February 2013

Slot Tech Magazine

Slot Machine Technology for the International Casino & Gaming Industry

Introduction to Digital Electronics

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Slot Tech Magazine

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Did you feel something missing from your life last month? Did you feel a vague emptiness that left you listless and unaware? Well, don't worry about it because Pat Porath is back this month with installment #92 of his popular "Quick & Simple Repairs" column.

By the way, the "Mystery Technician" from the January 2013 issue is none other than Chuck Lentine. I should have recognized the style. My bad.

If YOU have anything to share with your fellow slot techs, please conside contributing to Slot Tec hMagazine. See http://bit.ly/X6qefL for writer's guidlines.

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I have a few training events planned (see below). If any of these events interest you, please visit the website at slot-techs.com for more information and to download an enrollment form. If none of these dates interest you, or if you're interested in slot tech training (for up to 15 people) at your own property, please do not hesitate to contact me. Thanks.

Thanks. See you at the casino.

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Quick & Simple Repairs #92

By Pat Porath

Problem With Faded Barcode on Ticket

First off it was a FutureLogic GEN 2 type ticket printer in which the printed barcode had a faded appearance. Most of the time, a simple cleaning will cure a lot of the problems but not in this case. Without totally dismantling the printer, the dust was wiped out with a small brush, a Q-tip, then blown out with compressed air (sometimes a printer does need totally taken apart for cleaning for access to internal sensors). It was tested on the bench by powering up while holding down the "feed button." This procedure will print a "self test" ticket showing which software version is currently downloaded, the serial number, and such. Once again, the ticket appeared to be faded. As most of us know, a bill acceptor won't take a ticket with a faded or distorted barcode. If the ticket barcode won't scan at the cashier cage, the validation number would have to be entered in manually, providing the number is readable. Since the barcode still had a faded appearance after a cleaning, my thought was a bad printer head thermal board, the small rectangular board that actually puts the image on the paper. Instead of tearing the printer all apart and replacing the thermal board, wouldn't it be quicker and easier to replace the whole printer head? I did happen to have a couple of Future Logic GEN 2s in my "printer graveyard" that needed parts such as a new motherboard or had a couple of parts taken off of them so why not make one good printer out of parts laying around? I took the printer head off of the original unit and took the head off of a spare marked "bad motherboard" and swapped them. It wasn't very difficult, only six screws and a handful of connectors. After the swap, it was time for the test. This time the ticket looked as if it just came out of a brand new unit. As pictured, you can see the difference between the faded ticket and what it looked like after the printer head was swapped. A simple swap of printer heads fixed the problem.

Faded bar code due to bad print head

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Aruze “Paradise Fishing” Hot Power Supply

We had an Aruze “Paradise Fishing” game that would reboot itself about every 30 minutes and knock the rest of the game offline from the progressive bonus until boot up was complete. When I opened up the problem game, I could smell something very hot. Many technicians know what hot or cooked electronics smells like.

When touching the game power supply (located on the back wall of the game) it was very hot. I couldn’t even keep my hand on it for a period of time. A co-worker and I removed it and it was obvious the unit had some bad capacitors so a co-worker took it to the shop, replaced some caps (maybe some transistors too. I’m not exactly sure) and told me to try it in the game.

Unfortunately it didn’t last long and the game started to reboot itself again. Could it be a bad main processor board? We weren’t sure at this point. It was decided to have a replacement power supply sent to us to see if it fixed the problem. Even though caps were replaced on the original, there were some black spots on the circuit board so perhaps other components could have fried. Still not sure if the main problem was a bad power supply, a replacement was installed and it was time for the test. Thus far we haven’t had any errors or reboots from the game since. The replacement power supply cured the problem.

Aruze “Tech Tips”

While helping an Aruze tech install some new “Crystal” and “GOLD” games at the casino in which I’m employed, I asked if there were any “Tech Tips” he could pass along. The individual started rattling off all kinds of info. I was like “Hold that thought, let me get a pen and paper!”

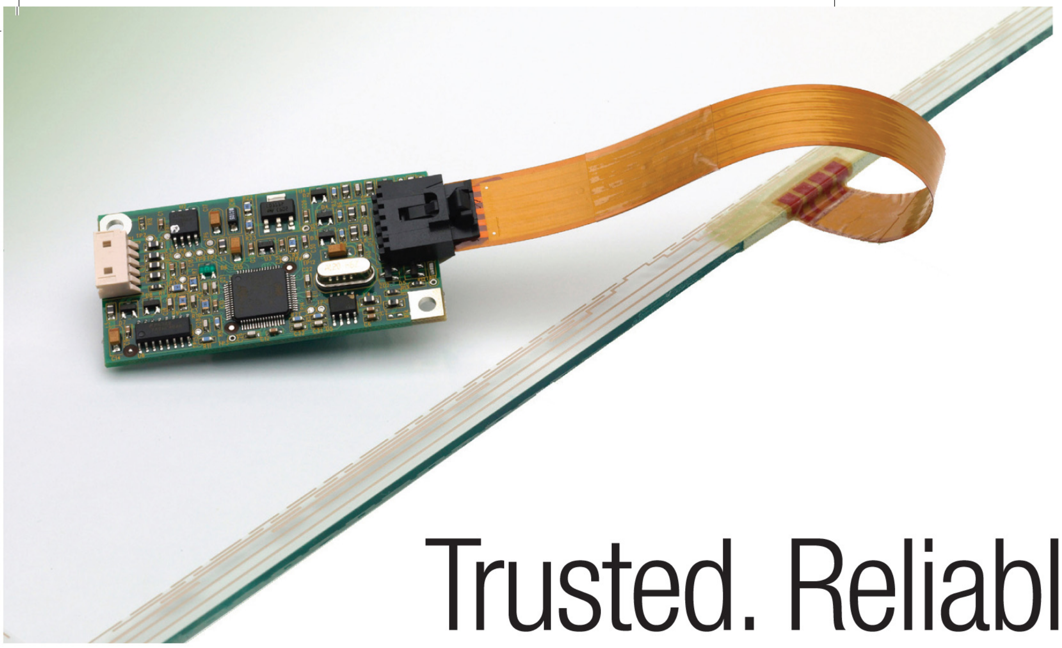
The following info is what I wrote down:
Aruze no display on screen: try rebooting the game two or three times. If on “game board” (located on main processor) a “FF” is shown on the number display, reboot game again. If another reboot doesn’t do it, reseat the video card and the “G” board (small board with software on it).

