

December, 2001

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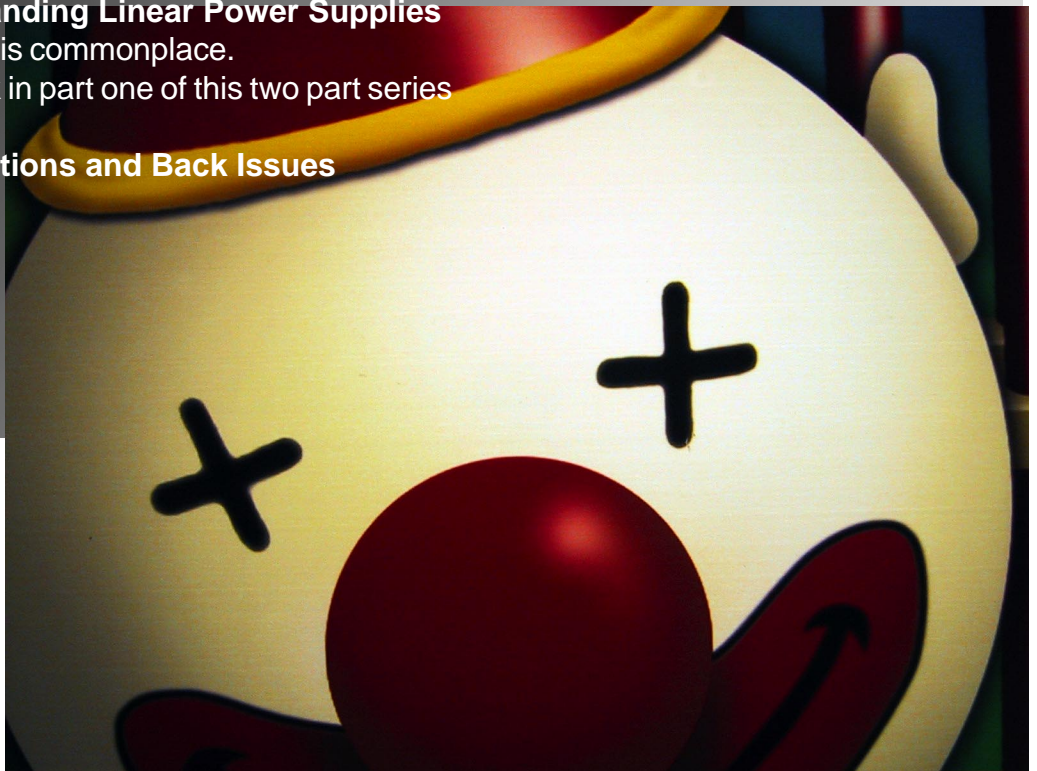
Power supply failure is commonplace.

Learn how they work in part one of this two part series

Page 36 - Subscriptions and Back Issues

Order form

IGT showed State Fair at the Global Gaming Expo. The game's artwork graces this month's cover.



If this month's Slot Tech Magazine had a title, it would be War and Peace, not for any relevance to the War on Terrorism but for the length of some of this month's articles. Two of them had to be split into two parts each and they're STILL long. But that means detail and in my book, that's good. Anyone can spout vague nonsense about slot repair. The devil is in the details so when you look at the table of contents and see fewer articles, you know why.

Happy Holidays to all and best wishes for a prosperous and happy new year

Randy Fromm's Slot Tech Magazine

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Dear Randy,

I was hired three months ago as a Slot Tech at the Spirit Mountain Casino in Mohave Valley, Arizona, a small Tribal casino.

I've learned a lot in a short time and I want to learn more. I'm a retired air traffic controller and I have a strong background in mechanics, administration, and writing skills. My weakness is electronics (Re: the article by Frank Sutter in the November issue). I took a yearlong course in radio shop in high school in the early 1960's. A lot has changed since then.

Thank you for sending me two issues of your Slot Tech Magazine. While I'm not totally familiar with all the terms yet, they were very informative and interesting. I particularly liked the articles about Common Machine Problems, Solutions and Repairs by Kevin Noble and Slot Tech Electronics 101. (I really needed the refresher)

Performance and Politics also caught my eye. I have no desire to enter that arena, having been an air traffic control supervisor and manager for over ten years.

I was impressed by the contents of Slot Tech Magazine and the limited amount of superfluous advertising. Your articles were informative, direct and to the point.

I am enrolled in your seminar in Las Vegas on Jan 9-11, 2002 and I look forward to meeting you and your Tech Writers.

The Slot Tech field seems to offer a fantastic opportunity for new people that want a respectable career (I am one) and a good stable job.

See you next Year.
May God bless America,

George Feick



Hi, George,

Thank you for your nice comments about Slot Tech Magazine. I am glad the articles have been helpful to you. I'd like to point out to you that the advertisements in Slot Tech Magazine are far from superfluous. Trade journal advertisements in this or any other trade journal serve to inform readers of new products and services as they become available. How else are you going to find out about this stuff?

On the practical side, subscriptions alone cannot cover the expenses of administration, production, printing and distribution of a monthly periodical such as Slot Tech Magazine. Through their continued support, our advertisers assure that we can continue to provide technical training and support to the industry's slot machine technicians.

I look forward to meeting you at Tech-Fest II in January. Your badge and other material has been sent to you.

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

Randy Fromm

Randy Fromm
December, 2001

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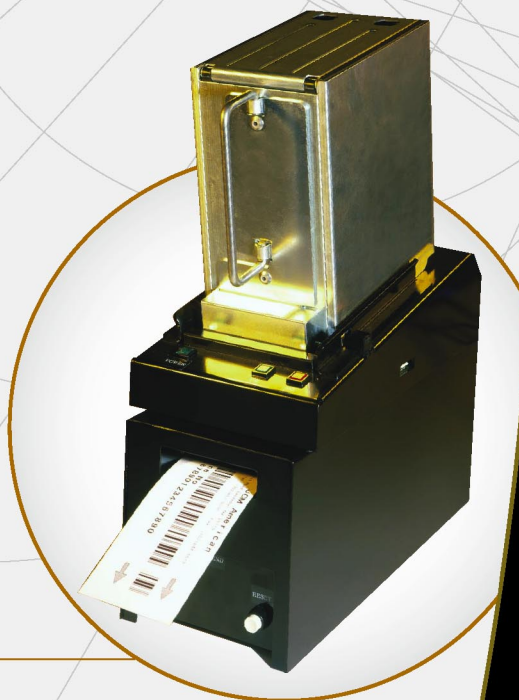


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PROBLEM—No door closure signal on IGT slant top poker

SOLUTION—Faulty power supply

Last month I was involved in a slot machine move that involved relocating ten IGT players edge plus slant top poker games. Of course there isn't a whole lot to this move. You disconnect the power and the player tracking harness and transport the slot machine to its new home. Next you reconnect the power and player tracking and the machine is ready to be refilled and coin tested. Apparently I left out a step according to a few of our games non-conforming behavior.

Once the games had been moved the whole five feet, two had a door open that would not clear. Of course I went straight for the door optics. I could not use diagnostics due to the fact that the Central Processing Unit, CPU, was locked in a CMOS failure. My dog ate my in-

frared tester leaving me no choice but to replace the optics without verifying their operation. Oh wow, the no brainer didn't fix the problem. I opened the award glass door to check the bill validator cherry switch and it was also good.

I decided to take the CPU to the tester in the shop and see what would happen. The game recognized the door closure and I was able to clear the CMOS error. The game played properly and eliminated the CPU as the problem. On my way out of the shop, I grabbed the digital multimeter and a spare motherboard just in case.

Once I arrived at the game I began to take continuity checks with my meter from the optics to the motherboard. I also checked the wiring from the bill validator cherry switch. They were all fault free. In the back of my mind thoughts of the motherboard being faulty were causing me to develop the shakes. I didn't particularly want to remove and replace it. I have developed a phobia of removing motherboards all because of those Williams slant tops. I need counseling but that is another article titled "Handle Mechanisms, Monitors, and Motherboards Sent Me To The Nut House".

I then took a very deep breath and unlocked and removed the CPU. I detached the seven connectors from the motherboard and removed the three screws and turned it this way and that way until it finally broke free. That wasn't so bad. Once removed, I studied the motherboard carefully looking for a burned trace or some sign of hope that I wasn't barking up the wrong tree. Everything looked to be fine and since looks can be deceiving, I opted to replace the motherboard with the new one. After a few uncomfortable minutes of twisting and squirming in the dried strawberry daiquiri that someone so graciously spilled on the floor of the game, the motherboard was installed.

I gathered my composure and asked forgiveness for a few adjectives that I had tossed about during the course of my troubleshooting. It went something like this, "If this works, I promise I won't say \$#@% again." I powered up the game closed the door and voila, the door still read open.

This seemed like a good point to open up a working slant top beside my game and look back and forth intelligently at the two hoping that the problem would appear to me

in neon lights. Once I got the feeling that people were on to me, I grabbed the meter and set it to voltage. I checked the voltage to the door optics and noticed a slight difference between the good game and the bad game. On the good game I read between 7.5 and 8 volts dc. While on the bad game I got a reading of approximately 5-5.5 volts dc.

Was this enough to cause the door to stay open? I decided to change the power supply. Luckily we had taken several poker slant tops to storage when we were moving everything around. So I closed all the games and made the journey to our temporary storage facility and began removing a power supply. Having never removed an IGT poker slant top power supply, I blindly began discon-

necting harnesses and removing screws. I removed a few screws and harnesses that weren't necessary. However, it wasn't too difficult but I was surprised to find that the motherboard is attached to the power supply housing. All in all it required removing about six nuts and screws including one ground wire and approximately ten harnesses.

I returned to the floor with my replacement power supply and a renewed feeling of confidence. I removed the power supply from the faulty game and now knowing what I was doing, accomplished the task in half the time. I installed the new power supply and once again paused for a moment of reflection after leaving behind some forearm hair in the strawberry daiquiri that now

closely resembled flypaper.

The moment of truth had arrived. Would the slot tech prevail or would he once again miserably crumble at the hands of an outdated slot machine. I wiped the sweat from my brow, flipped the switch and the monitor read, "now power up self-testing" for what seemed like an eternity. "Come on, I'm ready to see if this works." Finally it was time for me to close the door and I did so and the machine again entered into a CMOS error. This time however, the game received the door closure signal and I was able to clear the tilt with my reset key. The heavens opened and the slot gods sang. Actually, I opened the shop door and my slot tech manager sang.

- Bart Holden

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Author's Note: *On Monday night a technician on my shift had emergency brain surgery and is currently in a coma here in a Windsor hospital. I would like to dedicate this article to him. His name is Toufic but we all call him "T." We are holding a fundraiser for him. If you can help, please contact knoble@slot-techs.com. I hope you can help. Thanks greatly. -Kevin*

I have had great opportunities in my short career in training new technicians coming into our department. Starting the new techs off with policies and procedures, then into some sound advice such as documenting everything in the M.E.A.L. (machine entry authorization log) book so it's easier for the next technician to solve, always protecting your rear, and a slot machine is a slot machine, is a slot machine. What I mean by the last statement is that once you get to know how one manufacturer's machine works, the others usually fall into place: reel tests, hopper tests, limits, and so on.

This is the basic principle I use to train new technicians coming into the department. I find this the easiest way. Show them the basics, and then show them the differences between the other manufacturers. This is where the Mikohn Casino Link comes into play. I have worked with CDS, SDS, and then introduced into Mikohn's Casino Link. I applied the other two systems and the third just came naturally.

I remember the first time we had a major problem on the floor where the SMIB (Slot Machine Interface Board)

went off line on a number of games in a bank. I started the troubleshooting as if I was using the CDS system. I unplugged half the bank to see if the front half came up, then halved that until I came to the homerun and the four machines on a single splitter board. After unplugging the four machines and the bank, I started to plug in one game at a time to see if the game started communicating again or if the game brought the line down. When the game brought the line down, we checked the communication chip. It was so hot it burned the tips of your fingers.

We continued this process until we had completed the whole bank. We found that 18 out of 24 games had blown the communication chip. I have told the technicians on my shift that you should now be able to apply the same strategy towards the SDS and CDS systems.

