

# Integrated Circuits (IC's), Circuit Trainers, and Power Supplies

Version 1.2

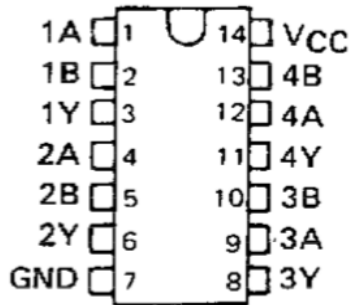
Conor Csongradi, Lacie Flores, Ryan Schick, and JT Wunderlich PhD, editor

May 15, 2018

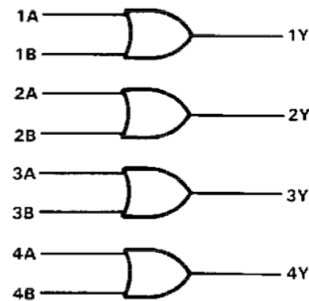
## Integrated Circuits (IC's) "Chips"

The E273 lab is equipped various **TTL** (Transistor-Transistor-Logic) SSI (Small Scale Integration) IC's (Integrated Circuit) "Chips" . Below is a list of IC's usually found in the lab, Remember that TTL chips require 5Volts DC to operate (unlike CMOS chips used for the old radio shack circuit trainer found in the lab)

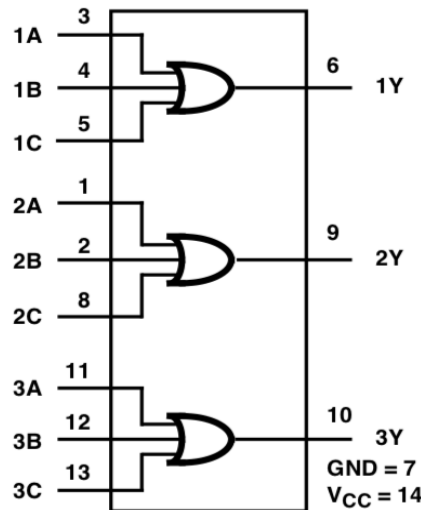
### 2 Input OR (SN74LS32N):



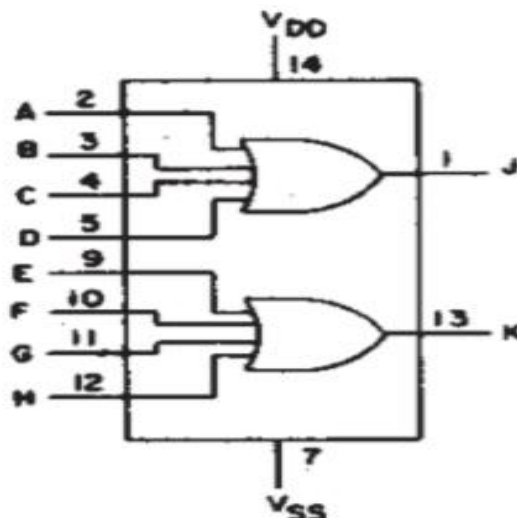
logic diagram



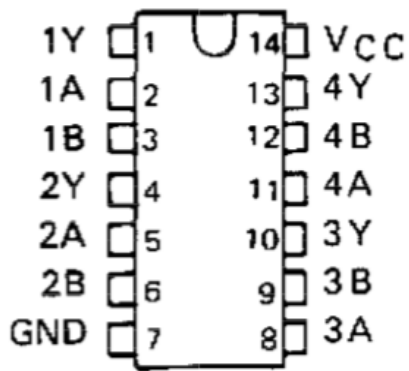
### 3 Input OR (CD74HC4075E):



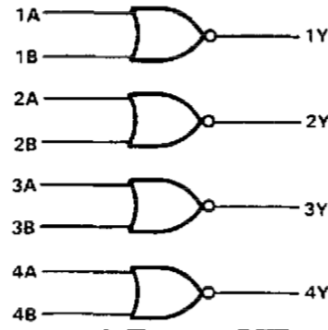
### 4 Input OR (CD4072BE):



