handle as measured between the collector and the base when the emitter lead is open. This is a measurement of the "strength" of the collector-to-base junction when it is reverse-biased. That is to say, it's an indication of how much voltage the transistor can withstand when the collector is at a very high positive voltage with respect to the base.

h_{FE} - Current Gain or "Beta" This is an indication of the transistor's ability to amplify an incoming signal. The higher the gain, the less current it takes to drive the transistor. For example, a transistor with a gain factor of 100 will require just 1/100 amp of base current for 1 amp of collector current.

We can lump most transistors into three general categories. Low gain transistors have a gain of up to 250. Medium gain transistors have a gain of 250-750. High gain transistors are those with a gain factor of more than 750. Admittedly, these figures are somewhat arbitrary. All horizontal output transistors are low gain transistors.

Substituting horizontal output transistors is a lot like substituting diodes. You can make the substitution as long as the replacement transistor is the same polarity (NPN or PNP) and has the same or higher voltage rating and current rating. However, you should try to match the gain rating of the transistor as best you can. Substitute only low gain transistors for low gain transistors, mediums for mediums and highs for highs. This is not actually too difficult. As long as you're in the ballpark you should be okay.

But there is another, very important consideration when selecting a replacement horizontal output transistor and that is the frequency response or "speed" of the transistor. This parameter is also known as the "switching time" of the transistor.

As monitor and computer technology has progressed, the horizontal frequency of monitors has increased markedly. Take a look at the chart below and you can see the dramatic increase in horizontal frequency.

Resolution	H(kHz)
640 x 400	31.47
640 x 480	31.47
640 x 480	37.50
640 x 480	43.28
800 x 600	35.13
800 x 600	46.87
800 x 600	53.68
1024 x 768	48.34
1024 x 768	60.00
1024 x 768	68.68
1280 x 1024	63.96
1280 x 1024	79.96
1280 x 1024	91.12
1600 x 1200	75.00
1600 x 1200	87.50

For around forty years, we have been looking at standard, NTSC monitors. That's a 525 line, interlaced raster picture, with 480 visible lines on the screen. At a leisurely 63 microseconds per horizontal line (including the horizontal retrace time) we're looking at a horizontal frequency of just 15,734 Hz. Because NTSC is so slow, the interlaced raster scheme requires us to lay down two alternating fields of just 240 lines each.

NTSC is okay for watching a low-resolution television program but if we want to display slick-looking computer graphics (and we do want to display slick-looking computer graphics) we're going

to need more lines and the way to accomplish that is to speed up the horizontal deflection circuit. If we double the horizontal frequency, we can put twice as many lines on the screen in the same amount of time. We can dump that crappy, interlaced scan and go for a 480 line, progressive-scan picture that we now refer to as "VGA" resolution or 640 X 480. The numbers refer to a picture that is 640 pixels wide by 480 lines tall, corresponding to the 4:3 aspect ratio of the CRT itself. The horizontal frequency is now doubled to 31,468 Hz or approximately 31.47 kHz.