The Mikohn System is being used all over Ontario, Canada. There are currently many sites throughout Ontario joined to a central site. Because this system is being so widely used here in Ontario and the United States, I would like to expand on this system from a technical point of view and discuss some of the parts, set-ups, error codes, test cards, LED's and all the other stuff that goes along with the system so you can see other

systems used in today's ever-growing and expanding field. So sit back, relax and imagine how the saying "a slot machine, is a slot machine, is a slot machine" could apply to the different accounting systems used in today's market.

The Parts

SMIB

(slot machine interface board)

The SMIB is usually mounted in the Award glass of the slot machines. The SMIB communicates with DCU (data collection unit), which is located somewhere off the gaming floor. The SMIB also communicates with the games information such as meters, door opens, game tilts, power downs and ups and all the other information that the game creates.

The SMIB also displays such codes as "S" codes that are SMIB errors, "M" codes that are the last machine errors, door open/close, and actual coin in, out, and drop to allow the technician to see if the meters increment when testing each meter respectively on the display.

There is a communication line that connects from the SMIB to the splitter board. This allows for the communication to the system via the SMIB to DCU, DCU to IOC, and then the IOC to the central system. The SMIB board has the capabilities to disable the machine

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from the central site where it is located. The setting of a dipswitch does this. (See dipswitch settings)

The Machine Harness

The machine harness links the SMIB and the game together. Each manufacturer has a different harness that plugs into the game's motherboard and sends information to the SMIB. Meter mismatch information often can be linked to this harness, especially when it becomes nicked, damaged, or has a loose connection. The slot door, cash box and drop door are part of this harness that connects to cherry switches on the machine.

Switches (fill, slot, drop, and cashbox)

These switches are used to monitor the cashbox, fill door, slot door, and the drop door, for entry to the games (especially when the machine is powered off) for any illegal entry except for employees who have access to the machines. This is done through the employee's type 99 cards.

PTM (player tracking module)

In simpler terms, this is the card reader. The PTM plugs into the SMIB, to the display and the keypad.

IOC

An input/output controller does all the handing of the communications to and from the DCUs and from the central location. The IOCs poll each DCU in order to collect, store, and transmit data to the file server. All data collected from the floor is received from the DCUs. The DCUs send and receive data from the individual slot machines on the

floor. The DCUs poll each slot machine on an individual address. If the slot machine has any activity to report, it responds with a packet of information which the DCU will then hold in storage until the IOC polls that DCU for that packet of information for processing.

DCU (data collection unit)

The DCU transfers data to and from the IOC. The DCU can control 4 lines coming from the floor, with up to 31 games on each line. The DCUs are mounted on racks in a separate room with the IOC off the gaming floor. Each line that is connected into the DCU has its own transmit and receive LEDs that blink when data is being transmitted and received. The DCU itself has one set of transmit and receive LEDs, which communicate with IOC. Also, there is one red LED that represents the "heartbeat" of the entire DCU. This also blinks when the DCU is powered up.

Splitter Board

The splitter board uses 6 positions for the bank in, or homerun coming on to the floor (#1), four communication lines (#2 to #5), and the bank out (#6). This can be mounted anywhere in the base where it will not be damaged by bags of coins or drop buckets. The splitter boards are usually daisy chained together depending on how many games are in each bank.

DID (Dallas id)

A unique, hexadecimal ID address that will be assigned to each game. The DID is never the same for any game and can only be used once. The DID connects to the SMIB board and will be displayed

first when the 99 card is first inserted. The DID number also will be displayed when the game loses communication with the SMIB or DCU. This ID number must be entered into the system before the SMIB board will communicate with the DCU.

Cabinet or Rack

The cabinet contains the IOC and a file server. The rack usually houses the DCUs as well.

Introduction

99 Card

(usually the employee card)
The 99-employee card allows the employee access into the machine without triggering an alarm to the surveillance room when the slot door, fill door, cashbox, or drop door is opened or closed. When the 99 card is inserted into the PTM, the display will cycle through different values starting with the DID number (in hexadecimal format) along with the DCU address that was assigned to that unit. The following information follows: the game type setting that is used set by the SMIB's dip switches, the coin in, out and drop, the SMIB version EPROM, the ROM version, the PTM version, and then the bill log meters starting from 03 that represents \$5.00 to 07 which represents \$100.00. Here in Canada we no longer have the \$1.00 or \$2.00 bill.

98 (Technicians Test card)

When the 98-test card is inserted into the PTM, the display will show a single screen that represents the state of the doors, "M" error code, "S" error code, and three 0's that represent the coin in, out, and drop movement. The "1" rep-

resents the coin in, "2" represents coin out, and "3" represents the coin drop. Each single digit will increment up to 9, and increments when a single coin is inserted, dropped, or paid out. The meter will not increment the number of coins, but changes state to show the technician that the meters are working. The "M" represents the last machine error reported, the "S" represents the last SMIB error reported, from left to right slot door, drop door and cash box door. The "0" means the door is closed and "0" would change state to "1" to tell us the door is open. To check for communication, the "S" would turn into a "B1" that tells us the game is communicating and "B0" telling us the game has lost communications with the machine. Another thing to think about when using this card is the fact that it does not allow entry into the machine without sounding an alarm, and that setting dip switch 8 to the on position and resetting the SMIB (unplug the power and reconnect), allows you to conduct the test sequences with the doors, and coin tests without the 98 card inserted.

SMIB BOARD LEDs

1. Power indicator – red – steady when the SMIB has power
2. Transmit – green- lit during transmission
3. Heartbeat – red – blinks off/on while SMIB software is running
4. Receive – green – lit during receiving
5. DCU transmit not – green – off when the SMIB is transmitting messages to the DCU

6. DCU transmit – green – lit during transmission
7. DCU receive – red – lit during receiving

SMIB Board DIP Switch Settings

DIP #1 to #4

-Assigns what kind of communication protocol used for a system or game type setting

- Example- IGT SAS 2 and 3 on, no game type- 1, 2, 3, set to off,

DIP #5

- Is used for ROM SIG verification

-On tells the SMIB not to disable the game

-Off allows the game to be disabled from a central site.

DIP #6

-This allows you to enable the diagnostic ports; it must be set to the on position

DIP #8

- Allows to get into the door, coin meters, and error codes to be displayed.

The IOC Processes

The IOC is essentially a computer that runs a certain set of processes in order to transmit and receive information from various slot machines via a SMIB board and DCU. The IOC must at least run the first three processes:

Pipe man

It creates pipes to communicate with other processes. It also routes messages to and from various processes.

Mconfig

This maintains the address configuration and machine property information for machines specified on the IOC. It is also responsible for the

DCU time requests.

Syscomm

It is used to control communications between the DCUs and the IOC. When it receives a message from the PIPE MANAGER, it sends it to the proper DCU, and when it receives a message from the DCU, it sends the message to the PIPE MANAGER.

Player Tracking

It receives messages from the SMIBs when a player inserts or removes their card.

Alarms

It handles alarm messages that are received within the system. These consist of door, DCU, and SMIB errors.

FillJack

It routes hopper empty and jackpot messages from the floor to the screens in the cage.

Points Sch

This communicates with the Player Tracking process to adjust the point bonusing formula.

IOC Power Fail Procedure

Problem: When a whole DCU goes down, the red "receive" light on the DCU will not flicker at the high rate of speed. You can notice the difference when watching any other DCU lights. The bottom lone red lights are for the IOC transmit and receive. The light is noticeably slower. The DCU will constantly show "POLL OFF" and whatever is on that DCU on the floor will show the large hexadecimal number from the DID. When this happens, a power fail is needed to bring each channel

on the DCU back on line one at a time. The procedure for this process is as follows:

- Unplug all channels on the DCU.
- Click on each process and close the file by clicking the "X" in the top right hand corner. Continue this sequence until all processes are completed or closed.
- Press control + alt + delete
- Click on log off, the system will start to log off the network.
- Press control + alt + delete to log back on
- Type in the username and password
- Click on the icon "IOC POWER FAIL" and the processes will come back on line.
- At this time you can plug in one channel and watch the status of the channel. The channel's receive red light should be flickering as fast as the others.
- After watching the status of the channel, the status will read on the DCU x, 0,0. The "X" representing the number of games on that channel. The next "0" represents "0" are down, and the next "0" represents "0" are missing. If all games are present on the channel, continue on to the next channel by plugging that in.
- After all channels and DCUs are running, the next step is to close all the processes down again quickly, and click back on the IOC CASINOLINK.
- This actually brings all

the processes back on line and gets the system running again to full capacity.

- This process can take from one-half up to an hour to complete depending on the play on the floor and the data being received by the DCU and the IOC.
- Remember, every person and/or site has their own way or procedure to do this. Please check into your own policies and procedures.

DCU Ram Clear

This process is used as a last result if the DCU is taking too much time to come on line. This process clears all the data that is stored in the DCU, which slows the dumping of the packet of information to the IOC. The meters are not lost, only the player points for that time the DCU is down. In conjunction with the IOC POWER FAIL procedure, proceed to do the following:

- Power down the DCU
- Remove all channels from the DCU
- Unplug the battery back at J2
- At J2 short the battery connection with a small screwdriver by touching both pins
- C9, C10, C11, and C12 also must be shorted with a screwdriver
- The battery connector can be placed back on to J2
- The power switch can be turned back on.
- Begin to plug one channel in at a time in the above process, making sure each channel's

status is up and running before plugging in the next.

Terminology

SMIB- receives data from the game, processes it, and sends it to the DCU.

DCU (Data Collection Unit)- sends and receives data from each game on the floor to the IOC.

SYSCOMM PROCESS- controls communication between the DCU and IOC, also sends messages to the correct DCU.

MCONFIG PROCESS- houses the addresses and machine properties

MCONFIG PROCESS (CAGE)- controls all the fill and jackpot requests

PROGRESSIVE LINK PROCESS- controls the contribution percentage for the coin in and the games.

PLAYER TRACKING PROCESS- player's services, player cards, ECT.

ALARMS PROCESS- all machine entries, jackpots, lost communications, power fails

CASINOLINK DATA BASE (ON SERVER) – records data used for process, displays, reports for accounting, and player tracking.

In part 2, we'll look at troubleshooting and provide you with a list of real world symptoms and solutions.

-Kevin Noble
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Suicide in the SENet

By Ken Locke



As your hawk-like gaze scans the gaming floor searching for failures, a feeling of confidence settles into you. This is your domain, your jungle. You rule as a benevolent dictator. Surely, there is nothing you can't handle.