If “A4” is displayed, reboot game up to five times. Game may appear it has a totally black monitor.

“Body PCB disconnected error” reseat all of the USB connections with game power OFF.

The “Noki board”is commonly known as a reel driver board (only three screws to remove it). If game has a “Noki PCB error COM #5, with power ON, pull power connector on power supply located behind the LCD (above reels) Reseat with power ON, error should clear.

The tech also stated it is a good idea to keep the games “IN SERVICE” when powering down. If “PLEASE WAIT” keeps flashing and won’t clear, toggle the reset



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key while pressing BET 1and BET 2 numerous times to get to the "audit menu." Put game "OUT OF SERVICE" then use the reset key to put the game "back in service." (end of notes)

As stated, this information is only what I was told. I have not tried any of the suggested repairs for myself on Aruze games.

IGT AVP Trimline "Green Screen" & "Temperature Error"

This IGT AVP Trimline 3.5 SBX game started off with a green error screen displaying a "temperature error" then went to a red screen error. The red screen error showed "press diagnostic button for more information." After a quick cleaning of the dusty air filter, the game was rebooted. Now it appeared to have a LCD issue. The top LCD was OK, but the main screen only flickered like the power was going OFF and ON.

For the heck of it, the game was rebooted again with the same result, a problem with the main LCD. Since the game just had a temperature error, maybe the processor chip in the brain box had overheated and fried? Maybe the video card or video section of the main processor board fried? Weak power supplies cause weird failures too.

I decided to start off by replacing the main LCD with a spare. It is quite easy to change on an upright IGT Trimline. Removing only a few connectors, a few screws, and a few nuts and the unit can be lifted right out of the game. After the spare was put into the game and power turned back ON, the replacement LCD had a similar error as the original one.

What the . . .? By looking at the remote board on the bottom (the board that has menu button, auto, select, etc.) the power LED for the LCD was slowly flashing ON and OFF. This indicated to me that the replacement

LCD may have a power issue.

Instead of tearing into the "brain box" of the game and power supplies, I thought why not swap with a known good one next door even though the replacement did come off of the good parts shelf. Sure enough, after swapping I determined that the replacement LCD was bad. A different spare was put into the game and both games were now up and running. Even though the replacement part is on the good parts shelf, rebuilt or even if the part is brand new, it still has that very tiny small chance of being bad. It is very rare, but it does happen.

Kind of reminds me of a few brand new Ainsworth games we installed about a year ago. They were brand new games but the main game power supplies had an issue and died within a couple of weeks. As we later found out, the company had a bad batch of them. Since they were replaced they haven't had any power supply problems at all. Point being, new games, new power supplies, and the power supplies failed. I guess ya just never know.

Atronic e-motion Wouldn't Start to Boot

I was told an Atronic e-motion game was rebooting itself once in a while and that the game had just been RAM cleared. Within


HSVL
BLUEWAVE
SENTRY
PAYCHECK 4
ICB 3.0
24/7
MW2
iPRO
TAIKO
UBA
iPRO-RC
20
20
VEGA
iVIZION
UBA-RC

an hour of the RAM clear, it had started to reboot itself once again. The main processor board and the COM board was reseated along with making sure the mother board was snug in place. This time when the game was turned ON nothing appeared on the either screen.

Maybe it was a heat and power supply problem? I did notice a cooling fan located on the bottom of the game (that we installed to assist with game cooling) wasn't working. So, the fan and the power supply were replaced. The cooling vent located on the right hand side under the player button panel was clogged with dust so it was cleaned.

Located directly on top of the motherboard processor chip is another cooling fan which was cleaned too. Afterward it was time again to turn on power to the game. Once again, absolutely nothing appeared on either LCD, not even a "no signal" message. At least a "no signal" error would indicate some power to the game and power to the LCD.

I did notice something not right though. Near the video card area, located on the game motherboard, there is a small red LED that was not lit. I did have my three red power LEDs lit that are located in the upper left hand side of the motherboard near the three fuses. Power was turned OFF to the game and a quick check of the video card indicated it may have been a little bit loose, so I pushed it into its socket so it made a good connection.

This time powering up the game I had a lit red LED near the video card along with game loading graphics on the screen. After it fully booted up and it was ready to be played, it was a waiting game. How long would it stay up? For the remainder of my shift I kept an eye on it. When receiving floor calls, going to break, or just walking a lap on the floor, I would walk by the game to make sure it wasn't rebooting again. So far so good, no one complaint was received to my knowledge. At time of writing article, day three and the game is still running well.

IGT S2000 Reel Touch Upper LCD CMOS Error

This game (with a "Kenny Rodgers Gambler" theme) is an S2000 and has five stepper reels and an LCD up top. I was told the game had an upper LCD problem but I wasn't clear on what the exact problem was. Where do you start? I turned on the game to see what the deal was to assess the issue and how I could resolve it. After partial boot up of the top LCD, a "CMOS error" displayed. Thinking back to the old IGT PE and S plus games, CMOS has to do with RAM. Were the RAM sticks bad? Was the hard drive bad? Were there other problems?

A good spare upper LCD replacement was found in the shop and put in the game. This time during the boot process "searching for CD data" appeared on the screen. To me this indicated no game specific software was loaded into the LCD and CD disks would need to be inserted and loaded, providing we happened to have a "Gambler" theme disk.

Instead of going through loading disk software, I had another idea. How about swapping the hard drive from the original unit to the replacement LCD? All of the game specific info SHOULD be on the hard drive as long as it didn't crash. A removal of a small Phillips screw, two 7mm nuts, one connector, and the hard drive was out. After the swap and power turned ON once again, everything was looking great but game graphics didn't appear quite yet. "Call Attendant" was displayed on the LCD now.