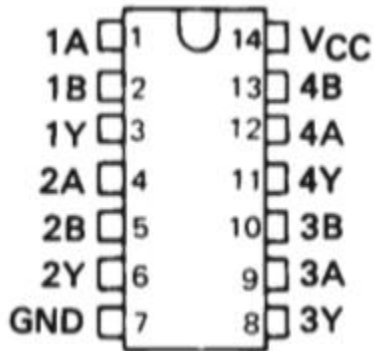
**2 Input NOR (SN7402N):**



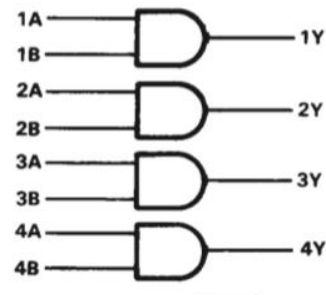
**logic diagram (positive logic)**



**2 Input AND (SN74LS08N):**

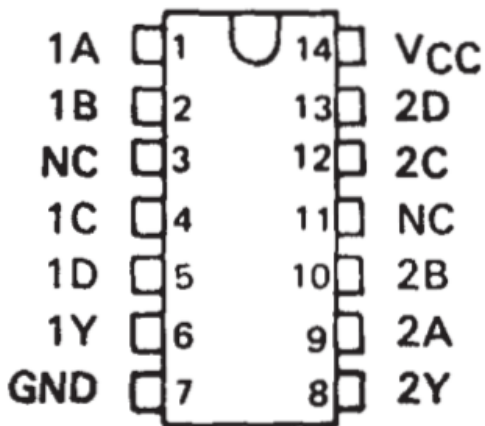


**logic diagram (positive logic)**

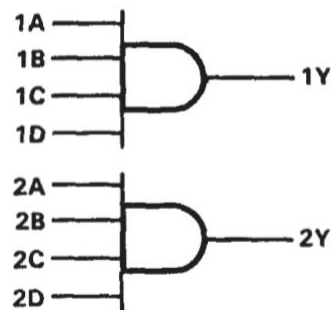


**3 Input AND:**

**4 Input AND (SN74LS21N):**

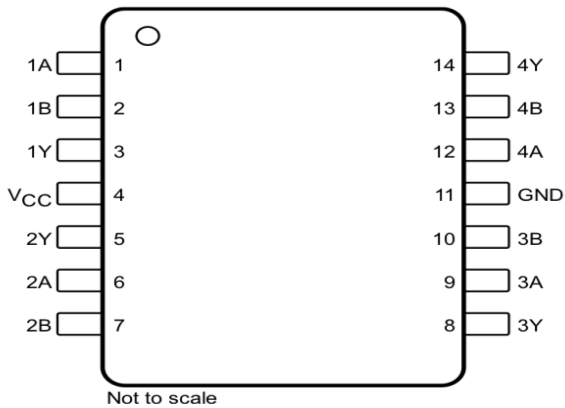


**logic diagram**



## 2 Input NAND (SN74LS00N):

SN74xx00 PS Package  
18-Pin SO  
Top View

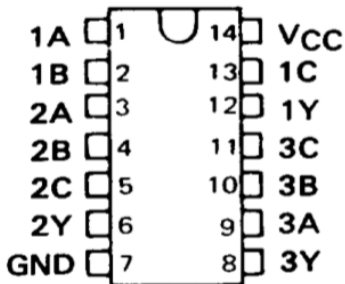


## Logic Diagram, Each Gate (Positive Logic)



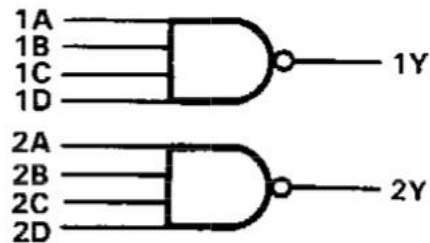
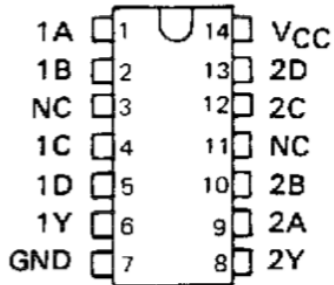
## 3 Input NAND (SN74LS10N):

(TOP VIEW)

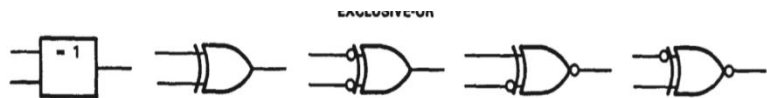
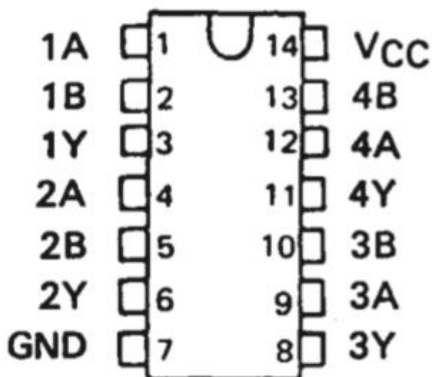


## 4 Input Quad NAND (74LS20):

logic diagram

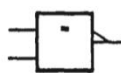


## 2 Input XOR (SN74LS86AN):



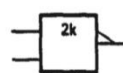
These are five equivalent Exclusive-OR symbols valid for an '86 or 'LS86A gate in positive logic; negation may be shown at any two ports.

LOGIC IDENTITY ELEMENT



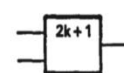
The output is active (low) if all inputs stand at the same logic level (i.e.,  $A=B$ ).

EVEN-PARITY



The output is active (low) if an even number of inputs (i.e., 0 or 2) are active.

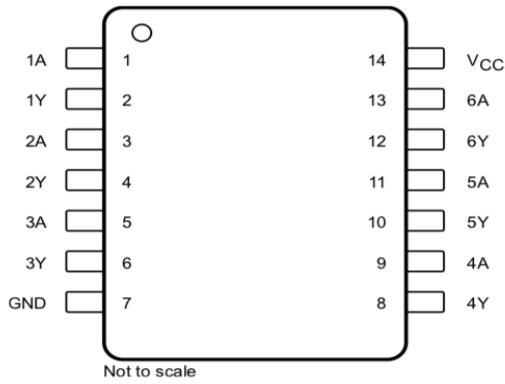
ODD-PARITY ELEMENT



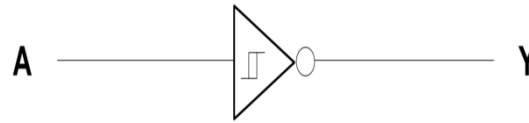
The output is active (high) if an odd number of inputs (i.e., only 1 of the 2) are active.