There, ahead in the distance, near the showroom you spot

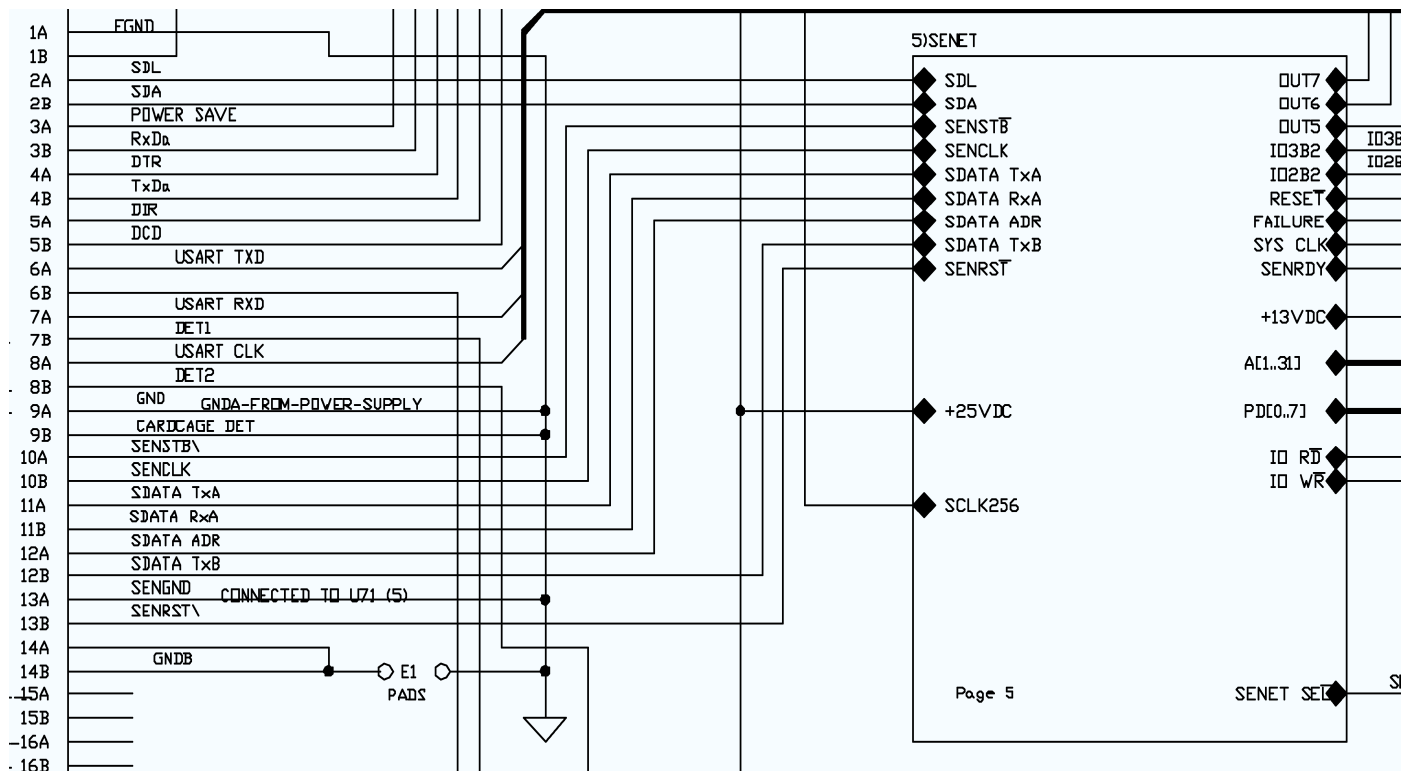
a flashing candle. Instinctively, you spring into action to quell the chaos. When you arrive, the S2000's vacuum fluorescent display reads "coin-in sequence error." A sardonic grin blazes upon your face. You know what to do.

You deftly open the main door and inspect the coin-in assembly for obstructions. Finding none, you reseal the door I/O card. "That should do the trick. Goddamn, I am good." You close the door waiting for the tilt to clear so you can return to your throne of technical power.

Nothing. "Oh yes, of course, it must be the other I/O card. Yet another bumbling floor

attendant has loosened it. There, that should definitely do it." You close the door once again, and.... Nothing. No reset, no reel spins, no lights.

"Ok, no problem" you think to yourself. "I read Slot Tech Magazine. I can fix this." Last month's STM said knowing your self-test diagnostics is the key. You start with Door I/Os and head straight to the coin in. You attempt to toggle the optics with a coin. Nothing. Then you test coin-out, then switches and lights. Still nothing. Your confidence is slipping and now a small crowd gathers. The pressure is on. What do you do?



Okay, I have beat this colorful scenario to death, so what's the answer, already? It's simple. Simple peripherals to be precise. To know what that means, it's time to head back to the shop and dig out the dust-covered schematics and find out. It's time to explore the secrets of the SENet.

For this conundrum, we'll need the IGT publication Electronic Diagrams & Parts, Vision Slot Upright, p/n 821-296-01. If you don't have a hard copy, you can get it online through www.igtproducts.com.

Taking a good hard look at our problem slot, we see that we have lost coin-in, coin out, switches, incandescent lights and the handle solenoid. The problem is widespread and most likely has a common denominator. Logic dictates we go directly to where it all begins, in the main processor.

Find the processor board schematic and identify U721, the SENet chip. Get your reading glasses out for this, the print is miniscule.

So there it is. This integrated circuit controls all the simple peripherals in and out of the processor. The question is, which ones and how? First, it is important to examine the definition of an Input and an Output.

In the simplest terms, an input is any signal that goes
Slot Tech Magazine

into the processor. Similarly, an output is a signal that is sent out of the processor. Now that we know that, we can surmise that the list of "gozintas and gozoutas" is pretty lengthy. It must take a fairly sophisticated system to handle all of them. That's where the SENet comes in.

The Synchronous Expansion

Network (SENet) is a serial communications channel for simple I/O devices; Simple inputs that report an "on" or "off" or 1 or 0 and outputs that produce an "on" or "off" or 1 or 0. They're just dumb animals, simple switches that are either in a high or low state. Examples of complex peripherals would be the bill validator, touchscreen

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controller and VFD. These are microprocessors in and of themselves and communicate with the processor on a much higher level, but that's another article.

The SENet can handle 256 inputs and 256 outputs. It works in direct conjunction with the I/O cards. Each of these cards handles sixteen individual peripherals and we can plug up to 16 I/O cards into the SENet or $16 \times 16 = 256$. This covers the "expansion" part of this chip. How about the "synchronous" part?

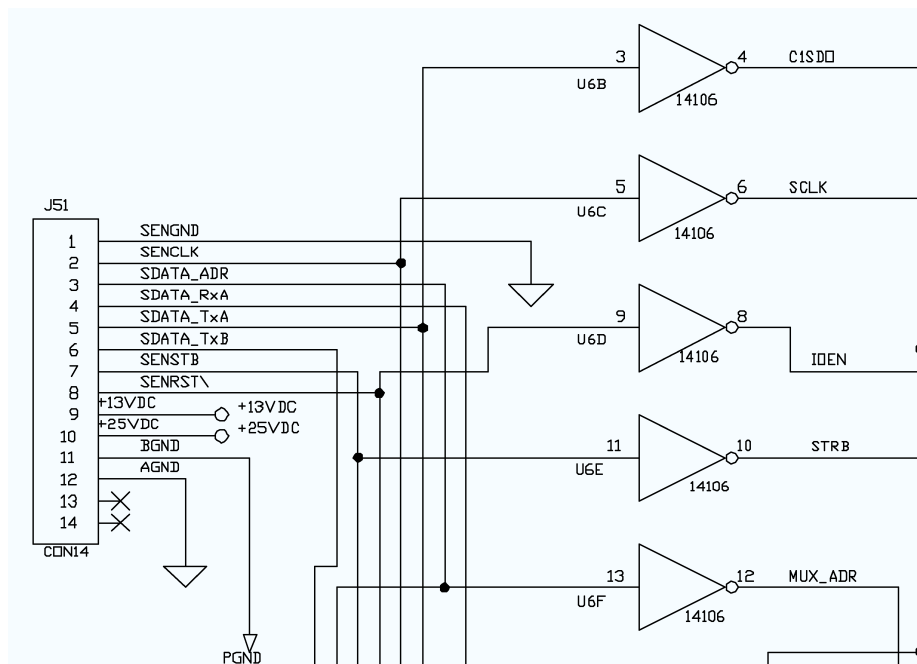


Figure 2. Lower Cabinet I/O board

Let's go back to the schematic and so on until all 16



Outputs, tick. Inputs, tock.

matic. In the upper left, we see a series of signals. Put the tip of your pencil on the one identified as "SENCLK". This is the SENet clock. A typical clock signal in any system has one primary job. It keeps time. It is the drummer in the Simple Peripheral Band.

The SENet works by addressing each individual board in sequential order. It sends signals to the first I/O card, handling the first output, then the first input associated with that board, then second output, then second

inputs and outputs have checked in. It continues to the next board dealing with its inputs and outputs in the same way.

In this way, the outputs from the processor are latched onto the I/O assembly during the rising edge of the clock. Inputs from the I/O cards to the processor are communicated during the falling edge of the clock.

Outputs, tick. Inputs, tock.

The SENet processes each of

the sixteen boards, zero through fifteen, whether the board is physically present or not. So even if we remove, say, the coin comparator completely, it does not halt machine operations.

Follow the SENCLK signal out to Pin 10b of J1. We can assume, for the moment, that this line is headed to the I/O cards.

Looking at the Lower Cabinet I/O board (Figure 2) At J51 we find SENCLK on pin 2. It is dispersed throughout the circuit to J52 (Figure 3.) and we get a look at the simple peripherals associated with this board.

This can also be said of the Door I/O board (see figures 4 and 5). The clock makes its appearance on J40, pin 2 (gozinta!) and out to peripherals on J41 (gozouta!).