Three main slot door resets later, the "keychip mode" appeared. All of the game options were checked, I exited out of "keychip mode" then finally the game graphics appeared. Another game fixed.

- Pat Porath
pporath@slot-techs.com

Introduction to Digital Electronics

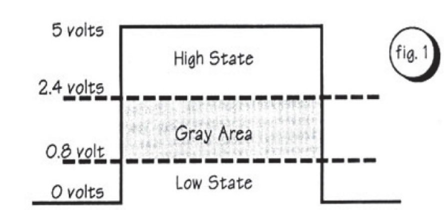
There are two distinct types of electronic circuits: analog and digital. If you've been working on power supplies and/or CRT monitors (on the video amplifier circuits or the vertical deflection circuit or the horizontal deflection circuit) or your garage-band's Fender Twin-Reverb amplifier, you have been working on analog circuits.

So, what is meant by digital electronics? What's the difference between the two? Well, there are lots of differences between analog and digital electronic circuits. In fact, they're so different that you really don't have to know much about analog electronics to be successful in repairing digital systems. Some of the best techs I've ever met are great on microprocessor systems but aren't worth a damn when it comes to fixing monitors.

In the analog world, you'll work on circuits that have all kinds of different voltages. As little as 7/10s of a volt will turn on a transistor. A video signal may have anywhere from 0 to 4 volts on it. The power supply circuit voltages are +5, +12, and even -5 volts! A monitor will have a B+ supply of +88 to +136 volts. There's even 15,000 volts or more at the second anode! LCD monitors use 750 VAC or more for the CCFLs.

The world of digital electronics is much simpler than the chaotic realm of analog circuits. You know how all the CPU boards are powered by +5 volts DC or 3.3 volts DC? Well, in digital electronics, that's just about all you'll see. If you use an oscilloscope to probe just about any "node" (any connections between integrated circuits are called nodes) you'll see that the voltage there will be either around +5 volts (or 3.3) or it will be close to 0 volts (or it will be alternating between the two as shown in figure 1). This is called "pulsing." That's it. In fact, if you see anything else, you've probably found something wrong—a circuit fault of some type.

Modern slot machines use a family of integrated circuits known as TTL—Transistor, Transistor Logic. They also use another family of ICs called CMOS (Complimentary Metal Oxide Semiconductor). To make the discussion a bit simpler, let's discuss TTL first. There are only two states allowed in TTL, digital electronics. Either a signal is at a logic "high" or a logic "low. A logic high isn't really exactly 5 volts. There's a threshold voltage of 2.4 volts. Anything above 2.4 volts is considered to be a valid logic high.



There are only two TTL logic levels. A logic "LOW" is from 0 to .8 volt. A logic "HIGH" is from 2.4 to 5 volts. Anything in-between is a disallowed state called the "gray area."

The threshold for a logic low is .8 volts. Anything in-between is a "disallowed state" called the "gray area." Normally, you will not see signals in the gray area. That's one of the things you look for when troubleshooting digital circuits. If I'm probing around in a circuit and I see a signal that's in the gray area, I gotta think that something's not correct. A gray area violates the "rules" of digital electronics and that's what I'm looking for.

Digital electronics follows very specific rules of operation. The rules state things like "if this input is high, this output will be low" or "if these two inputs are both low, the output will be high." This is called "digital logic."

Troubleshooting digital electronics is kind of like playing baseball. If you don't know the rules, you can't play the game. The rules of operation are contained in a reference book called a "databook." It contains a fact sheet (in some cases, many fact sheets) on each device and tells you how the integrated circuit is supposed to operate. It's the rulebook! Without this book, you can't play the game. Individual datasheets are also available online from numerous sources. Your best bet here is to perform a Google search for the part number. Another good source is http://www.chipdocs.com.

There are other books available,

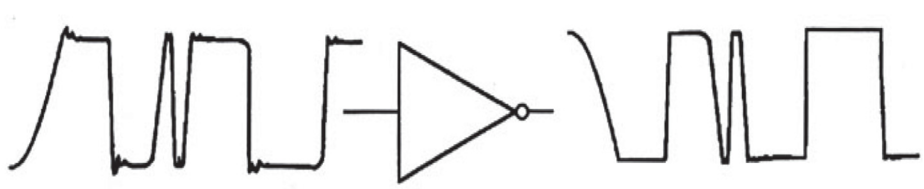


fig. 2 The inverter flips the signal upside-down. In the process, the signal is also cleaned-up!

too. Radio Shack (believe it or not) has a number of books and pamphlets on the subject of digital electronics. These were written by well-known technical writer Forrest Mimms. Another one I highly recommend you get is the "TTL Cookbook" by Don Lancaster. Just about anyone interested in learning digital electronics should get this one. Another is the "CMOS Cookbook."

The Inverter & Buffer

The simplest circuit is called an "inverter." To invert something means to flip it upside down. That's exactly what the inverter does. If the input signal to an inverter is mostly high, with narrow, downward going pulses, it comes out upside down; the pulses are now going up (figure 2). Sometimes a signal is upside-down from what we need in a circuit and an inverter is used to flip it right side up.

So, the rules for the inverter are: when the input is low the output

A	Y
0	1
1	0

is high and when the input is high the output is low. The rules are printed in the "truth table" that's in the data book (figure 3). A is the input; Y is the output. 'Nuff said?

The 7404 is called a "HEX INVERTER" because there are actually six inverters in the one package. They only share a common power connection.

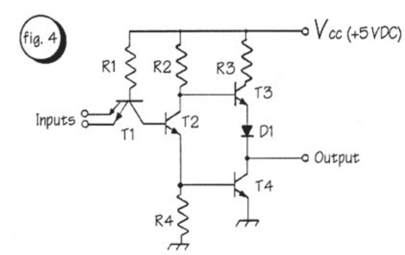
You may notice that the signal looks cleaner that it did before (figure 2). See how the input is not a clean waveform but the output is? In addition to inverting the signal, the inverter also cleans it up. Remember, anything above 2.4 is a high. Anything below .8 is a low. The inverter ignores all the garbage. Digital circuits kind of clean themselves up as the signal is passed from device to device.