## Inverter (SN74LS14N):

Top View

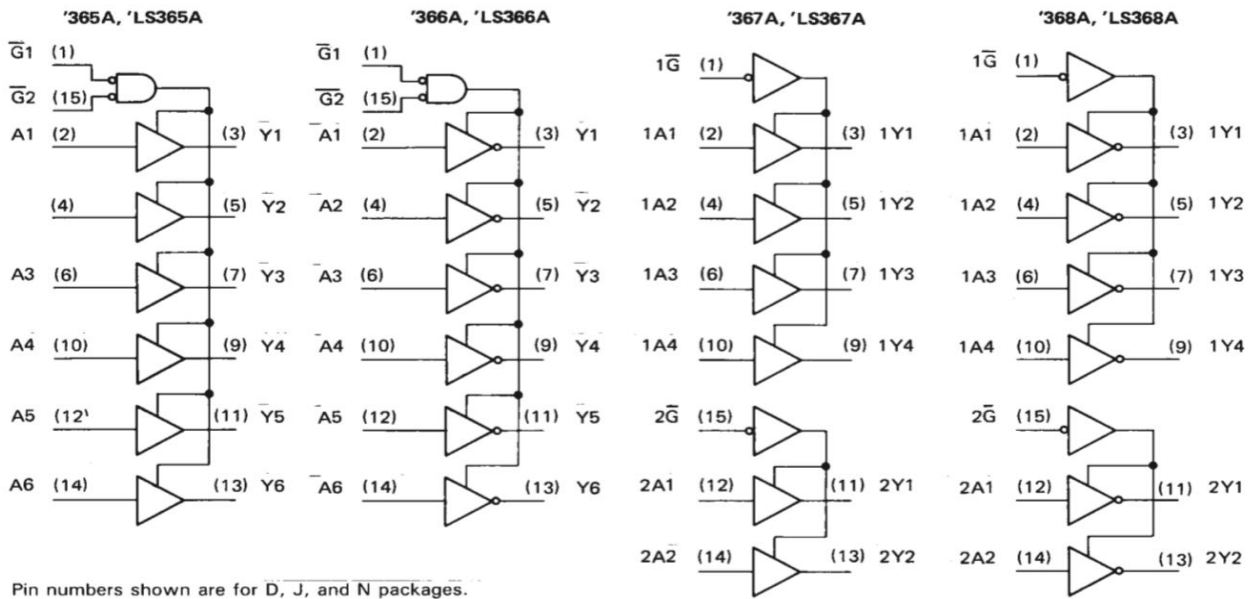


Logic Diagram (Positive Logic)

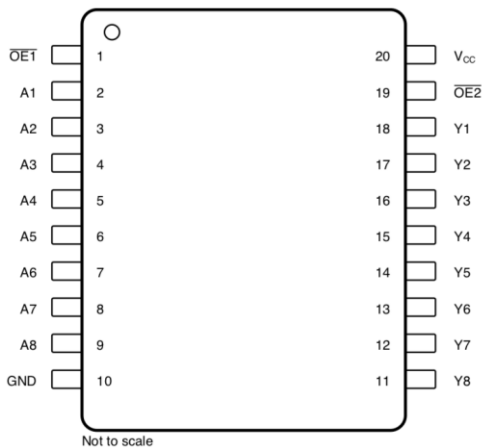


## Hex Busdriver with 3-State Outputs (74367AN):

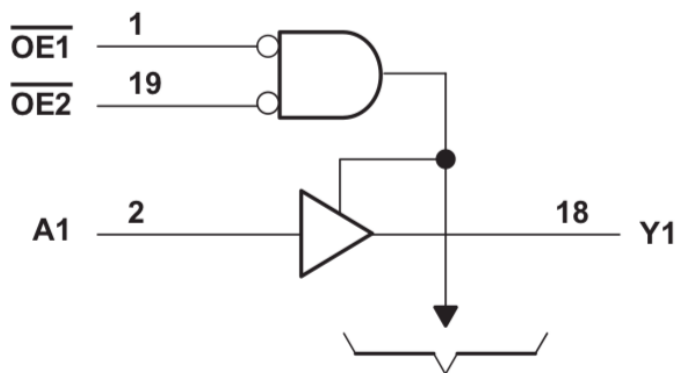
logic diagrams (positive logic)



## Buffer/Drivers 3-States (SN74HC541N):

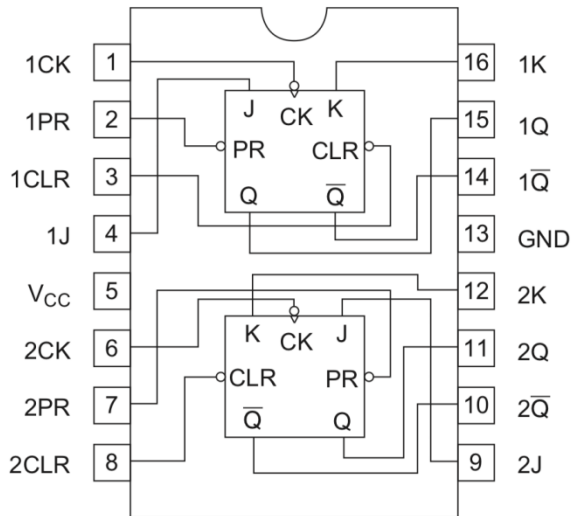


Logic Diagram (Positive Logic)

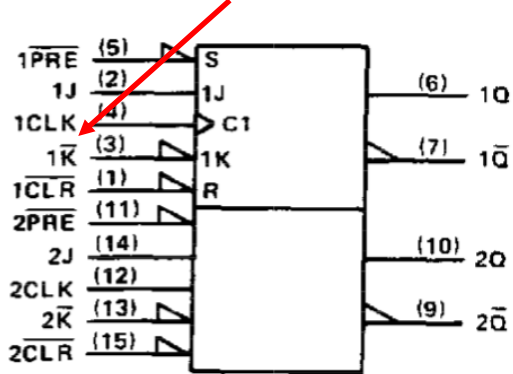


To Seven Other Channels

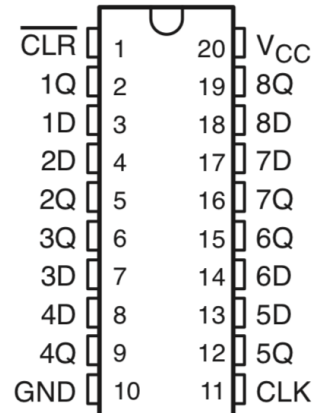
### JK Flip Flop (HD74LS76AP):



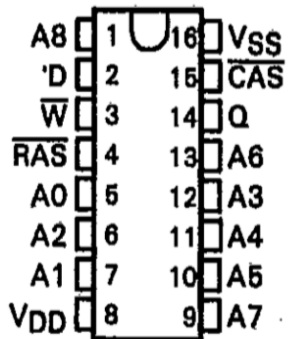
### JK Naught (i.e., J not-K Flip Flop (SN74LS109AN):



### D Flip Flop (SN74LS273N):



### DRAM (TMS425612N)



## Excitation Tables for Flip-Flops

Excitation tables can be used to determine the inputs of the flipflops when the present state ( $Q(t)$ ) and the next state ( $Q(t+1)$ ) are known.