The beat goes on and this

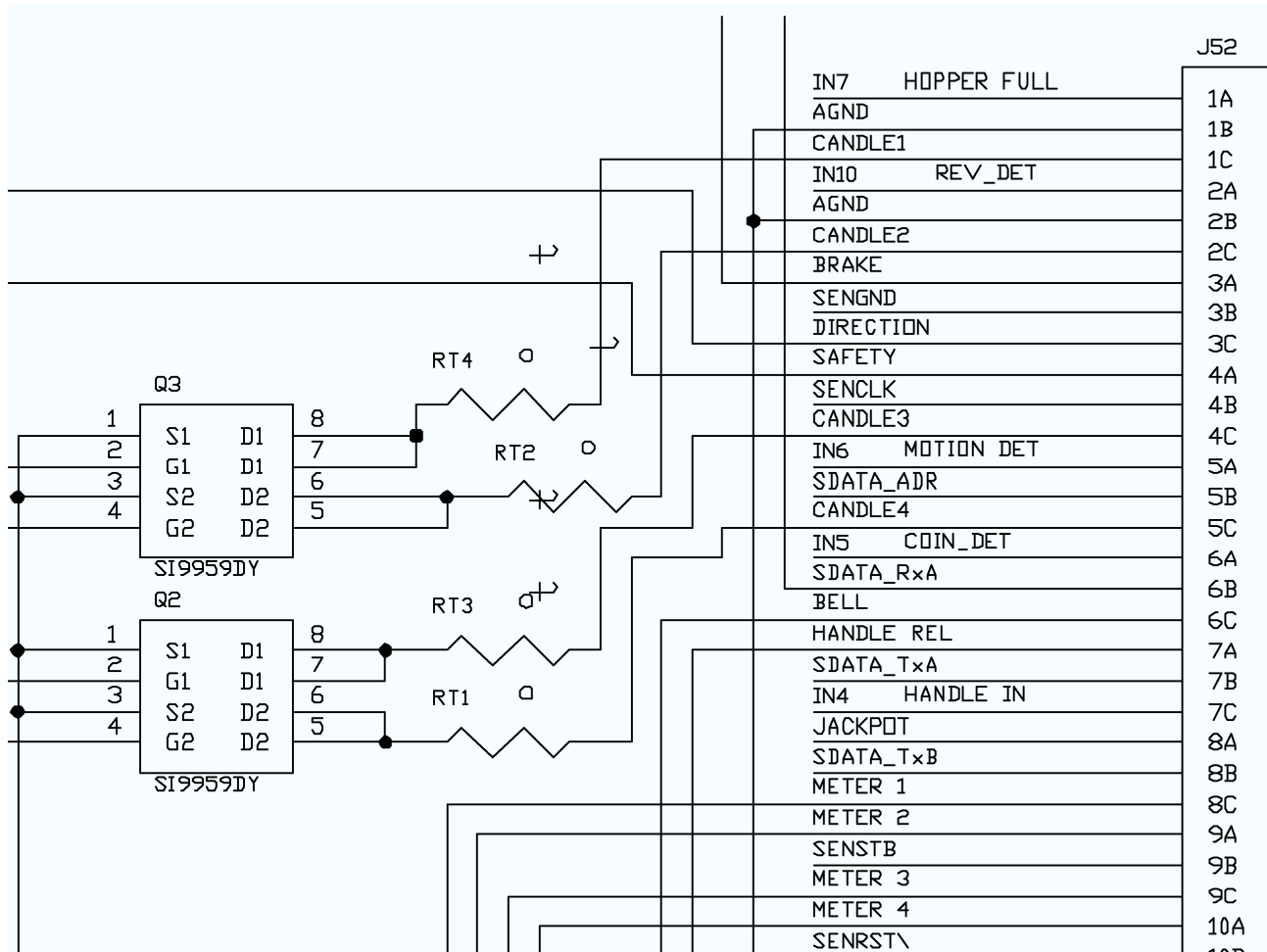


Figure 3. The simple outputs

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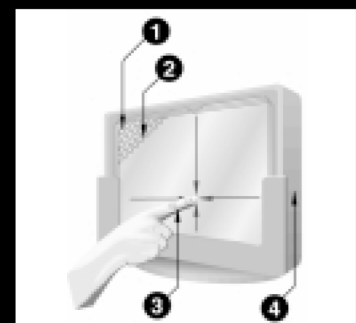
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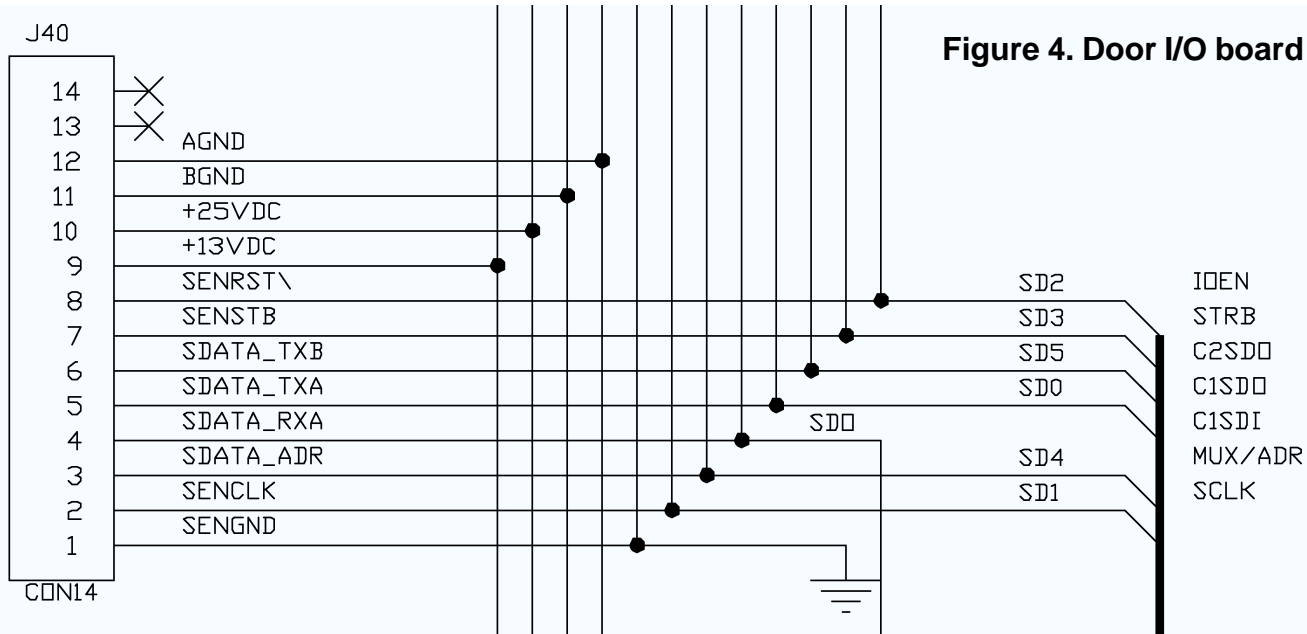


Figure 4. Door I/O board

SENet clock is key to the whole thing. But like spotting an Adam's Apple on your prom date, you get the feeling there is something just beneath the surface that you're not seeing yet.

Take another look at your machine. You've lost your simple ins and outs. Another thing that's missing is the seven-segment display. The question is, what does losing the SENet devices have to do with the seven-segment display? After all, it was not even listed on the pin-out of either of the I/O cards. For the answer, return to the schematic.

On the lay out for the seven-segment circuit, notice J51. Merry Freakin' Christmas! Right there on pin 2 is our little drummer boy. The seven-segment display, for all intents and purposes, is a SENet device. Once more, you feel the power of slot knowledge seep into your veins.

And now, here's the reason you read this mag in the first place. What you can't find in any manufacturer's manual is that all of these troubles originated here. U8 (found just to the right of J51) appears as a series of

triangles called inverters. It is this component that causes our catastrophic failure and is the inspiration for this article.

U8, known to many techs as the "suicide chip," is highly

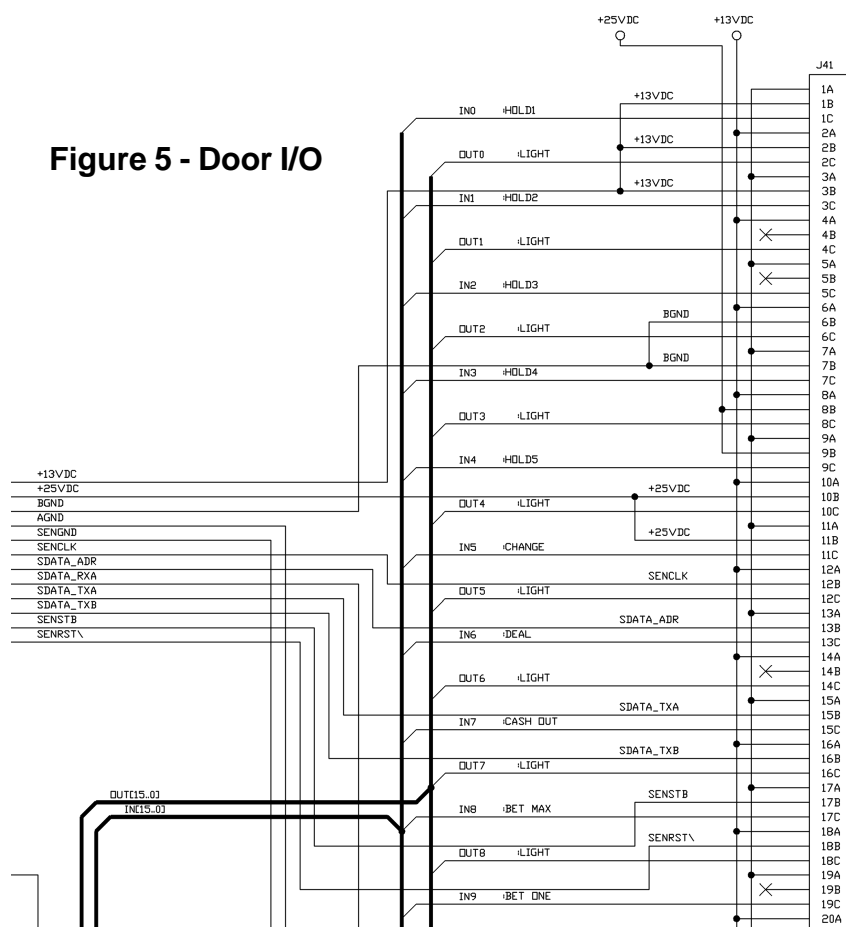
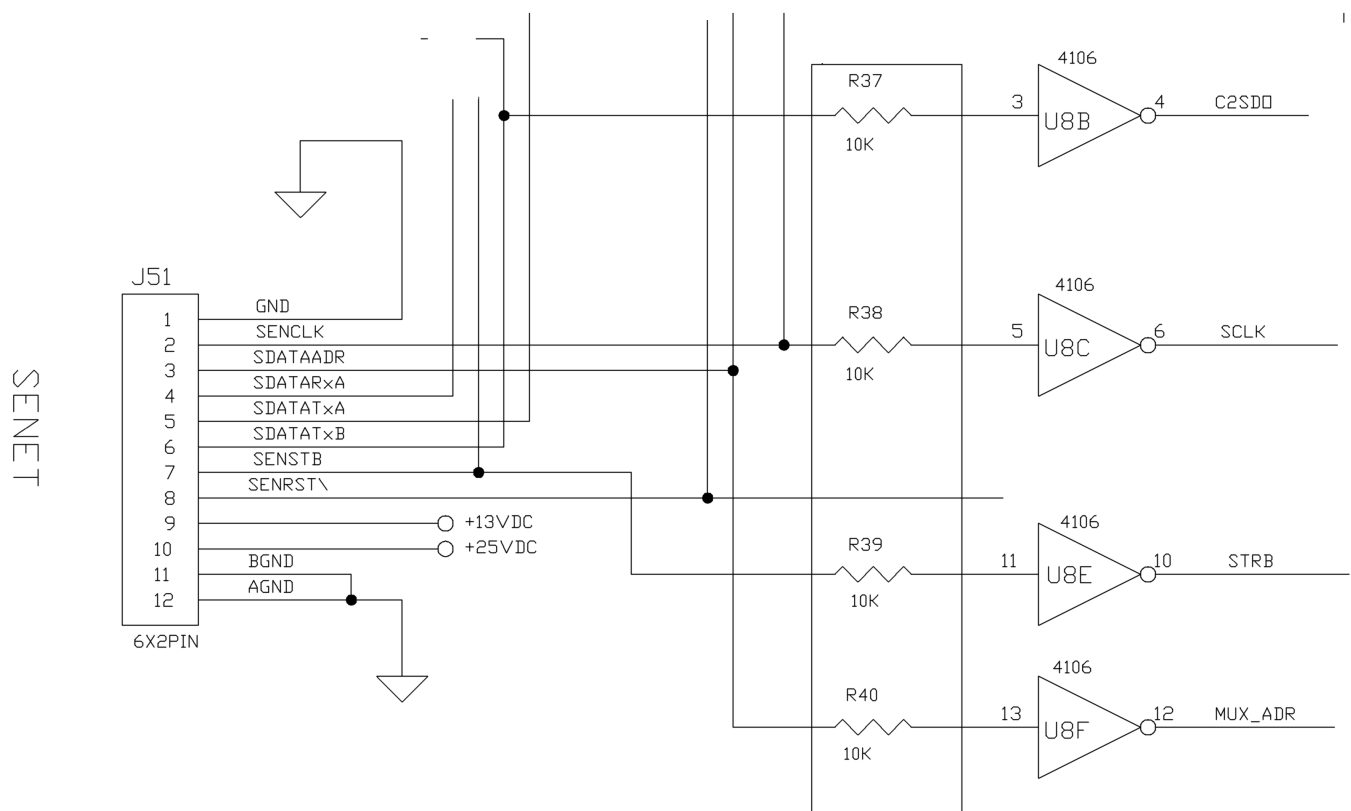


Figure 5 - Door I/O



susceptible to hot swapping, specifically as it pertains to the coin comparator. In some casinos, I won't mention any names (but they're in Atlantic City) it is still standard operating procedure to put a machine out of service by disconnecting the power harness on the coin mechanism. Since it works on unstable AC power, the old S-Plus holds up nicely to this abuse. However, the new Visions and S2000s are wusses in comparison.

Basically, by hot swapping it sends a power spike throughout the SENet and this U8 chip takes it on the chin and shunts our clock to ground. The result: none of the simple I/Os can talk to the processor. Additionally the "meters disconnected" or

"coin-in sequence" message comes up because this is one thing to which the program can react. No clock equals no meters or coin-in, which comes through as this tilt message.

Swap out the seven-segment display board and order to your kingdom is restored. Once again, you are Da Bomb.

As this incredible year comes to a close, I would like to ex-

press my sincere gratitude for your readership and your letters. Things in our world will never be the same and I thank the Big Guy that you and I are still here. Enjoy your holidays; hug your kids just a little harder and here's hoping the best of your past will be the worst of your future.

- Ken Locke
ken.locke@igt.com

Are you a slot tech with something to say? Do you have some special technical tips you'd like to share with your fellow slot techs around the world? Slot Tech Magazine is read by slot machine technicians, slot managers and engineers in Argentina, Australia, Canada, Cyprus, Germany, Gibraltar, Ireland, Korea, Mexico, New Zealand, UK, Japan, Saipan, South Africa and casinos across the US. For writer's guidelines, visit the website at slot-techs.com

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That Feeling of Rejection

By Frank Sutter

One of the more common faults that a technician will face on the floor is coin rejection. The procedure for dealing with this problem is quite simple, and for that reason, it needs to be done in the most expedient fashion possible. The best way for the new technician to insure that he can consistently put this problem behind him quickly is to develop a plan that will efficiently cover all common possibilities. It should go without saying that, as soon as you find evidence that suggests the cause of the problem, you should drop the procedure and address your suspicions.