If we need to clean up a signal without inverting we can use a circuit called a "buffer." The buffer passes the signal through unchanged but cleaner. The buffer is also used when the output of an IC is used to drive a lot of other inputs. This is called "fanout." A typical fanout for TTL is 10. That is, the output of one chip can drive up to 10 inputs on other integrated circuits. Each input is called a "unit load." A typical TTL output can drive up to 10 U.L. If you're a designer, this is an important consideration. As technicians, it's not generally too important. By the way, some inputs are more than 1 U.L. and some are less. Again, this is more important to design engineers than technicians, who are only interested in locating and replacing bad parts.

Totem Pole Output

The output of a TTL device is known as a "totem-pole" output (see figure 4). The way it works is really simple. To make the output go high, (output a logic 1) transistor T3 is turned on. This allows the +5 volt power source (also known as Vcc) to pass through resistor R3, transistor T3, and diode D1 to the output pin of the chip. When the output is high, the chip is said to be "sourcing" current.

To bring the output low, transistor T4 is turned on. This grounds



TTL gate with Totem-pole output

the output pin, making it 0 volts; a logic 0. When the output is low, the IC is "sinking" current.

Never connect two totem-pole outputs together. If one output goes low while the other tries to go high, the low will always win over the high because transistor T4 connects the output directly ground. A logic high must be delivered through resistor R3 and the diode. Also, the "high" output chip might be damaged due to excessive heat dissipation across R3, T3, and the diode.

A different type of digital IC known as a "tri-state" device allows multiple outputs to be wired together. Tri-state devices can completely disconnect themselves from the common output, allowing only one active output regardless of the fact that the output pins of the integrated circuits are hard-wired together on the printed circuit board. Tri-state devices are common in microprocessor systems.

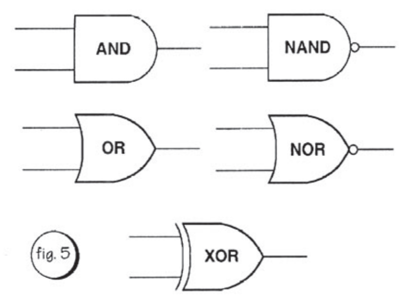
Since the totem-pole output does a better job of "sinking" current than "sourcing" it, the "active" output of an integrated circuit is often a low rather than a high. An "active low" function is called a "NOT" function. That's what the small circle on the end of the inverter symbol is for. The circle is sometimes called a "bubble" or a "zirc." The circle indicates the NOT function. That is, whatever function the device performs, the output comes out LOW.

The Gates

Inverters and buffers can't make any logical decisions. To do that, we need to use something called a "gate." Gates are the building blocks for all the logical functions in digital integrated circuits.

The first gate we'll look at is called an "AND" gate (figure 5). It looks like the letter "D" with the inputs on the flat side of the D and the output on the rounded end. If both inputs are high, the output will be high. That is to say, if one input is high AND the other input is high, the output will be high.

Offhand, that may seem pretty



The 5 basic types of gates

limited but here's what you can do with it. If you have a signal that needs to be turned on and off (for example, a momentary audio tone that sounds off when an event occurs) you can connect a continuous audio signal to one of the inputs of a gate (figure 6). The other input is connected to the "control" signal - a momentary pulse that goes high when the event occurs.

When the control signal is low, the audio signal is blocked and the output of the AND gate is low. Remember, both inputs must be high in order to get a high out. But when the control signal is high, the audio signal is passed through to the output. It's like opening a gate and letting the signal through. That's why it's called a gate!

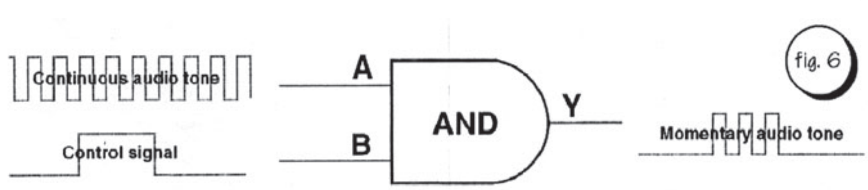
Remember when I mentioned that it's easier for an IC to go low than it is to provide a high? There is another kind of AND gate. This one includes the NOT function we saw in the inverter. It's called a "NAND" gate. NAND stands for "NOT AND." It's like an AND gate followed by an inverter. Take a look at the 7400 integrated circuit. It looks like the AND gate but it has the bubble on the end. Look at the truth table for the NAND gate. It's exactly the same as the AND gate, but the output is reversed. In the NAND gate, both inputs must be high in order to get a low out.

There are some other types of gates as well. One is called an "OR" gate. If one or the other or both inputs are high, the output will be high. The active low version of the OR gate is called the "NOR" gate. If one or the other or both inputs are high, the output will be low.

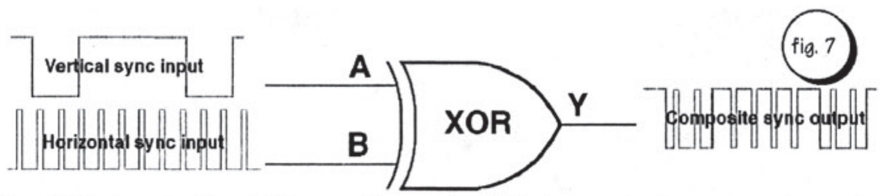
Another type of OR gate is called the "exclusive OR." You'll see it abbreviated XOR. If one or the other input is high, the output will be high but not if both inputs are high. If both inputs are high, the output is low. An example of the XOR in action is in a video circuit where the vertical sync is connected to one of the XOR inputs and the horizontal sync is connected to the other (figure 7). The output of the XOR gate is composite sync.

When you are thinking about logic functions, don't get hung up on the name of the gate. To illustrate my point, let's go back to the AND gate. When one input AND the other are both high, you'll get a high out. That's logical, huh? After all, it is called LOGIC, isn't it?