SR Flip-flop				D Flip-flop		
$Q(t)$	$Q(t+1)$	S	R	$Q(t)$	$Q(t+1)$	DR
0	0	0	X	0	0	0
0	1	1	0	0	1	1
1	0	0	1	1	0	0
1	1	X	0	1	1	1

JK flip-flop				T flip-flop		
$Q(t)$	$Q(t+1)$	J	K	$Q(t)$	$Q(t+1)$	DR
0	0	0	x	0	0	0
0	1	1	x	0	1	1
1	0	x	1	1	0	1
1	1	x	0	1	1	0

## JK Naught Excitation Table

$Q(t)$	$Q(t+1)$	J	$\bar{K}$
0	0	0	X
0	1	1	X
1	0	X	0
1	1	X	1

# TRANSISTORS

by JT Wunderlich PhD

**ATOM:** Smallest particle of a substance that can exist by itself or be combined with other atoms to form a molecule

**MOLECULE:** Smallest particle of a substance that retains all properties of the substance and is composed of one or more atoms

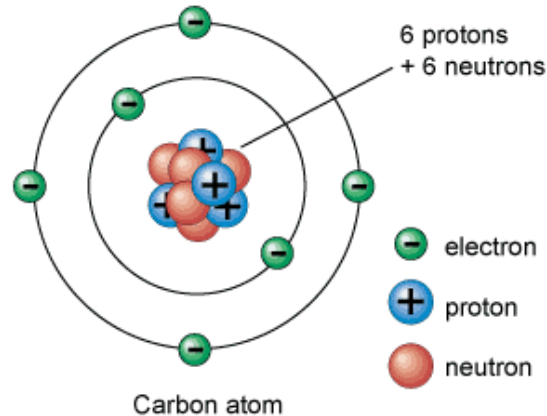
From: <http://www.merriam-webster.com/dictionary/atom> :

**CRYSTAL LATTICE STRUCTURE:** a unique arrangement of [atoms](#) or [molecules](#) in a [crystalline liquid](#) or [solid](#).<sup>[1]</sup> A crystal structure describes a highly ordered structure, occurring due to the intrinsic nature of molecules to form symmetrical patterns. A crystal structure can be thought of as an infinitely repeating array of 3D 'boxes', known as unit-cells.

From [http://en.wikipedia.org/wiki/Crystal\\_structure](http://en.wikipedia.org/wiki/Crystal_structure)

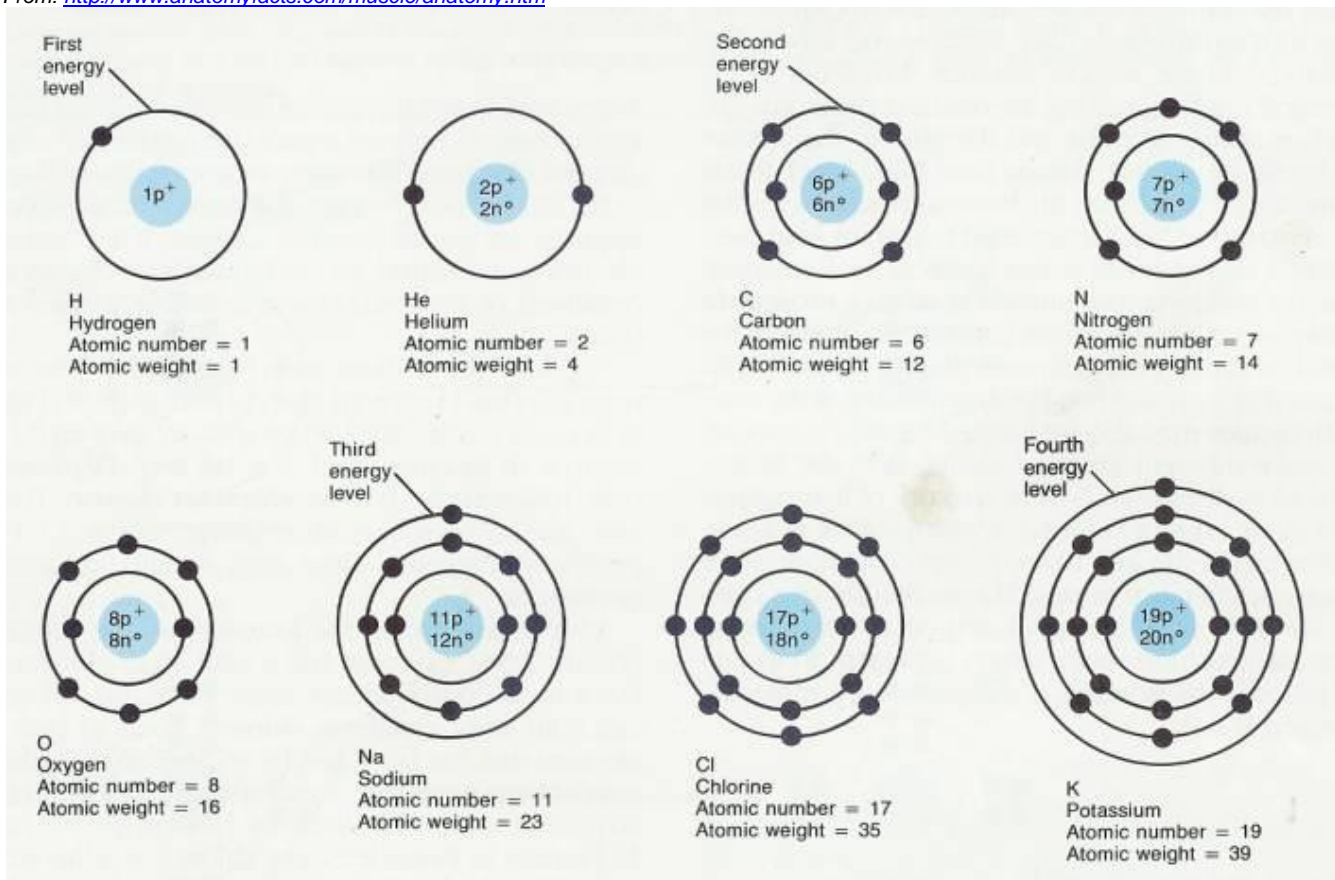
Anatomy of an Atom (Bohr Model); electrons circling a nucleus containing protons and neutrons.