First, remember that the machine itself will reject coins by design whenever a fault is present in the machine. This is a feature designed in as a courtesy to the customer and helps to guard them against experiencing needless losses. Yes, it's true. Customers will try to play the machine, even when the power is off.

I'll never forget the time I was working on a machine, near the power supply. The door of the game was open and the power was off. I had the coin

tray off the game and the hopper was on the floor next to me. My head was deep inside the lower part of the game, with barely enough room for me, a screwdriver and a flashlight to all fit in. I was distracted from my intense concentration and discomfort by the close-up sound of a dropping coin. Because of the amazing acoustics in the bottom of an upright game, I had assumed that someone was playing the game next to me. I heard it again and then something hit my leg. I gave my leg a quick glance and saw another quarter bounce off.

In sheer disbelief (and at the risk of giving myself a concussion) I pulled my head out of the machine to look through the reel glass of the open door. I came face to face with a man who looked nearly as surprised as I was! He had another coin in his hand and he was ready to drop it! He really thought he was going to play. When I popped up in the reel glass, he must have thought he hit the ugly jackpot! I tried my best to keep a straight face while I explained to the man that the game was being worked on and would be down for a while. Then I

snagged a few quarters from the hopper to hand to him and he shuffled off into the crowd without a word. I'm not sure how many quarters I handed him but I had no doubt that he would give them back to the casino in less than a minute. Even when you've been on the floor for a while, there are still some things that happen that make you shake your head. It's part of what makes the job so great!

Besides a machine fault, one of the most common causes for coin rejection is an electronic glitch in the logic of the CPU board. For that reason, the first thing that the technician should do is to turn the machine off and on again. If the machine comes back up with a fault still on it, clear the fault and try again to insert coins. If coin rejection still occurs, remember that the bill validator also has to be functioning properly in order for the machine to accept coins. Glance over and make sure that it is enabled and ready to play.

If the machine is a Bally, there is usually a switch mounted on the front of the CPU tray that is used to disable the coin and the bill

validators. This switch is for use by slot attendants if there is a reason to turn the game down. I hope I'm not the only technician who set about troubleshooting one of these games, only to find out later that the switch was in the wrong position. I'm sure however, that I'm the only one ever to admit it in print.

If those steps haven't led you to the cause of the problem, open the door and check that the coin validator is plugged in. If there is any reason at all to suspect the connections, confirm them by unplugging and replugging the connectors at both ends. In gaming jurisdictions that are located near the ocean, salt air can corrode the metal of the connection. This process slowly adds resistance to the current flow by building a layer of oxidation between the contacts of the connection.

Plastic also has a way of changing characteristics over time. Urethane plastics are formed by infusing a chemical resin with a catalyst, which will cause the resin to react, or "kick" into a plastic form. This reaction continues through the life of the plastic, which means that over time, the plastic will become progressively harder and more brittle. Both the heat of machine operation and the ultraviolet light put off by its fluorescent bulbs tend to accelerate this curing process. If you've ever found a ping pong ball that has been out in the weather for a summer,

you will know what I mean.

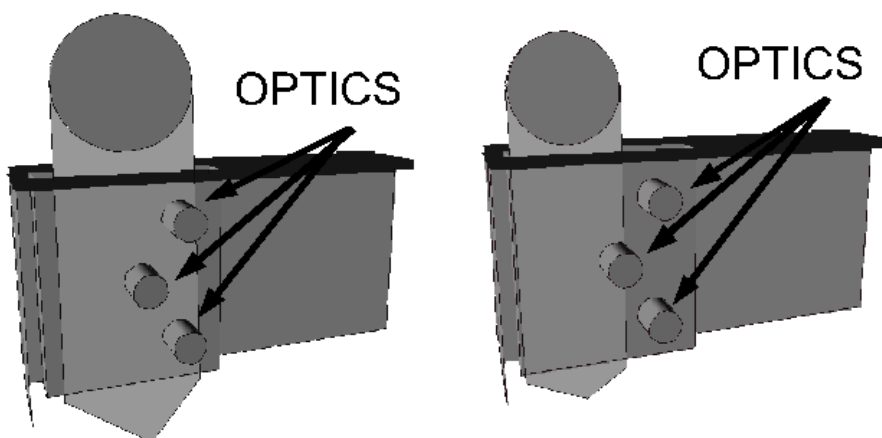
Through this slow but constant process, connectors can actually loosen themselves without ever being touched. Fortunately, unplugging and replugging the connectors will usually solve the problem. If it does not, visually inspect the connectors for looseness or bent pins. Trace the wiring harness as far as you can easily see it, looking for pinched or bare wires. Check carefully along the door seam. The door's hinge can sometimes pinch the wiring. Glance at the connectors for fraying and gently stress each of the wires for possible looseness.

If the connections are solid, remove the validator and examine it. Check for coins or debris lodged in the coin path. If the validator requires a sample coin, make sure a clean new coin is used for that function. With the validator out, visually inspect the encoder, more frequently referred to as the coin optic chute. The chute comes in different sizes for different

denominations and if the encoder is too small, this configuration cannot physically accept a coin and count it. On the other hand, if the encoder slot is too large, coins may pass through without being counted. Confirm that the validator is the correct denomination. Try all its moving parts for free motion and no binding.

If the coin path passes visual inspection, the next step is to swap out the validator with a similar unit from a known-good operating machine. While you do this, check the coin head for proper denomination and confirm that the validator lines up with both the coin head and the encoder. On slant top games, a bent door or even a loose hinge can cause misalignment. Make sure that all of the mounting posts are in good repair.

The next step is to insure that the coin validator is getting the power it needs to operate. Remember that the coin validator is supposed to lose power with the door open, so you are going to



The drawing on the left shows the proper encoder for the denomination of the game. The drawing on the right shows the wrong encoder, and the coin missing the optics.

have to fool the machine into thinking that the door is shut. The machine monitors the door position with a sensor, in most cases an optic. On older machines which use a cherry switch to sense the door, fooling the machine is easy! Simply pull out the cherry switch and the job is done. On machines that use an optic sensor to monitor the door, there is usually a self-test mode to accomplish the same job. By the way, if the validator is powered up with the door open, on some games this is a hint that there may be a short in the door wiring. Be sure to check the coin optic wiring if you find this situation to be the case.

If you are sure that you are in the door-closed mode and the substitute, known-good

validator fails to power up in the original machine, check the machine's 24-volt fuse, and pray that it is blown. If this fuse is good, you are probably facing a wiring or connector problem somewhere in the machine. If the known-good validator comes on dimly, check for an overheated diverter coil.

By now you have confirmed that the validator works, that it is getting power and that it is properly mounted and aligned, so it ought to be able to accept coins. Grab a handful, throw them in the tray and shut the door. When the insert coin light comes on, attempt to play the game and see what the customer might be experiencing.


If the acceptor accepts coins intermittently, some techni-

cians will adjust the sensitivity of the acceptor to be more forgiving. This will get the game going again, but you must understand that the chances of the game accepting slugs goes up dramatically when you do this. I do not recommend this technique; I simply include it because I know it's sometimes used.

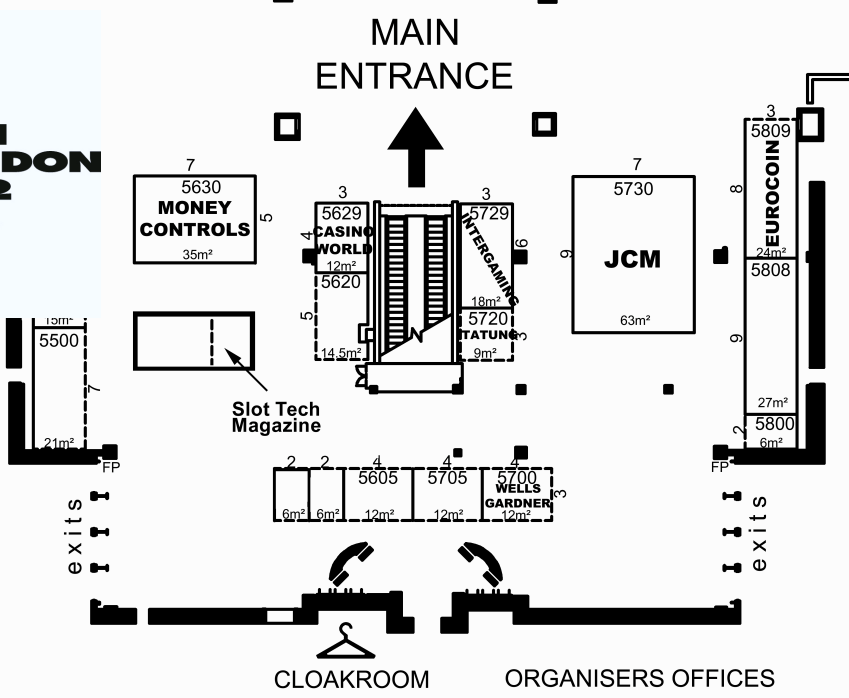
The key to this simple procedure is speed. Since there isn't much to this problem, the key is to get through it quickly.

Problems beyond that would include CPU, I/O or RAM problems, and will be discussed in the future in those contexts. Till next time, keep 'em runnin'

-Frank Sutter
fsutter@slot-techs.com



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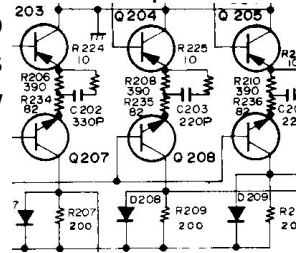
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Schematic diagrams are the "blueprints" for electronics. Learning to read schematics is easy once you know how the parts work!



Dion's Corner

By Dion Anderson



Coin-In Time Out?

Here is an interesting problem for you. You get a call to an IGT Player's Edge poker game with a door open and coin-in timeout tilt. The floor person has already checked the comparator and has blown out the optics and the coin-in tilt hasn't cleared. First, you try to get the door tilt solved so you can find the coin-in problem. You check the door optics and the BV door to see if they are the problem. They all check out to be working fine. Well, maybe it's the fuse. If the fuse checks out good, remove the CPU and check the resistor packs in the top left corner of the board. You'll probably find that someone had removed the board and hit it on the chassis. In the process, they have inadvertently removed RP3. Replace the resistor pack and you'll be back in business.

Confused Buttons

So there is a guest playing a poker game and the floor person calls you on the radio and tells you that the buttons are not working. You arrive on the scene to find out that the buttons are actually working, they're just confused and don't know which switch they

really are. When you hit the "hold" switch for card number one, it holds three too just because it thought you really needed that card as well.

This can be a couple of things. First, you could have a bad switch in that circuit or maybe the floor person got in to the problem a little further than they told you and swapped all the wires around. After checking all the switches and the wiring, the buttons still aren't working. Remove the CPU and check all the diodes in the top left corner. They will be labeled CR1, CR2, CR7, CR8, CR9 and CR10. You'll probably find that one of them is smoked. Replace the smoked component, reinstall the board and hope that it doesn't smoke again. If it does, get out the schematic and enjoy.

Scrambled Bally

If you get a call to a Bally and there is no display or it's scrambled, you know right out of the gate that it's a board problem. First, try the partial clear then the full clear but there's still nothing. You take the board out and find that there is no visible damage. You take the board to the shop, dig out the schematics and begin a process that could be very frustrating and time consuming. Where do you start? Start with U68, which is an SRAM. Replace it and try the board in the tester. Ta-da!

Bell Ringer

Here is a real piece of work. If you have these on the floor, get rid of them. Just kidding. I'm sure you have all come across the famous 91 F code. No communication to the top unit. No big deal except they do it all the time. If there is a

permanent fix, let me know (e-mail danderson@slot-techs.com). Anyway, power down and open the top box. Open the cover on the CPU in the top box. Move your jumper for a partial clear. Try it with the top box first. If that doesn't do it, you'll have to clear the top and the bottom together. When doing them together, make certain that the plug going into the bottom board for the top box is unplugged while clearing. This should clear the 91 F. If all else fails, FULL CLEAR. What a wonderful game.

Bally

Got a coin in problem with a Bally and it's not the comparator or the optics? Check the switch on the board. It should be in the up position.