But think about it like this: imagine both inputs as being high. If both the inputs are high, the output of the gate is high, right? But if one input OR the other input goes low, the output will be low, won't it? In this case,



The AND gate in action using a continuous audio tone on one input and control signal on the other. The output is a momentary audio tone.



The XOR (exclusive OR) gate in action. With vertical sync at input A and horizontal sync at input B. The output Y is composite sync.

we are using the AND gate to perform a kind of OR function, aren't we? This is a perfectly acceptable way to think of the AND gate. It's called "negative logic."

It's the same with the OR gate. The truth table states that if one input OR the other input is high, the output will be high. In terms of negative logic, if one input and the other input are both low, the output will be low.

How does this affect us as technicians? Not much as far as testing the individual gate is concerned. That remains the same no matter what. It does go toward understanding how that particular device is being used within the system.

Next, we'll take a look at some more advanced types of integrated circuits called "flip-flops" and "counters." We'll also take a look at digital troubleshooting, and I'11 show you a way to find bad ICs using just a battery, two wires, and a finger!

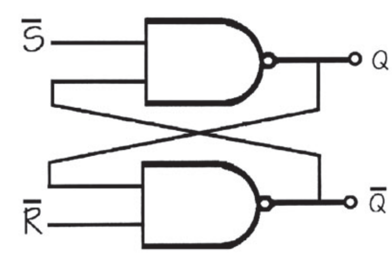
Flip-Flops and More

By combining gates into more complex circuits, it's possible to design a digital circuit that will do almost anything. In fact, just about all of the digital integrated circuits in use today are simply combinations of the basic gates we have already examined.

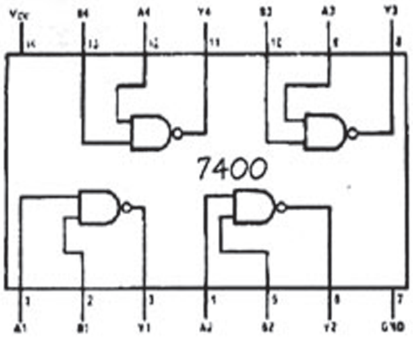
As we have seen, the gates can only respond to a certain set of input conditions. When the input conditions are met, the output responds according. But the gates function only as transient circuits; they cannot store any information.

A flip-flop is a type of circuit that can store a single bit of data. There are several different types of flip-flops. The simplest is known as an RS flip-flop. The RS stands for "RESET/SET."

We can make an RS flip-flop with two NAND gates connected as shown below. R and S are the two inputs to the flip-flop. The flip-flop also has two outputs. Both are labeled with the letter "Q" but one has a bar over the top of it. The bar indicates a complimentary function and is read "NOT Q" or "Q NOT." That is to say, if the Q

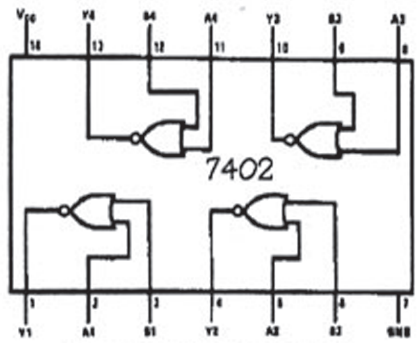


The most basic of all flip-flops is the RS flip-flop. RS stands for "reset/set."

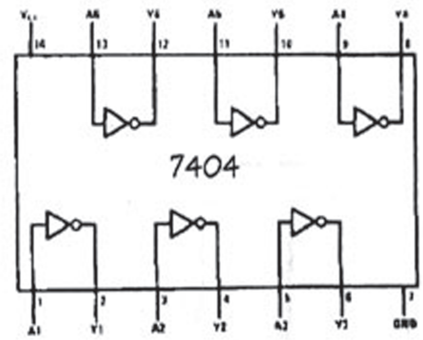


Inputs		Outputs
A	B	Y
L	L	H
L	H	H
H	L	H
H	H	L

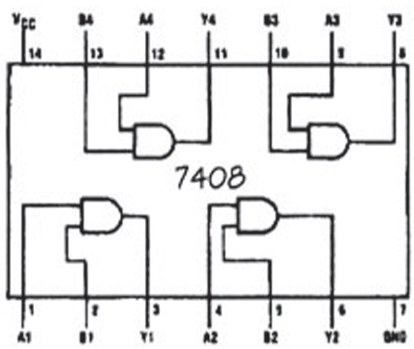
H = High Logic Level
L = Low Logic Level



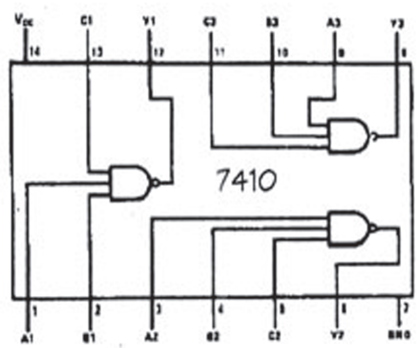
Inputs		Output
A	B	Y
L	L	H
L	H	L
H	L	L
H	H	L



Input	Output
A	Y
L	H
H	L

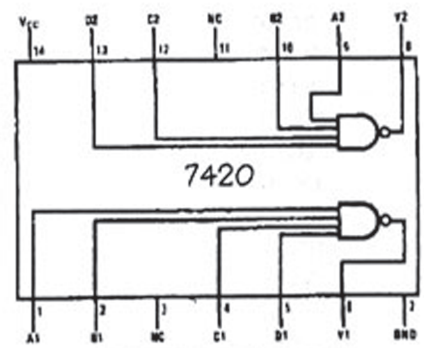


Inputs		Output
A	B	Y
L	L	L
L	H	L
H	L	L
H	H	H

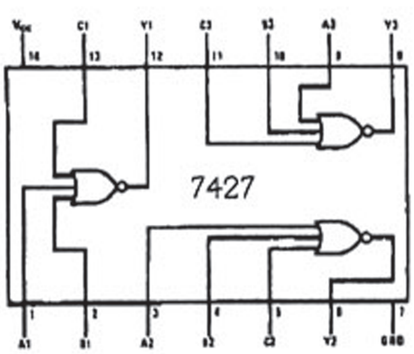


Inputs			Output
A	B	C	Y
X	X	L	H
X	L	X	H
L	X	X	H
H	H	H	L

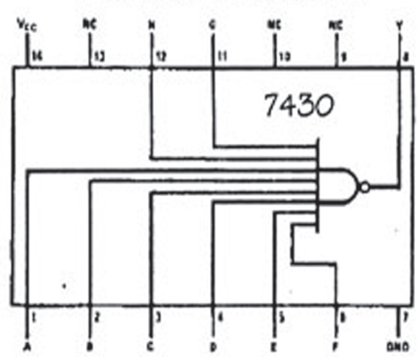
H = High Logic Level
L = Low Logic Level
X = Either Low or High Logic Level