From: <http://www.freethought-forum.com/forum/showthread.php?t=24978&garpq=2>



Electrons are in *shells (Energy Levels)* around nucleus, with a certain number of electrons that fit into each shell. The outer shell is called the **valence shell**.

From: <http://www.anatomyfacts.com/muscle/anatomy.htm>



PERIODIC TABLE is a grid of every element that exists, arranged in order of atomic number, the number of protons each atom has in its nucleus. The **rows are called PERIODS and all have the same number of shells**; and the **columns called GROUPS which all have the same number of electrons in their outermost shell**. Hydrogen (H) is the first element because it has just one proton in its nucleus. Helium (He) is second, because it has two. As you go across a period, atoms get heavier, but also get smaller because the number of electron shells stays the same across the period, but the number of protons in the nucleus increases. The stronger, attractive force from the positively charged protons sucks the negatively charged electrons tighter into the centre.

From <http://www.infoplease.com/dk/science/encyclopedia/periodic-table.html>

1 H Hydrogen 1																	2 He Helium 4
3 Li Lithium 7	4 Be Beryllium 9											5 B Boron 11	6 C Carbon 12	7 N Nitrogen 14	8 O Oxygen 16	9 F Fluorine 19	10 Ne Neon 20
11 Na Sodium 23	12 Mg Magnesium 24											13 Al Aluminum 27	14 Si Silicon 28	15 P Phosphorus 31	16 S Sulphur 32	17 Cl Chlorine 35	18 Ar Argon 40
19 K Potassium 39	20 Ca Calcium 40	21 Sc Scandium 45	22 Ti Titanium 48	23 V Vanadium 51	24 Cr Chromium 52	25 Mn Manganese 55	26 Fe Iron 56	27 Co Cobalt 59	28 Ni Nickel 58	29 Cu Copper 63	30 Zn Zinc 64	31 Ga Gallium 69	32 Ge Germanium 74	33 As Arsenic 75	34 Se Selenium 80	35 Br Bromine 79	36 Kr Krypton 84
37 Rb Rubidium 85	38 Sr Strontium 88	39 Y Yttrium 89	40 Zr Zirconium 90	41 Nb Niobium 93	42 Mo Molybdenum 98	43 Tc Technetium 97	44 Ru Ruthenium 102	45 Rh Rhodium 103	46 Pd Palladium 106	47 Ag Silver 107	48 Cd Cadmium 114	49 In Indium 115	50 Sn Tin 120	51 Sb Antimony 121	52 Te Tellurium 130	53 I Iodine 127	54 Xe Xenon 132
55 Cs Caesium 133	56 Ba Barium 138	57-71	72 Hf Hafnium 180	73 Ta Tantalum 181	74 W Tungsten 184	75 Re Rhenium 187	76 Os Osmium 192	77 Ir Iridium 193	78 Pt Platinum 195	79 Au Gold 197	80 Hg Mercury 202	81 Tl Thallium 205	82 Pb Lead 208	83 Bi Bismuth 209	84 Po Polonium 209	85 At Astatine 210	86 Rn Radon 222
87 Fr Francium 223	88 Ra Radium 226	89-103	104 Unq Unnilquadium 260	105 Unp Unnilpentium 262	106 Unh Unnilhexium 263	107 Uns Unnilseptium 262	108 Uno Unniloctium 265	109 Uue Unnilennium 266									
57 La Lanthanum 139	58 Ce Cerium 140	59 Pr Praseodymium 141	60 Nd Neodymium 142	61 Pm Promethium 145	62 Sm Samarium 152	63 Eu Europium 153	64 Gd Gadolinium 158	65 Tb Terbium 159	66 Dy Dysprosium 164	67 Ho Holmium 165	68 Er Erbium 168	69 Tm Thulium 169	70 Yb Ytterbium 174	71 Lu Lutetium 175			
89 Ac Actinium 227	90 Th Thorium 232	91 Pa Protactinium 231	92 U Uranium 238	93 Np Neptunium 237	94 Pu Plutonium 244	95 Am Americium 243	96 Cm Curium 247	97 Bk Berkelium 247	98 Cf Californium 251	99 Es Einsteinium 254	100 Fm Fermium 257	101 Md Mendelevium 258	102 No Nobelium 255	103 Lr Lawrencium 256			

**Atomic number**  
is the number of protons in the atom's nucleus

32

**Ge**

Germanium

74

**Symbol**  
is used as a short-hand and in chemical equations

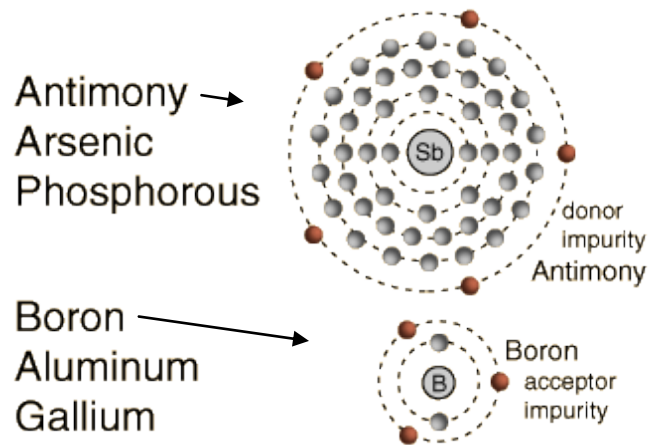
**Mass number**  
is the number of protons and neutrons in the nucleus

**A SEMICONDUCTOR can be either a single element (like Silicon, Si), or a compound (like Gallium Arsenide, GaAs) Semiconductors are not conductors of electricity like gold (a metal), and not an insulator which prevents electricity from flowing. Semiconductors are useful because they can be “doped” to control electrical properties and to make transistors, the basic building blocks of computers.**