Naturally, this means that the horizontal output tran-

① 2SC Series

Part Number	Maximum Ratings			** pack -age	*** Di	h_{FE}			$V_{CE(sat)}$ Max(V)			Switching Time (Typ.)				Gene-ration
	V_{CBO} (V)	I_C (A)	P_C (W)			Min (–)	Max (–)	@5 V / I_C (A)		@$I_{C(sat)}$ (A)	@ I_B (A)	t_{stg} (us)	t_f (us)	@ f_H (kHz)	@ I_{CP} (A)	
2SC5280	1500	8	50	H	✔	4	8.5	6	5	6	1.5	4	0.2	31.5	6	4th
2SC5339	1500	7	50	H	✔	4	8	5	5	5	1.25	4	0.2	31.5	5	4th
2SC5386	1500	8	50	H		4.3	7.5	6	3	6	1.5	2.5	0.15	64	5	4th
2SC5387	1500	10	50	H		4.3	7.8	8	3	8	2	2.5	0.15	64	6	4th
2SC5404	1500	9	50	H		4	8	7	3	7	1.75	2.5	0.15	64	5.5	4th
2SC5411	1500	14	60	H		4	8	11	3	11	2.75	2.5	0.15	64	8.5	4th
2SC5421	1500	15	180	LH		4	8	11	3	11	2.75	2.5	0.15	64	8.5	4th
2SC5422	1700	15	200	LH		4.5	8.5	11	3	11	2.75	2.5	0.15	64	8	4th
2SC5445	1500	20	200	LH		4.5	8.5	15	3	15	3.75	2	0.1	100	8	4th
2SC5446	1700	18	200	LH		4	8	14	3	14	3.5	2.1	0.1	100	7	4th
2SC5570	1700	28	220	LH		4.5	7.5	22	3	22	5.5	1.4	0.1	130	8	4th
2SC5587	1500	17	75	H		5	8	14	3	14	3.5	1.8	0.1	100	7.5	4th
2SC5588	1700	15	75	H		4.8	8	12	3	12	3	1.8	0.1	100	6.5	4th
2SC5589	1500	18	200	LH		5	8	14	3	14	3.5	1.8	0.1	100	7.5	4th
2SC5590	1700	16	200	LH		4.8	8	12	3	12	3	1.8	0.1	100	6.5	4th
2SC5612	2000	22	220	LH		4.8	9	17	3	17	4.25	4	0.15	32	8	4th
2SC5695	1500	22	200	LH		4.5	8.5	17	3	17	3.75	1.6	0.1	100	8	*5th*
2SC5716	1700	8	55	H	✔	3.8	9	6	5	6	1.5	3.5	0.2	32	5.5	4th
2SC5717	1500	21	75	H		4.5	8.5	17	3	17	3.75	1.6	0.1	100	8	*5th*
2SC5748	2000	16	210	LH		4.8	7.5	12	3	12	3	4	0.15	32	8	*5th*
2SC5855	1500	10	50	H		4.3	6.7	8	3	8	2	2.3	0.1	80	5.5	*5th*
2SC5856	1500	14	55	H		4.5	7.8	11	3	11	2.75	1.8	0.1	100	6.5	*5th*
2SC5857	1700	21	75	H		5	7.5	17	1.5	17	4.25	3.5	0.1	45	8	*5th*
2SC5858	1700	22	200	LH		5	7.5	17	1.5	17	4.25	3.5	0.1	45	8	*5th*
2SC5859	1700	23	210	LH		4.5	8	18	3	18	4.5	1.8	0.1	100	7.5	*5th*
* S3G18	1700	(16)	75	H	✔	(4)	(8)	(12)	(3)	(12)	(3)	(3.5)	(0.1)	(45)	(8)	*5th*
*2SC5997	2000	(14)	75	H		(5)	(7.2)	(11)	(1.5)	(11)	(2.75)	(5)	(0.12)	(32)	(6)	*5th*
* S3G90	1500	(18)	60	H		(5)	(8)	(14)	(3)	(14)	(3.5)	(1.8)	(0.1)	(100)	(7.5)	*5th*
* S3H58	1500	(10)	50	H	✔	(4.5)	(7.5)	(8)	(3)	(8)	(2)	(3.5)	(0.2)	(45)	(6)	*5th*
* S3H60	2000	(10)	60	H	✔	(4.5)	(7.5)	(8)	(3)	(8)	(2)	(3.5)	(0.2)	(45)	(6)	*5th*

② 2SD Series

Part Number	Maximum Ratings			** pack -age	Built-in damper diode : ✔	h_{FE}			$V_{CE(sat)}$ Max(V)			Switching Time (Typ.)				Gene-ration
	V_{CBO} (V)	I_C (A)	P_C (W)			Min (–)	Max (–)	@5 V / I_C (A)		@$I_{C(sat)}$ (A)	@ I_B (A)	t_{stg} (us)	t_f (us)	@ f_H (kHz)	@ I_{CP} (A)	
2SD2498	1500	6	50	H		5	9	4	5	4	0.8	7	0.4	15.75	4	3rd
2SD2499	1500	6	50	H	✔	5	9	4	5	4	0.8	7.5	0.3	15.75	4	3rd
2SD2500	1500	10	50	H		4	8	6	3	6	1.5	8	0.35	15.75	6	3rd
2SD2539	1500	7	50	H	✔	5	9	5	5	5	1	6	0.3	15.75	5	3rd
2SD2550	1700	4	50	H	✔	8	22	1	8	3	0.8	7.5	0.3	15.75	3	3rd
2SD2551	1700	5	50	H	✔	5	10	4	5	4	0.8	7.5	0.5	15.75	4	3rd
2SD2553	1700	8	50	H	✔	5	9	6	5	6	1.2	9	0.3	15.75	6	3rd
2SD2559	1500	8	50	H	✔	5	9	6	5	6	1.2	6	0.4	15.75	6	4th
2SD2586	1500	5	50	H	✔	4.4	8.5	3.5	5	3.5	0.8	7.5	0.3	15.75	3.5	4th
2SD2599	1500	3.5	40	H	✔	8	25	0.5	8	3	0.8	7.5	0.5	15.75	3	4th
2SD2638	1700	7	50	H	✔	4.5	7.5	5.5	5	5.5	1.2	7	0.4	15.75	5.5	4th

sistor will have to switch on and off twice as fast. If the horizontal output transistor is not able to change state fast enough, the entire horizontal output circuit will become terribly inefficient. The transistor will generate huge amounts of heat and fail after just a few minutes, hours or days of operation.