Another one you might come across is a Bally stealing coins. OPTICS but what on the optics are bad? It might be the IC U1. I have found that it can be the crystal Y1 as well. If there is no light on the optics, change out Q3. This is a PNP general-purpose transistor. NTE 129 or 2N4403.

Williams

I have come across two Williams games in the past two days where the BV drop door has come open and when you attempt to close it, will not latch. Open the validator door. Down by the door switch, there is a bracket. The screw for this bracket is underneath the assembly. Remove it to reveal four nuts. Tighten these and close the door

Bada Bing Bada Boom

Hope to see ya all at TECH FEST

-Dion Anderson
danderson@slot-techs.com

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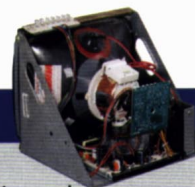


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Low Voltage Equals High Brightness

Understanding the Relationship Between Cathode Voltage and Electron Gun Emission

When does not enough become too much? There are a couple of interesting monitor failures that will cause all three electron guns in a picture tube to operate wide-open, blasting out billions of high-energy electrons and causing an uncontrollably bright white screen with clearly visible vertical retrace lines.

When it comes to the cathodes of the electron gun, low voltage translates into big emission. That's right . . . The lower the voltage at the cathode of the electron gun, the brighter the screen will be.

At first glance, this seems like just the opposite of the way you would expect the electron gun to operate. I mean, generally speaking, you squirt some juice into an output device and it does something. The more juice you squirt into the device, the more you get out of it. The higher the voltage on a lamp, the brighter it burns. The higher the current through a coil, the stronger the magnetic field. Greater output power from an audio amplifier translates into louder sound coming from the speakers.

But in the electron gun of a picture tube, the emission of each gun is modulated by changing the voltage at the cathode and here, grounding the cathode will cause the output to go to 100%. Try it sometime. Ground the cathode of the red, green or blue gun at the CRT socket. You

will see the screen come on full red, green or blue depending on which of the three cathodes are grounded.

By the way, this is a quick and easy way to test the electron gun in a CRT. When you are missing a color, your problem could be in either the chassis or the CRT. To quickly determine which one, try grounding the cathodes of the cathodes one at a time. You should see a bright screen with vertical retrace lines. If you don't, the electron gun in the CRT is at fault. This saves a lot of time.

But what can cause all three guns to come on full blast? Well, a couple of things can cause this. A simple test or two will quickly pinpoint which one.

One cause is loss of the voltage to the video output stages on the neck PCB. This voltage is generally derived from a tap on the primary winding of the flyback transformer in the high voltage unit. The output is rectified and filtered to provide a power supply of around +175 to +190 volts DC depending on the make and model of the monitor. In some monitors, the video output stage is powered by the B+.

If this power supply is missing, either through a bad component or broken conductor, the voltage at the cathodes drops to zero and all three electron guns come

on full blast. I know it seems weird that a missing power supply would cause too much output but this is the case with the electron guns.

If you suspect this is your problem, measure the voltage at the collectors of all three video output transistors with no input signal. If you find the voltage to be low or non-existent, you MAY have located your problem. I say "may" because there is another possibility here.

The three video output transistors are driven by the video amplifiers as we saw in last month's Slot Tech Magazine. In a modern monitor, an integrated circuit handles the job of amplifying all three color signals and passes the amplified signal to the output stages.

The outputs of the video amplifier IC typically drive the bases of the output transistors directly. They are DC or Direct Coupled amplifiers. What that means is that if the IC fails in such a way that it puts out too much DC voltage, it will turn on all three video output transistors. In fact, the transistors will be "saturated" or turned on as hard as they can be. When you measure the voltage at the collectors, it will be very low because the collectors are now connected more-or-less to ground through just 1 kilohm or so of resistance.

There are a couple of ways to determine where your problem lies. One is to use a

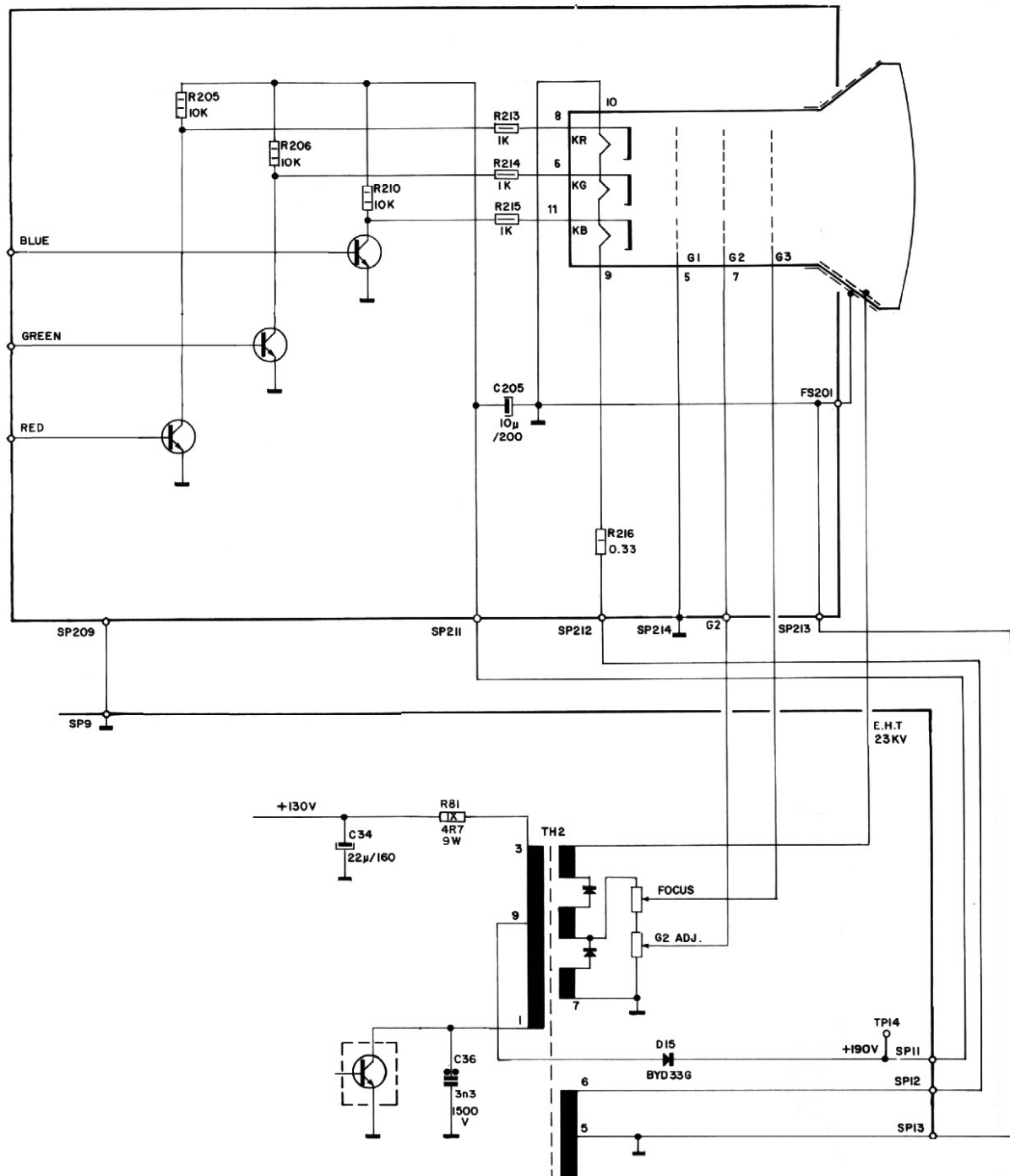
meter to measure the power supply voltage of the video output stages. In other words, after you've checked the collector voltage and found it to be very low, move your meter lead to the other side of the collector resistor and measure the voltage there. It's always easy to locate these resistors on any monitor because they are

three identical resistors and typically two watts. One side of all three resistors will be tied together and connected to the video output power supply. That's where you measure the voltage. If the voltage is low there as well, you have a problem with your video output power supply.

On the other hand, if the

power supply is good but the voltage is low when measured at all three video output collectors, your outputs are probably being over-driven by a bad IC. An easy check is to touch the collector resistors. If they are really hot, you've narrowed down your problem.

-Slot Tech Magazine



Understanding Linear Power Supplies

Modern electronics use switching regulator or switched-mode power supplies for a wide variety of different systems. They're used in monitors to obtain the B+ power supply. They're used as low voltage power supplies for slot machines. Of course, there's a low voltage, switching regulator power supply inside every computer that's on everyone's desk in the world. We'll discuss these types of power supplies in future issues of Slot Tech Magazine.

But not all power supplies are switching regulator power supplies. Some power supplies are of the much simpler "linear" or "conventional" power supply design. These supplies are used in a variety of applications as well. In some cases, we'll even see a power supply that doesn't actually power anything at all. What's up with that? Read on and see.

First of all, what the heck is a power supply? Surely the power for the game comes from the AC wall receptacle. Isn't that the power supply? Well, not really. It is a power source for sure but it is not a suitable power supply.

You see, the AC power that comes from the wall receptacle is really good for some things but not others. Alternating current is great for things like weed-wackers and toasters and hair driers and fluorescent lights and incandescent lamps and such. But AC is not useful as a power supply for electronics. Electronic systems such as radios, televisions, computers and VCRs require direct current to operate.

Regardless of the fact that these devices might be plugged into the 120 volt AC wall receptacle, once inside the box the first thing that happens to the AC power is that it is turned into DC by

the unit's power supply. That's what a power supply does. The power supply takes the 120 volt AC input and turns it into a DC output. This DC is then used to power the electronics.

In addition to changing the power from AC into DC, a power supply is likely to change the voltage as well. For example, a computer requires +12 volts DC, +5 volts DC and +3.3 volts DC. The computer's power supply takes the 120 volt AC input and provides these low voltage, DC outputs. The power supply in a plasma display might do just the opposite, taking 120 VAC in and producing a +200 volt or higher DC output. In some monitors, the main B+ power supply has a +120 volt output. In this case, the 120 volt AC wasn't changed in voltage at all.

Regardless of whether the output is lower, higher or the

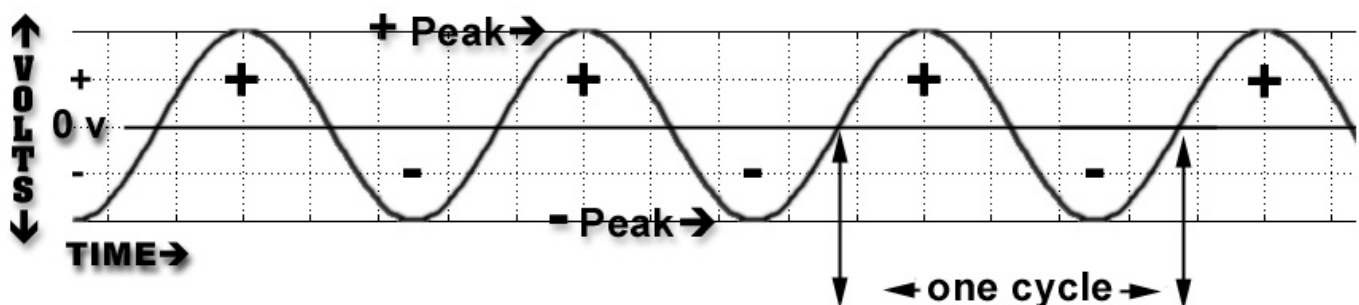


Figure 1. This is a graph of the AC power. The waveform pictured here is known as a sine wave.

same voltage as the input, the power supply always changes the AC input into a DC output.

Alternating Current

Before we take a detailed look at power supplies, let's take a closer look at alternating current. The best way to understand alternating current is to look at AC in the form of a graph as shown in figure 1. This is a simple graph that shows TIME in the horizontal direction and VOLTAGE in the vertical direction.

The horizontal line down the middle of the graph represents ground. Ground is zero volts. Any time the voltage is positive, a line or point is drawn above ground. Negative voltages are represented by a point or line drawn below ground.