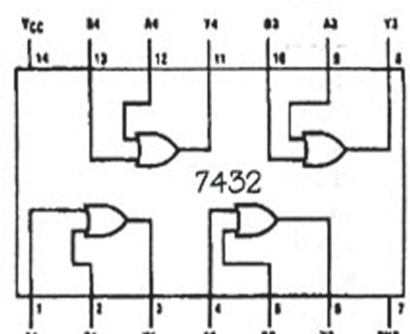
Inputs				Output
A	B	C	D	Y
X	X	X	L	H
X	X	L	X	H
X	L	X	X	H
L	X	X	X	H
H	H	H	H	L



Inputs			Output
A	B	C	Y
L	L	L	H
X	X	H	L
X	H	X	L
H	X	X	L



Inputs	Output
A thru H	Y
All inputs H	L
One or more input L	H



Inputs		Output
A	B	Y
L	L	L
L	H	H
H	L	H
H	H	H

A sample of TTL inverters and gates with their truth tables

output is high, the Q NOT output will be low and vice-verse. Integrated circuits will often sport complimentary outputs if for no other reason than that the extra pins are available in the IC package so they might as well be used for something.

When inputs R and S are both high, the flip-flop is in a steady state. For the sake of discussion, let's say that the flip-flop is "set" with its Q output high. Naturally, the Q NOT output will be low.

If the R input is momentarily brought low, the Q output will go low. The flip-flop is now in its "reset" condition and will stay that way, even when the R input goes high again. Only a brief pulse is needed to reset the flip-flop. Subsequent toggling of the R input will have no effect on the outputs. Once the flip-flop is in the reset condition it will stay that way; storing its single "bit" of data.

In order to "set" the flip-flop, the S input is momentarily brought low. This brings the Q output high again. Again, subsequent high/low transitions on the S input will have no effect on the outputs. Once the flip-flop is set, it's set.

Bringing both inputs low is a disallowed condition for the RS flip-flop, since this would force both outputs high simultaneously.

You can easily make an RS flip-flop yourself out of a single 7400 IC. In fact, since the 7400 is a "quad" NAND gate, you can make two RS flip-flops out of one IC!

Can you imagine where we might use an RS flip-flop? Think about a redemption game with its ticket dispenser. When a player earns a ticket, the game might send a momentary pulse that "sets" an RS flip-flop, activating the motor in the ticket dispenser. The motor continues to run until the ticket notch sensor sends a low going pulse that "resets" the flip-flop and shuts off the motor.

Clocked Logic

With the RS flip-flop, the outputs change as soon as the appropriate input conditions are met. This is known as "asynchronous" operation. However, in a computer system we often need things to happen simultaneously or sequentially. A computer "clock" is used to make sure that things happen exactly when they're supposed to. An integrated circuit that uses a clock signal to initiate a function is known as having a "synchronous" operation. This is also known as "clocked logic."

A good example of clocked logic is the "type D" flip-flop. The "D" stands for data. The most common type D flip-flop is the 7474. This is a "Dual D Flip-Flop" with two completely independent devices in one, fourteen pin package.

As with the RS flip-flop, the type D flip-flop has complimentary outputs. Remember the little bubble on the end of the inverter, NOR and NAND gates? Here we see it again on the Q NOT output of the flip-flop. Remember, the bubble means "active low."

The remaining four connections are all inputs to the flip-flop. "D" is the "data" input of the flip-flop; "C" stands for "clock." The other two inputs are "set" and "clear."

Here's how the type D flip-flop works:

When the flip-flop is "set," the Q output is high. The Q NOT output is, of course, low. If the data input is brought low, the outputs do not immediately change state. The logic low at the data input is transferred to the Q output only when the flip-flop receives a clock pulse. Specifically, the data is transferred on the positive edge of the clock pulse, when the clock pulse makes a low to high transition. Once the clock pulse is high, the data input is "locked-out" and any changes are ignored. Any information present at the D input will not be transferred until the next rising edge of the clock pulse input.

If the condition of the D input remains low, subsequent clocking of the flip-flop will not produce any change in state at the outputs. The flip-flop will remain "reset" with the Q output low. If the D input is brought high, the Q output will go high with the next low-to-high transition of the clock pulse. In other words, any change in the outputs is "synchro-

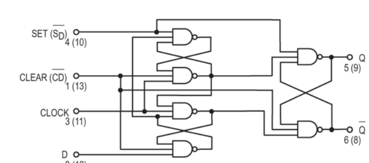
7474 FLIP-FLOP

DUAL D-TYPE POSITIVE EDGE-TRIGGERED FLIP-FLOP

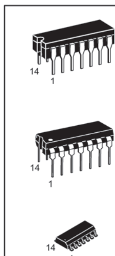
The 7474 dual edge-triggered flip-flop utilizes Schottky TTL circuitry to produce high speed D-type flip-flops. Each flip-flop has individual clear and set inputs, and also complementary Q and Q outputs.

Information at input D is transferred to the Q output on the positive-going edge of the clock pulse. Clock triggering occurs at a voltage level of the clock pulse and is not directly related to the transition time of the positive-going pulse. When the clock input is at either the HIGH or the LOW level, the D input signal has no effect.