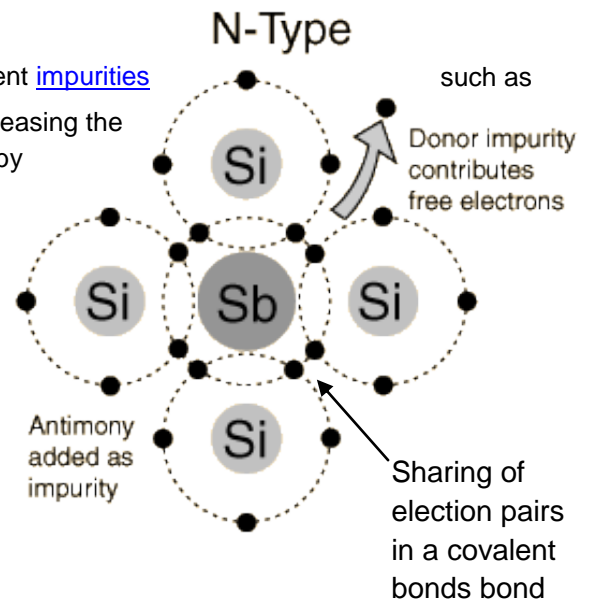
# The Doping of Semiconductors

The addition of a small percentage of foreign atoms in the regular [crystal lattice](#) of silicon or germanium produces dramatic changes in their electrical properties, producing [p-type](#) semiconductors. Impurity atoms with 5 [valence electrons](#) produce n-type semiconductors by contributing extra electrons.



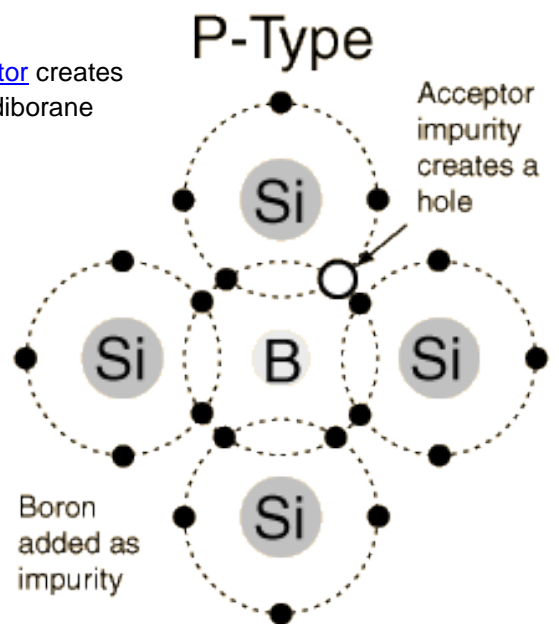
## N-Type Semiconductor

The addition of pentavalent [impurities](#) such as antimony, arsenic or phosphorous contributes free electrons, greatly increasing the conductivity of the [intrinsic semiconductor](#). Phosphorous may be added by diffusion of phosphine gas ( $\text{PH}_3$ ).



## P-Type Semiconductor

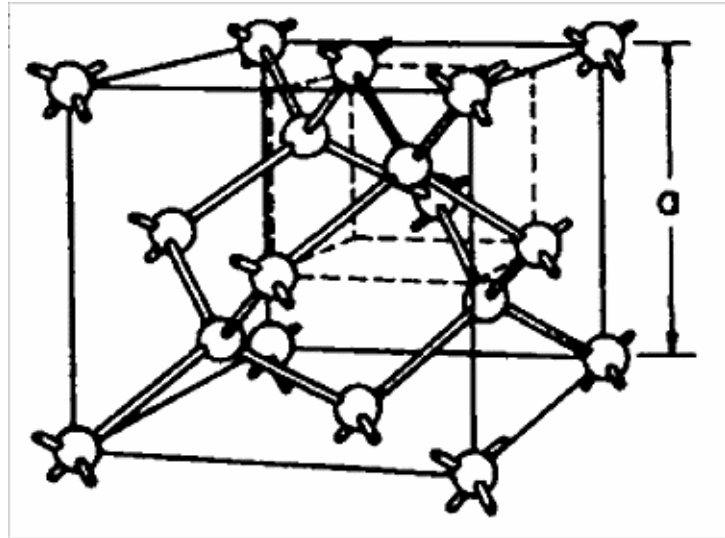
The addition of trivalent [impurities](#) such as boron, aluminum or gallium to an [intrinsic semiconductor](#) creates deficiencies of valence electrons, called "holes." It is typical to use  $\text{B}_2\text{H}_6$  diborane gas to diffuse boron into the silicon material.



From: <http://hyperphysics.phy-astr.gsu.edu/hbase/solids/dope.html#c3> :

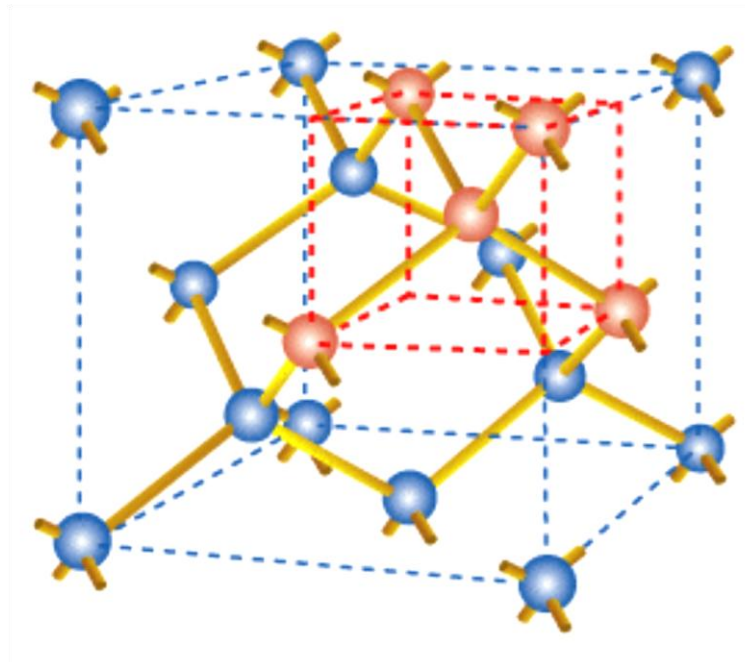
## **Silicon LATTICE STRUCTURE (un-Doped)**