It's really a heart-breaker as well because you locate the bad horizontal output transistor and replace it in just 10-15 minutes, you fire-up the monitor and it works great! You get all excited that you've fixed the monitor and you're looking forward to savoring your triumph with a cup of coffee and a smoke when . . . Pfffft! The monitor goes dead and you hear the tell-tale sign of a bad horizontal output transistor - the SMPS begins its subtle ticking or chirping sound - and you know that that cup of Joe is just gonna have to wait.

Other resolutions require even higher horizontal frequencies. In some monitors (we don't use them in gaming . . . yet!) the horizontal frequency approaches 100 kHz.

The point is that when you're obtaining a replacement component, you need to pay attention not only to the three specifications mentioned previously (voltage, current and gain) but to the frequency response of the

JIS Part Numbers

2SA - PNP transistor for High Frequency Application
2SB - PNP transistor for Low Frequency Application
2SC - NPN transistor for High Frequency Application
2SD - NPN transistor for Low Frequency Application
2SK - N Channel Field Effect Transistor

●Video Display Monitor Horizontal-Deflection-Output Transistors (VCBO = 1500 V series)

Intended Uses for Horizontal-Deflection-Output Transistors Screen size <Icp> & maximum horizontal frequency <fH(max)>													Package / Recommended Alternative Product (for reference)				Maximum Ratings	
15 inch ICP = 4.5 A: ● ▲ ICP = 5.0 A: ○ △		17 inch ICP = 5.5 A: ● ICP = 6.0 A: ○		19 inch ICP = 6.5 A: ● ICP = 7.0 A: ○			21 inch ICP = 7.5 A: ● ICP = 8.0 A: ○						TO-3P(H)IS		TO-3P(LH)		IC	PC
fH@(max)													Damper diode		Damper diode		(A)	(W)
54 kHz	69 kHz	69 kHz	82 kHz	96 kHz	82 kHz	96 kHz	107 kHz	120 kHz	96 kHz	107 kHz	120 kHz	135 kHz	Built-in	Not Built-in	Built-in	Not Built-in		
▲													2SC5339				7	50
	○													2SC5386			8	50
▲													2SC5280				8	50
	○	●												2SC5404			9	50
	○	○	●											*2SC5855*			10	50
	○	○	●											2SC5387			10	50
				○	○	●								2SC5411			14	60
				○	○	●	●							*2SC5856*			14	55
				○	○	○	●	●	●							2SC5421	15	180
								○	○	●				2SC5587			17	75
							○	○	●	●				* *S3G90*			18	60
																2SC5589	18	200
											○	●				2SC5445	20	200
										○	●			*2SC5717*			21	75
											○	●				*2SC5695*	22	200

●Video Display Monitor Horizontal-Deflection-Output Transistors (VCBO = 1700 V series)

△													2SC5716				8	50
				○	○	●								2SC5588			15	75
				○	○	○	●									2SC5590	16	200
							○	●								2SC5446	18	200
							○	●						*2SC5857*			21	75
								○	●							*2SC5858*	22	200
									○	●						*2SC5859*	23	210
											○	○				2SC5570	28	220

transistor as well. Here is where a little bit of knowledge about the JIS part numbering system can help you out.

JIS

JIS stands for "Japan Industrial Standard" and it's a standard part numbering scheme for semiconductors used worldwide. It's really pretty clever because unlike the American system (called "JEDEC" for Joint Electron Device Engineering Council) a JIS part number actually tells you something about the specifications of the device.

As it is in the JEDEC system, the first number indicates the number of PN junctions in the device. Diodes, for example, have only a single PN junction. A typical JEDEC part number is something like 1N4004. A typical JIS diode might be something like 1S1234.

Transistors have two PN junctions, so their part numbers begin with "2." But here is where the standards split. JIS follows with the letter "S" while JEDEC uses "N" but what's neat is that JIS part numbers are then split into four groups: A, B, C and D. As and Bs are PNP transistors while Cs and Ds are NPN so, unlike JEDEC part numbers that don't tell you anything at all about the component's specifications, you can tell from the part number whether it's an NPN or a PNP transistor. Since the horizontal output transistor is always an NPN transistor, its part number will be 2SC or 2SD.