LOGIC DIAGRAM (Each Flip-Flop)



DUAL D-TYPE POSITIVE EDGE-TRIGGERED FLIP-FLOP



ORDERING INFORMATION

SN54LSXXJ	Ceramic
SN74LSXXN	Plastic
SN74LSXXD	SOIC

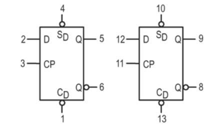
MODE SELECT — TRUTH TABLE

OPERATING MODE	INPUTS			OUTPUTS	
	$\overline{S_D}$	$\overline{S_D}$	D	Q	$\overline{Q}$
Set	L	H	X	H	L
Reset (Clear)	H	L	X	L	H
*Undetermined	L	L	X	H	H
Load "1" (Set)	H	H	h	H	L
Load "0" (Reset)	H	H	l	L	H

* Both outputs will be HIGH while both $\overline{S_D}$ and $\overline{C_D}$ are LOW, but the output states are unpredictable if $\overline{S_D}$ and $\overline{C_D}$ go HIGH simultaneously. If the levels at the set and clear are near V_{IL} maximum then we cannot guarantee to meet the minimum level for V_{OH}.

H, h = HIGH Voltage Level
L, l = LOW Voltage Level
X = Don't Care
i, h (q) = Lower case letters indicate the state of the referenced input (or output) one set-up time prior to the HIGH to LOW clock transition.

LOGIC SYMBOL



V_{CC} = PIN 14
GND = PIN 7

nized" with the clock pulse. This is reflected in the truth table.

So, what about the other two inputs? Notice that they both have the bubble on them (active low, remember?) The "set" input does just what the name implies. A logic low on the set input "sets" the flip-flop, making Q high. A logic low on the "clear" input has just the opposite effect, making the Q output a logic low. Both the set and clear are asynchronous inputs that are independent of the clock and data inputs. When set goes low, Q goes high immediately, regardless of what is happening at the D and clock inputs. When clear goes low, Q follows no matter what going on with the clock and data inputs. A simultaneous low on both set and clear will force both outputs high. In this case, the outputs are obviously not complimentary.

The logic diagram for the type D flip-flop is shown at right. You will not need to follow this schematic in the course of your normal work as a technician but it's interesting to see how the basic gates are combined to make a new type of IC.

Here's a neat way to hook up a type D flip-flop. Connect the Q NOT output to the D input. What will this do? Let's think about it. Let's start with the flip-flop "set". The Q output is high and the Q NOT output is low. This puts a logic low on the D input, doesn't it? What will happen when the next clock pulse occurs? The low at the D input will be transferred to the Q output and Q NOT will go high. Since the D input is connected to the Q NOT output, the D input is also high now, isn't it? What happens at the next clock pulse? The flip-flop changes state again doesn't it? Each subsequent clock pulse "flips" or "flops" the circuit to the opposite condition. This is called "toggling."

Since it takes two clock pulses to cycle the toggle circuit from one state to another and back again, a toggle circuit is very useful for dividing the frequency of a signal. For example, if a clock pulse of 1000 Hertz (1000 cycles per second) is applied to the circuit, the outputs will change at a rate of 500 Hertz. It's not unusual to see this circuit in videogames where a crystal-controlled clock frequency of more than 14 megahertz (14 million cycles per second) is divided in half by a type D flip-flop connected in a toggle circuit.

FUNCTION TABLE

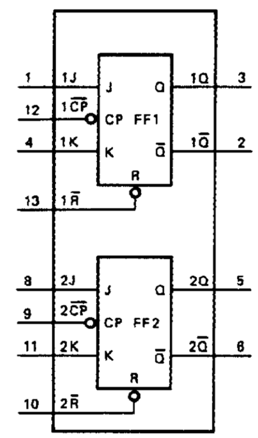
OPERATING MODE	INPUTS				OUTPUTS	
	$n\overline{R}$	$n\overline{CP}$	J	K	Q	$\overline{Q}$
asynchronous reset	L	X	X	X	L	H
toggle	H	↓	h	h	$\overline{q}$	q
load "0" (reset)	H	↓	l	h	L	H
load "1" (set)	H	↓	h	l	H	L
hold "no change"	H	↓	l	l	q	$\overline{q}$

Note

1. H = HIGH voltage level
   h = HIGH voltage level one set-up time prior to the HIGH-to-LOW CP transition
   L = LOW voltage level
   l = LOW voltage level one set-up time prior to the HIGH-to-LOW CP transition
   q = lower case letters indicate the state of the referenced output one set-up time prior to the HIGH-to-LOW CP transition
   X = don't care
   ↓ = HIGH-to-LOW CP transition

JK Flip-Flop

Another popular type of flip-flop is the type JK flip-flop. A common part is a 74107. The JK flip-flop works in much the same way as a type D flip-flop with a few enhancements and minor changes in the way it operates.



Functional diagram.

Like the type D flip-flop, the JK flip-flop has two, complimentary outputs, Q and Q NOT. It has four inputs as well. The “clear” input works the same way as it did in the type D flip-flop. The clock input works in a slightly different way, transferring data to the outputs on the falling edge of the clock pulse rather than the low to high transition of the clock as it did in the type D flip-flop.