From: <http://www.irf.com/technical-info/guide/semi.html>



## **Silicon LATTICE STRUCTURE (Doped)**

From: <https://sites.google.com/site/reeetech/home/photovoltaic/silicon-cell>



# Combine N and P type materials to make Transistors (and Diodes)

From: <http://content.aviation-safety-bureau.com/allmembers/faa-h-8083-31-amt-airframe-vol-2/sections/chapter-11.php>

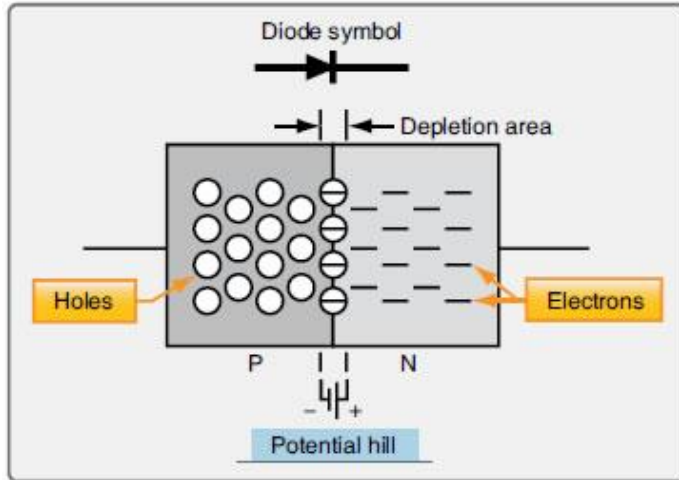


Figure 11-19. A potential hill.

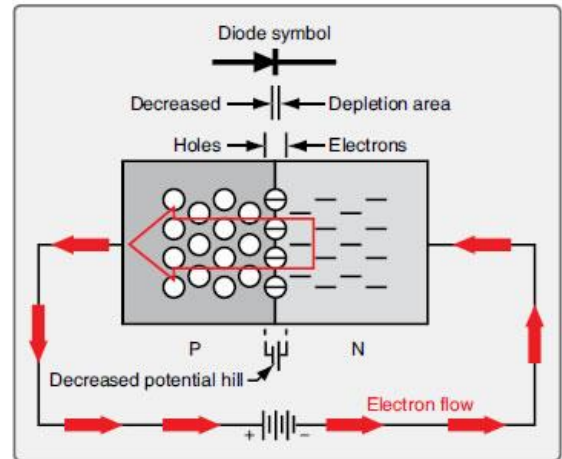


Figure 11-20. The flow of current and the P-N junction of a semiconductor diode attached to a battery in a circuit.

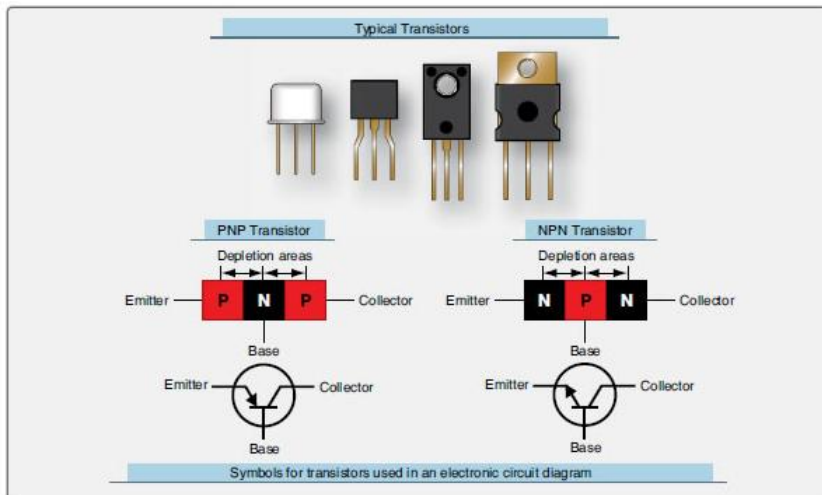


Figure 11-26. Typical transistors, diagrams of a PNP and NPN transistor, and the symbol for those transistors when depicted in an electronic circuit diagram.