The alternating current we use as a power source changes polarity 120 times each second. As the AC makes the change from positive to negative and back again, it doesn't instantly change polarity. It takes a bit of time for the voltage to rise from zero volts, increasing in voltage until it reaches its maximum or "peak" positive voltage. The voltage does not remain at the peak, however. An instant after reaching its peak, the voltage begins to drop. The voltage continues to drop until it has returned to zero volts.

But we're not through yet.

After the voltage has dropped to zero volts, it keeps dropping. It has become a negative voltage now. This is called the "zero crossing." The voltage continues to drop until it reaches a negative peak voltage that is just as far below zero volts as the positive peak is above zero volts. In other words, the positive and negative peaks are the same voltage but opposite polarity. After reaching its negative peak, the voltage then rises back up to zero volts. This completes one cycle of alternating current. The process is then repeated 60 times each second. The frequency of the AC power in North America is 60 cycles per second or 60 Hertz. Elsewhere in the world, it is 50 Hz.

This graph that we have just created is called a waveform. This particular waveform has a name. It's called a sine wave. No matter in the world you are, the AC power is always a sine wave. You'll probably see a tiny sine wave on your digital multimeter that indicates the AC voltage setting.

So if the graph of AC power is a sine wave, what does the graph of the DC output of a power supply look like? Of course, it's just a straight line. DC does not change polarity the way AC does. It doesn't change voltage the way AC does either. Because the voltage and polarity remain constant, the graph is just a straight line.

So, somehow the power supply changes the sine wave into the straight line. It changes AC into DC. Let's see how it works:

Changing the Voltage

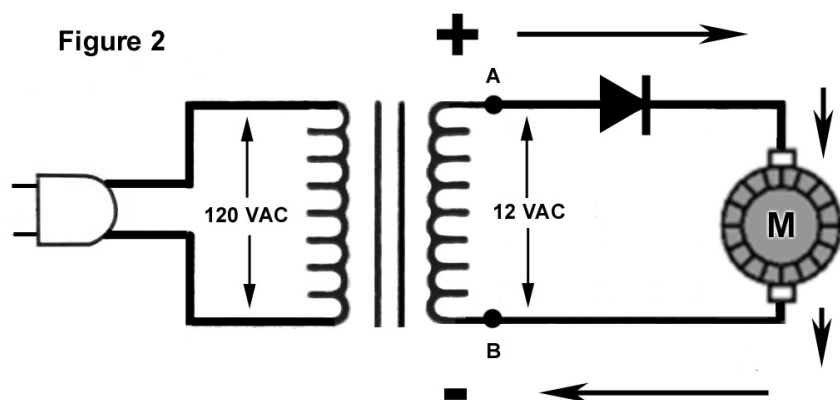
In a linear power supply, if the power supply is going to change the output voltage such that it differs from the input voltage, it will generally do that first and use a transformer to do it. We looked at transformers in the October, 2001 issue of Slot Tech Magazine.

Let's begin this month's look at linear power supplies with a 12 volt, step-down transformer. The primary input of the transformer is connected to the 120 volt AC input. The output voltage at the secondary winding is, of course, 12 volts AC.

Let's power something with this transformer. Let's say for the sake of discussion that we want to power a 12 volt motor. We connect the 12 volt motor to the 12 volt secondary winding of the transformer, plug it in and . . . nothing happens. The motor doesn't turn at all. What's up?

This is quite puzzling for a minute or two until we realize our mistake. Upon closer inspection of the motor, we realize that this is a DC motor and we've connected it to the AC output of the transformer. Remember that a transformer is strictly an AC device. It uses AC as an in-

Figure 2



When point A is positive and point B is negative, current (flowing from positive to negative) flows through the diode to the motor. This is the source path. The current then flows through the motor and follows a return path back to the negative side of the transformer. This current flow pushes the motor and starts it rotating.

put and gives us an AC output.

The way a DC motor works is that the polarity of the power supply determines the direction of rotation. Of course, this is how a reversible hopper works. The motor is controlled by the polarity of its power supply.

In this case our motor doesn't turn because the output polarity of the transformer is reversing so quickly that before the motor even has a chance to begin its rotation in one direction, its power source has already been reversed. In fact, a DC motor connected to an AC power source will just sit there and vibrate. It will not turn at all.

Rectification

Let's see what we can do to rectify this problem and get the motor to turn. Let's break the source path of this circuit and connect a diode in series with the transformer

and the motor as shown in figure 2. Remember that in a series circuit, all of the current must pass through one component in order to get to another component. In this case, the electric current coming from the transformer must pass through the diode before it gets to the motor. Let's see how this works:

Since AC is constantly changing polarity, let's look at things one step at a time. When point A is positive and point B is negative, current (flowing from positive to negative) flows through the diode to the motor. This is the source path. The current then flows through the motor and follows a return path back to the negative side of the transformer. This current flow pushes the motor and starts it rotating in one direction. Let's call it clockwise.

1/120th of a second later, the transformer's polarity is reversed. Point A is now negative while point B is positive.

With the polarity reversed, the current now wants to flow from B to A but it cannot. The current wants to flow from point B to the motor. That part is fine but when the current gets to the diode, it is reverse biased and will not conduct in this direction. That's just the same as if the diode is completely open and, of course, no current actually flows at all when the polarity is reversed.

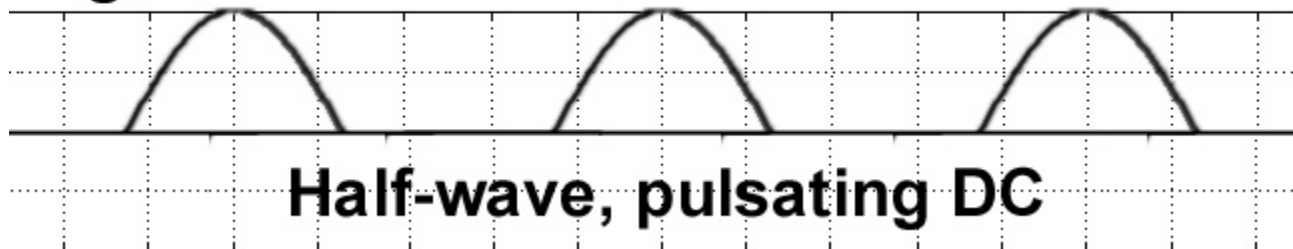
At this point, instead of the motor receiving a reversed pulse, pushing it back from whence it came (rotationally speaking, that is) the motor simply coasts along in the same rotational direction as it was being pushed when point A was positive and point B was negative.

1/120th of a second later, the transformer's polarity is reversed once again and the motor receives another pulse through the diode and gets another shove. The process is repeated 60 times each second and the motor is now turning.

By adding just a single diode, we have changed the AC into DC. The process of changing AC into DC is called "rectification." We had to rectify the problem of AC by turning it into DC with a diode. Another term for diode is "rectifier."

If we look at a graph of the current flowing into the motor, it now looks like the waveform shown in figure 4.

Figure 4



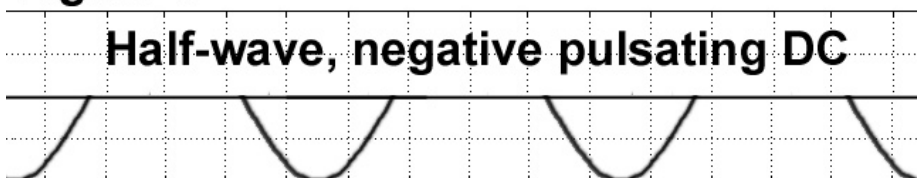
During the positive half-cycles, current flows right through the diode and straight to the motor but when the polarity is reversed, no current flows at all. During the negative half-cycle, the voltage is zero.

This type of DC is called "pulsating DC" for an obvious reason. The current comes out in pulses. It's nowhere near the straight line of pure DC that we're looking for but at least we can make the motor turn. This type of power supply (using just a single diode) is called a "half-wave" power supply because it uses just half of the AC sine wave.

What do you suppose happens if the diode is reversed, with the cathode connected to the transformer's second-

ary winding and the anode connected to the motor as shown in figure 3? This will reverse the polarity of the current flowing to the motor and the direction of the motor's rotation will reverse as well. Let's see how this works:

Figure 5



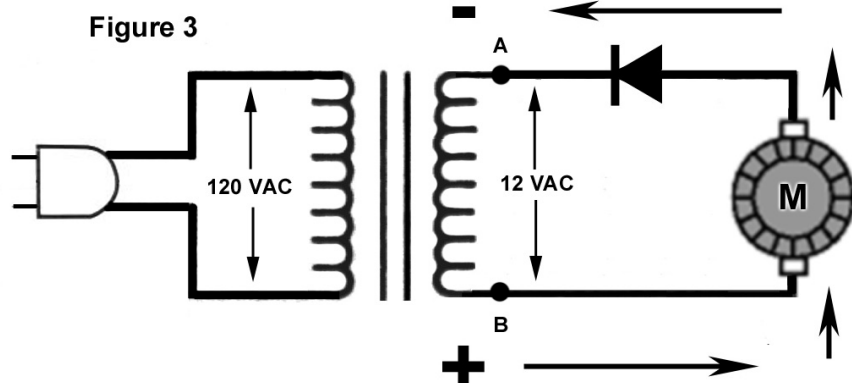
When point A is positive and point B is negative, no current flows because the diode is reverse biased. But when point B becomes positive and point A is negative, current flows from the transformer, through the motor, through the diode (now forward biased so that it will conduct)

and back to the transformer. A graph of the current flowing into the motor now looks like figure 5. It's still pulsating DC. This time, it's negative.

By turning the diode around, we have created a negative power supply. In fact, that is how we create a negative power supply. We simply reverse the diode. This is, in fact, an important thing to know about power supplies. When the output of a power supply comes from the cathode of a diode, it is a positive power supply. When the output comes from the anode of a diode, it is a negative power supply.

Full-Wave Supply

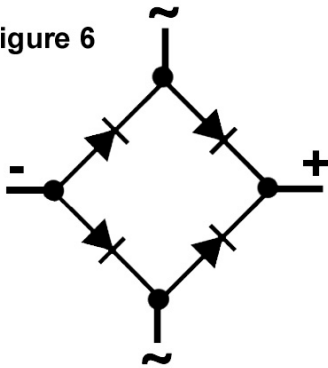
The half-wave power supply allows us to power the motor and make it turn but it's not very efficient. We have power to the motor for only half of each cycle. During the other half cycle, the voltage and current is zero. The current



If the diode is reversed, with the cathode connected to the transformer's secondary winding and the anode connected to the motor, the polarity of the current flowing to the motor and the direction of the motor's rotation will reverse as well.

exists. It's just going the wrong direction. If we can use both halves of the AC, we'll be twice as efficient. This is where the bridge rectifier comes in.

Figure 6



A bridge rectifier is four diodes connected together

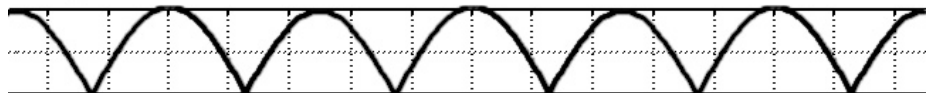
The bridge rectifier is simply four diodes connected in a circuit as shown in figure 6. A bridge rectifier can be a single unit or it may be comprised of four individual diodes. Starting when point A is positive (see figure 7) current flows through D1, the motor, and D3 before returning to Point B. When the polarity reverses and point B becomes positive, current flows through D2, the motor and D4 before returning to point A.

Take a closer look at diode D2. Can you see what it's doing? Instead of just cutting off the current flow when it's going the wrong direction, D2 acts like a detour and re-directs the current to where it's needed, at the positive output of the bridge rectifier. Notice too that the positive output of the bridge rectifier is found where the two cathodes come together. Remember, when we take the output from the cathode, it is positive.

power supply can be positive or negative. Typically, the negative side of the bridge rectifier is grounded and the output is taken from the positive side. This of course, is a positive power supply. Alternatively the positive side of the bridge rectifier can be grounded and the output taken from the negative.