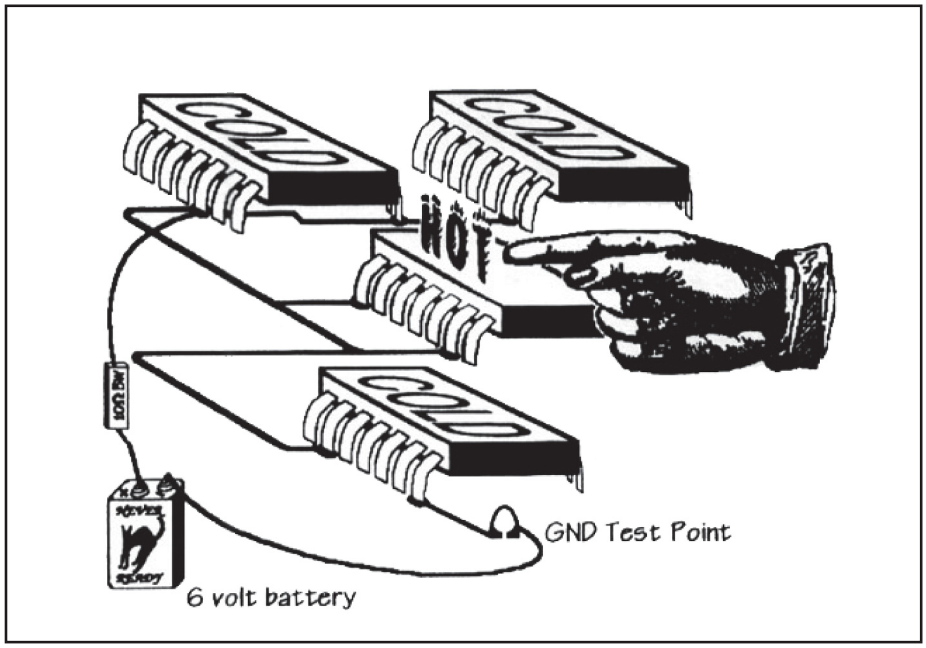
The truth table for the JK flip-flop shows you the difference between the two. When J and K are both low, the clock pulse has no effect on the outputs.

When J and K are set to opposite states, the state of the inputs is transferred directly to the associated outputs. If J is high and K is low, clocking the flip-flop makes Q high and Q NOT low. Conversely, a low on J and a high on K will cause the Q output to go low and the Q NOT output to go high following the falling or negative going edge of the clock pulse.

Making both J and K inputs high puts the JK flip-flop into the “toggle” mode. When a clock pulse is applied, the outputs change to the opposite state from what they were before the clock pulse. In other words, the first clock pulse “flips” the device while the following pulse “flops” it.

Digital Troubleshooting

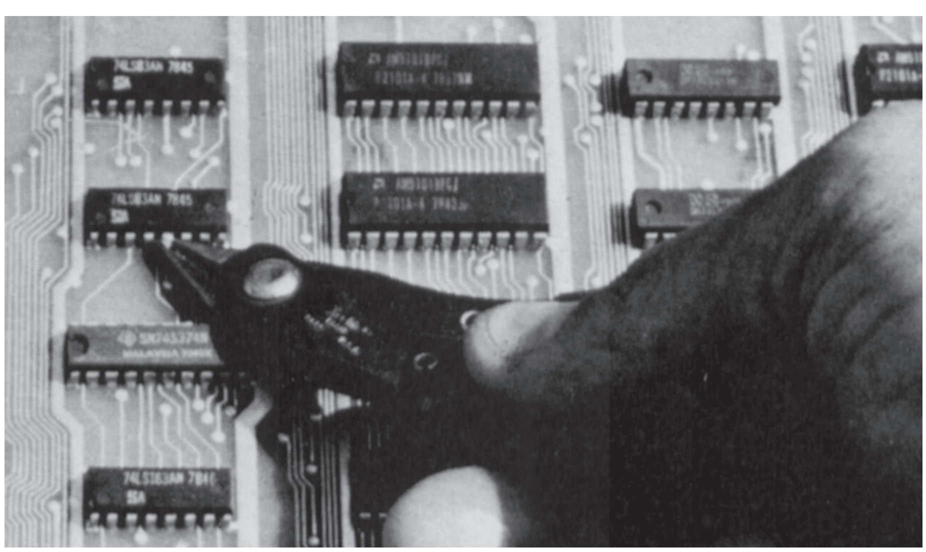
Here’s a troubleshooting tip that can be a real time saver. In general, the output of one integrated circuit will be connected to the inputs of a number of other ICs. This common connection between circuits is called a “node.” The most common IC failure is a shorted input. The input shorts almost directly to ground, bringing anything connected to it down to a logic low or, in some cases, dragging logic levels down into the gray area. The shorted input prevents that node from ever achieving a logic high.



It’s generally pretty easy to find the shorted node but how can you tell which IC is actually bad? All of the IC pins connected to the bad node will have identical signals on them when examined with an oscilloscope or logic probe. Likewise, if you try to use an ohmmeter to find the short, all pins on that node will show the exact same short circuit.

Most technicians use a technique called “clip & lift” to pinpoint the cause of the shorted node. First, the output pin is cut and lifted slightly off the surface of the printed circuit board. This isolates the output IC from all the inputs that it’s driving. If the output pin now tests good (goes to a logic high when it’s supposed to) the problem lies in one of the other ICs on the shorted node. Each input pin on the node is then clipped and lifted one at a time until the shorted input is located. Once the bad IC has been replaced, the lifted pins are pushed back down and soldered to the PCB.

Even if you’re armed with a schematic diagram, locating, clipping and lifting all the pins on a node can be a time-consuming process. Without a schematic, it can be very frustrating as well, following traces all over the board in an effort to track down the shorted chip.



Clipping the pin to isolate a short

I discovered this trick by accident as I was trying to develop a fast way to find a single shorted IC on a common node without having to have a detailed knowledge of digital electronics. My original idea was to inject a DC voltage into the shorted node and use a digital multimeter to measure tiny differences in voltage at each pin on the node. The lowest voltage was to have indicated the location of the shorted pin.

I used a 6-volt battery as my DC source. To limit the current, I used a 10-ohm, 5-watt resistor in series with the battery. I prefer to use a battery for this test because it has a limited output current and it's a completely isolated source. However, I have no doubt that the 5-volt output of a power supply would work fine as well.

I found the bad IC all right, but not by measuring the voltage as planned. I found the bad IC because the damned thing nearly burned my hand when it touched it. It was hot, Hot, HOT! Since current will only flow through the short and not through any other connection on the node, the other integrated circuits will remain cold. Only the bad chip will get hot.

Just use some clip leads to connect the battery as shown in the illustration. Radio Shack has some clip leads that will enable you to connect directly to one of the pins on the shorted node. It does not matter which pin you connect. Any pin on the shorted node will do nicely. Remember, only the shorted pin will actually draw current and get hot.

- STM

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