Not only can you tell its polarity, you can also tell if it's a low frequency part or a high frequency part. As and Cs are high frequency transistors while Bs and Ds are low frequency transistors.

Armed with this bit of knowledge, I can make some informed decisions about substitutions when it comes to horizontal output transistors. First of all, I can completely forget about any transistor that's 2SA or 2SB. They're PNP. I can also forget about replacing any 2SC with a 2SD. If the design engineer felt that it was important to install a 2SC then I'm not going to second-guess him.

Generally speaking, you can use a 2SC to replace a 2SD. A high-speed transistor can switch be used to switch at a slower speed without problems, just not the other way around.

But Wait . . . There's More

Before you go charging off to order a slew of horizontal output transistors, there are a couple of other things to look at. Actually, you can't really look at them at all because they're inside the transistor package. Your horizontal output transistor might include a built-in diode called the "damper diode." All horizontal output transistors in all monitors require a damper diode. In some cases, the damper diode is a separate component but in many cases, the damper diode is built-in to the transistor. The damper diode is critical. Without it, the horizontal output transistor will last about 15 seconds before shorting. If the transistor that came out has a built-in damper diode, the replacement component must have one as well.

Many horizontal output transistors also will contain an internal resistor, connected between the base and the emitter. A typical value for this resistor is 40-50 ohms. Like the diode, this resistor serves as a damper. Generally speaking, damping is not necessary in this circuit, as the output impedance of the secondary winding of the horizontal drive transistor is very low (it's just a handful of turns of wire). If the distance between the horizontal drive transformer and the horizontal output transistor is sufficiently great, some ringing can occur. If so, the resistor will damp the ringing. If you didn't understand all that, don't sweat it. If the original transistor had an internal resistor, I suppose the replacement should as well. I can't say that I've experimented in this regard.

This internal resistor is the reason that many horizontal output transistors do not test properly, even when they're perfectly good and tested out of circuit. They often seem to have a short between base and emitter due to the low value of this resistor. When testing the horizontal output transistor, don't bother with the base-to-emitter junction. When the horizontal output transistor is bad, it will almost always have an emitter-to-collector short circuit.

Of course, it's nice to be able to consult a data sheet whenever possible. Toshiba makes a great selection of horizontal output transistors. A selection guide (with specifications) is included in this article.

I suppose that one of the points to realize here is that you do not have to order different replacement horizontal output transistors for each of the different makes and models of monitors you have in the casino. Look around the shop and see what you already have. Maybe it will work. Generally speaking, there's no risk in trying what you have on hand (you're already replacing a shorted transistor, remember?) but you can greatly increase your chances of finding a proper replacement if you follow these simple guidelines.

Naturally, if you can obtain an exact replacement you should do so. Most cities have at least one electronic component retailer who carries a series of universal replacement components that can be used as substitutes. The most popular is the NTE line of replacement components. NTE publishes an extensive cross-reference catalog that will allow you to make substitutions as quickly as locating a word in the dictionary. You simply look up the original part number of the component you want to replace and the index will tell you which substitute to use. These "Master Replacement Guides" are usually available from your local electronics retailer. If you can't find one, you can solve your semiconductor replacement woes easily with just a few mouse-clicks and keystrokes at www.nteinc.com.

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Day One

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How Monitors Work - Part 1
Theory of Operation - Beginning level

1:15pm - 3:15pm
Mars Electronics, Inc. - BV troubleshooting and repair

3:30pm - 5:30pm
FutureLogic Printers - Printer troubleshooting and repair

Day Two

9:00 am - 12:00pm
How Monitors Work - Part 2
Narrow Down the Problem - Intermediate Level

1:15pm - 3:15pm
Asahi Seiko - Hopper troubleshooting and repair

3:30pm - 5:30pm
Coin Mechanisms, Inc. - Coin Comparitor technology and repair

Day Three

9:00 am - 12:00pm
How Monitors Work - Part 3
Circuit Analysis and Component Level Troubleshooting - Advanced Level

1:15pm - 3:15pm
Money Controls - Coin validator and coin hopper maintenance and repair.

3:30pm - 5:30pm
JCM - Bill Validator Troubleshooting and Repair

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Slot Tech Magazine is strictly technical. As such, the magazine's contents are not time critical. The repair information and technical data contained in past issues is just as valid today as it was the day it was published.

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Randy Fromm's
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