Another way to obtain a full-wave power supply is to use a center-tapped transformer and just two diodes as shown

Figure 8

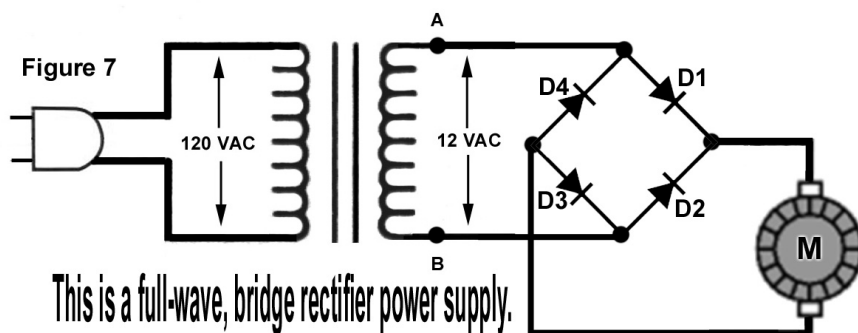


Full-wave, pulsating DC

A power supply like this is called a "full-wave, bridge-rectifier" power supply. A graph of the motor current would now look like figure 8. Notice that it's still pulsating DC but now there are twice as many pulses in the same period of time making it twice as efficient.

A full-wave, bridge-rectifier

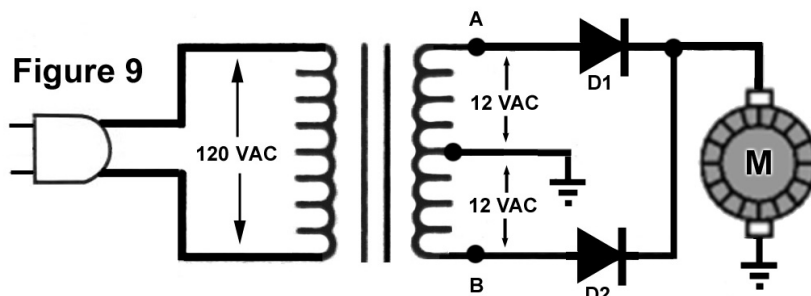
in figure 9. When point A is positive, current flows through D1 and the motor. The return path is through the grounded center-tap of the transformer. When point B is positive, current flows through D2. Notice how, once again, D2 acts like a detour and redirects the current up to the top of the motor. As before, the return path is through the grounded center-tap of the transformer.



This is a full-wave, bridge rectifier power supply.

Starting when point A is positive, current flows through D1, the motor, and D3 before returning to Point B. When the polarity reverses and point B becomes positive, current flows through D2, the motor and D4 before returning to point A.

The output of this power supply is full-wave, pulsating DC just like the bridge rectifier. However, because this design utilizes just one half of the transformer secondary at a time, the output voltage is cut in half. In other words, in order to obtain a 12 volt output, a 24 volt, center-tapped transformer must be used.

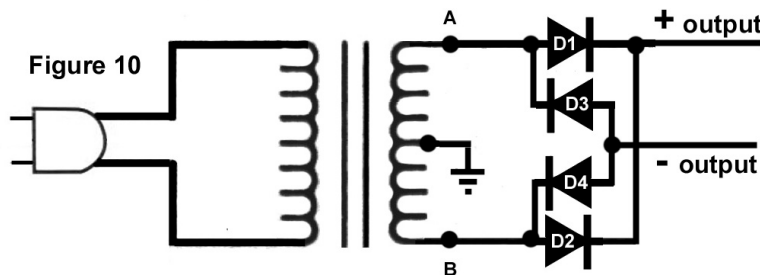


A full-wave, center-tapped power supply uses just two diodes instead of four.

This is called a full-wave, center-tapped power supply. Reversing the two diodes creates a negative power supply. With their anodes tied together, we create a negative output.

scribed above (There are a few other methods, by the way. However, they are rarely used and you're not likely to see them.). Unfortunately, we still cannot use this power supply to power any elec-

odes is at its peak voltage, electric current flows not only into the load but into the capacitor as well, charging the capacitor to the peak voltage. After reaching its peak voltage, the output from diodes will drop. However, the capacitor is now fully charged and it keeps the voltage (and current) up until the next pulse comes along (just $1/120^{\text{th}}$ of a second later) and recharges it. In other words, the capacitor first acts as a load, taking in a charge from the diodes, then as a source, releasing its stored energy into the actual power supply load itself.



We can create a power supply that's both positive and negative at the same time by using a center-tapped transformer and a bridge rectifier. It's called a split supply. We obtain a positive output where the two cathodes of D1 and D2 are tied together and a negative output from the junction of the two anodes of D3 and D4.

Here's another neat trick. We can create a power supply that's both positive and negative at the same time by using a center-tapped transformer and a bridge rectifier as shown in figure 10. It's called a split supply. We obtain a positive output where the two cathodes of D1 and D2 are tied together and a negative output from the junction of the two anodes of D3 and D4.

Filtering

Now we've succeeded in converting the AC into DC using one of the methods de-

tronic system. Referring again to the graph in figure 8, the full-wave, pulsating DC we have created is still nothing like the straight line we need. The voltage drops to zero volts twice each cycle, during each zero crossing of the sine wave.

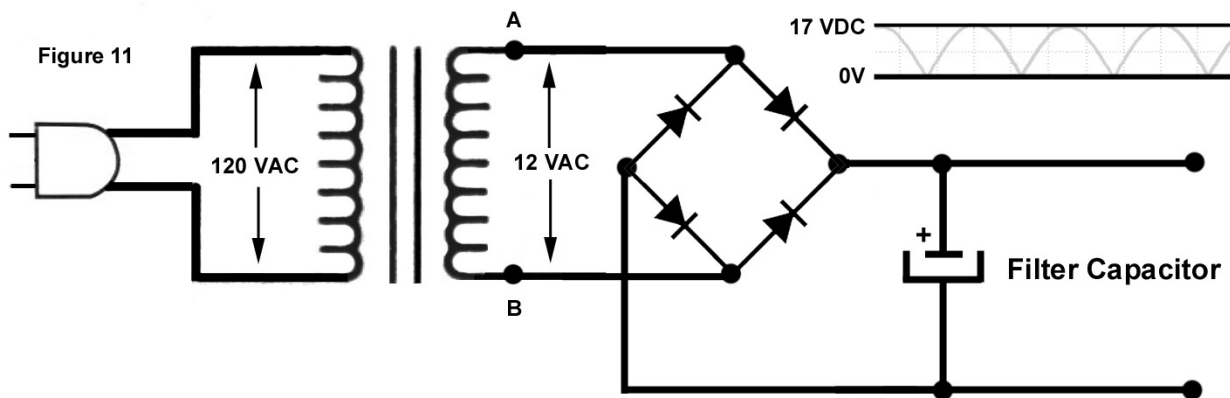
This problem is solved by adding an electrolytic capacitor to the power supply (see figure 11) following the diode(s). Let's see how adding the capacitor changes the output of the power supply:

When the output of the di-

A graph of the output current now looks like a straight line. This is now known as "filtered DC" as the electrolytic capacitor has filtered out the peaks and valleys of the pulsating DC. In fact, this capacitor is called the "filter capacitor."

The analogy here is your car. While you are driving around, the vehicle's generator or alternator powers the electrical system of your car. This is analogous to the time when the output of the diode(s) is at the peak. During this time, your car battery, like the filter capacitor in the power supply, is being charged as well.

When you stop the engine, the output of the generator drops to zero. However, you can still listen to the radio and run your headlights and all of the other electrical systems in the car because the



A graph of the output current now looks like a straight line. This is now known as "filtered DC" as the electrolytic capacitor has filtered out the peaks and valleys of the pulsating DC. In fact, this capacitor is called the "filter capacitor."

battery is fully charged and remains so until you start the engine again. In the same way, the filter capacitor maintains its charge and powers the load between pulses. Instead of dropping to zero volts between pulses, the filter capacitor maintains the voltage more or less at the peak output voltage of the diode(s).

Peak Voltage

Which brings us to another interesting phenomenon in the world of power supplies. Earlier in this discussion, we used a 12 volt transformer to power a motor. If we were to make a full-wave, bridge rectifier power supply using this transformer, and hang a filter capacitor on the output, the output voltage would be around 17 volts DC, not 12 volts DC as you would imagine. Huh? Where did the extra voltage come from? Well, in fact, it was always there and it came from the transformer. Try to follow me on this. It has to do with the way we measure voltage.

DC is easy to measure. Remember, it's just a straight line as seen on a graph. No matter when you measure it, it's always the same voltage; it's always the same polarity. But how the heck do you measure something like AC when it's always changing? It starts at zero volts, climbs to a positive peak, drops back to zero, drops to a negative peak and returns to zero volts, all in the space of $1/60^{\text{th}}$ of a second.

As it happens, there are actually a few different ways to measure AC. One is to measure the voltage between the positive peak and the negative peak. This is known as a "peak-to-peak" measurement. Peak-to-peak voltage measurements are generally reserved for non-symmetrical, non-repetitive waveforms such as audio or video signals. Since a sine wave is a repetitive, symmetrical waveform, the positive peak is exactly the same voltage as the negative peak. In this case, measuring the voltage between peak ground and either peak reveals what is known

as the "peak" voltage of the AC. In the case of a sine wave, the peak voltage is always exactly half of the peak-to-peak voltage.

But this is still not a wholly descriptive measurement because the voltage is really not at its peak for very long. In fact, the peak voltage is really just an instant in time. Throughout the remainder of the cycle, the voltage is below the peak. There is a third measurement for alternating current that is an average measurement; a measurement that takes into account the peak voltage as well as all of the other voltages at every point along the curve of the sine wave. It's known as the RMS average.

RMS stands for "root mean square." RMS is a mathematical average that takes the value of every point along a curve, squares them, adds them together, takes a mean average by dividing the sum of the squares by the number of points and finally takes the square root of the mean average. Whew! Now

you know why I flunked out of engineering and I remain, to this day, a high school graduate.

The RMS calculation differs for each type of waveform but since our AC power is always a sine wave, we only have to make this calculation once. In fact, we really don't have to make it at all because someone else has already done it for us a hundred years ago. It turns out to be $.707 \times \text{PEAK}$. The RMS average of a sine wave is 70.7% of the peak voltage.

In a nutshell, the RMS average is a measurement of the AC's ability to perform work. Look at it this way: Suppose we connect a light bulb or a toaster to an AC source of exactly 100 volts peak. The bulb glows with a specific brightness and gives off a certain amount of heat. The toaster toasts a slice of delicious (and nutritious) white bread in exactly 100 seconds.

Connect that same light bulb to a DC source, and it will require only 70.7 volts DC to light the bulb to the exact same brightness. Connect DC to the toaster and the toast will be done to the same degree of "toastness" in just 70.7 seconds instead of 100 seconds.

If you think about it for a second, you'll realize why this is. Although the AC peaks at 100 volts, it's not at 100 volts all the time. Therefore, it takes less DC (which is con-

stant) to perform the same amount of work as the peak voltage of an AC source. Averaging the peaks with the times that the voltage is less than peak (including the two zero-crossings, remember those?) reveals the magic number: the RMS average of a sine-wave is .707 times the peak voltage. In other words, 70.7 volts DC performs the same amount of work as 100 volts peak AC.

So what does all this have to do with the reason why the DC output of a filtered power supply is apparently higher than the AC voltage coming out of the transformer? Okay, here's the deal: Transformers are rated by their RMS voltage. In fact, just about all measurements of AC power are RMS unless stated otherwise. Remember that 12 volt transformer? Well, that's actually the RMS output voltage. (In fact, it's very likely to be a 12.6 volt RMS trans-

former rather than an exact 12 volts.) The output of the transformer actually peaks at around 17 – 18 volts ($\text{RMS} \times 1.414 = \text{peak}$).

When the alternating current is rectified by the diodes and filtered by the filter capacitor, the capacitor keeps the voltage at the peak! That is why we seemingly obtain a higher DC output voltage than the AC voltage we used as an input. Although we called this a 12 volt transformer, that was an RMS rating. The output of the transformer actually peaked at 17-18 volts and that's what we get out as DC. This is totally normal. It happens every time. When, for example, we rectify and filter the 120 volt AC current from the wall receptacle, the DC output ends up at around 170 volts DC.

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Randy Fromm's

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