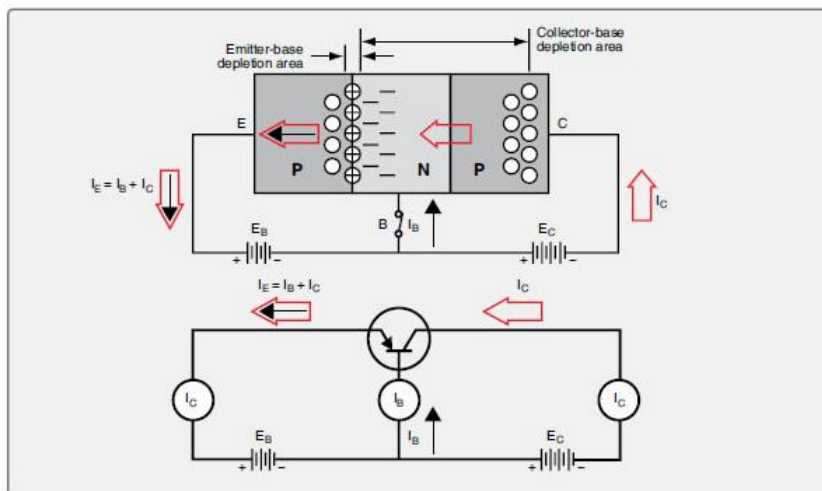


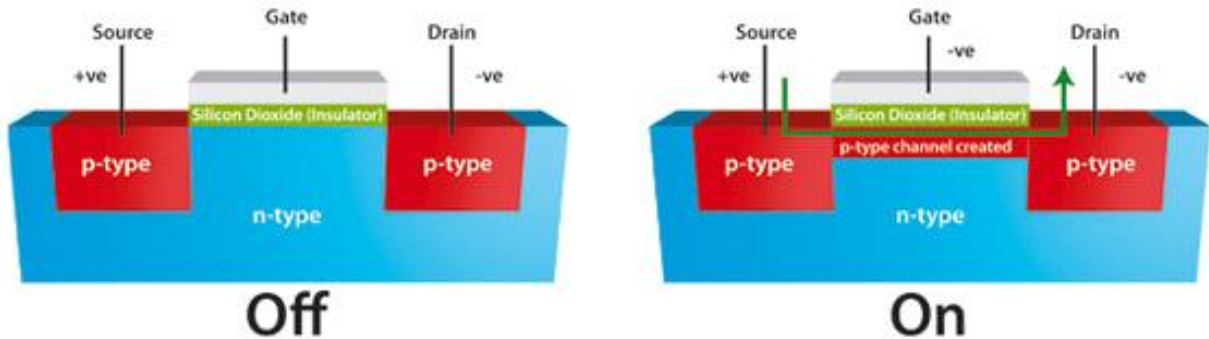
Figure 11-27. The effect of applying a small voltage to bias the emitter-base junction of a transistor (top). A circuit diagram for this same transistor (bottom).

NOTE: This is one kind of transistor, called a **Bipolar Junction Transistor (BJT)**

## Another type of Transistor is a Field Effect Transistor (FET)

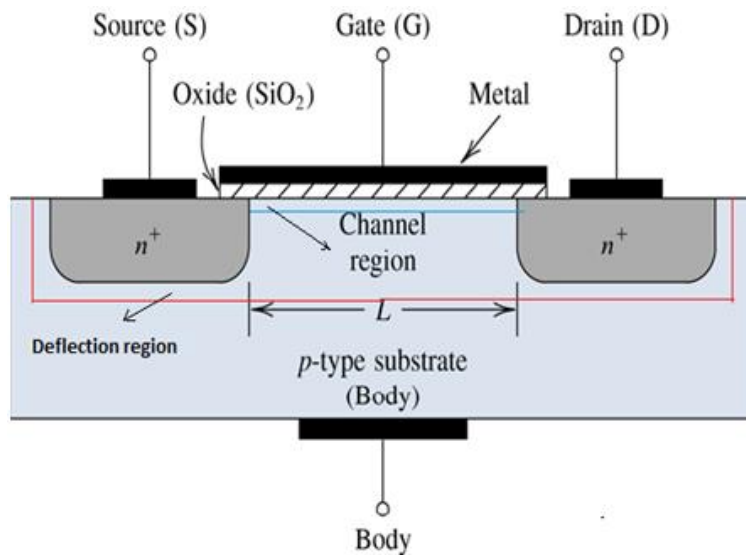
When a voltage is applied to the gate, a magnetic FIELD is created below the gate, which creates a conducting channel between the Source and Drain.

From: <http://www.rignitc.com/mosfets/>



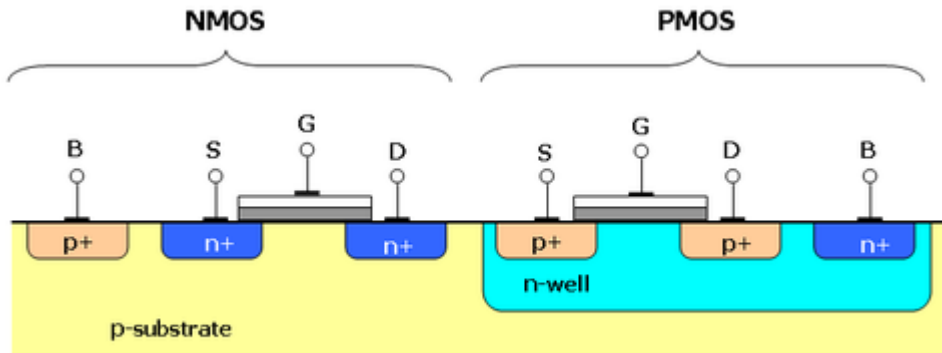
These are called Metal Oxide Semiconductors (MOS), i.e., **MOSFET's**

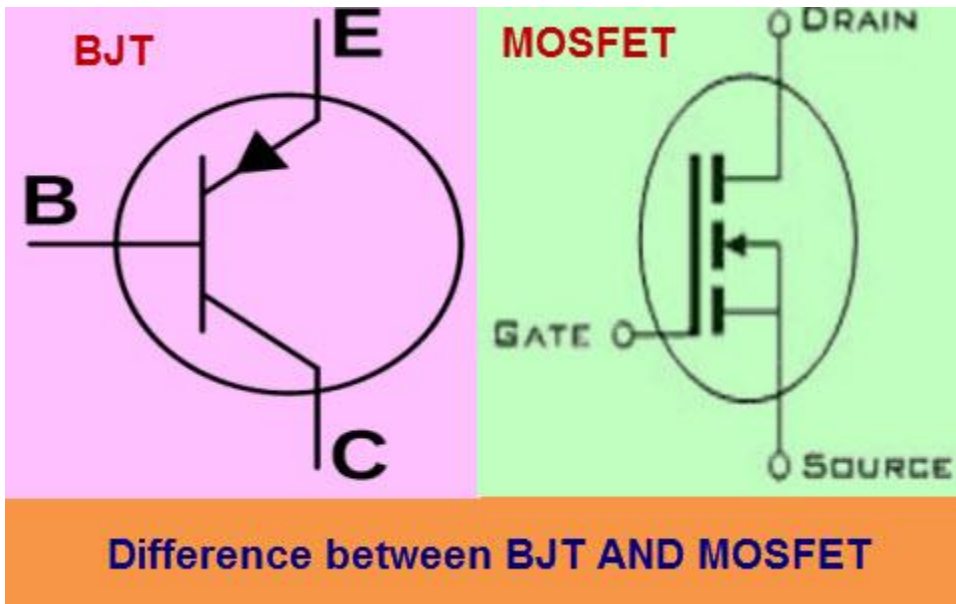
From: <https://www.elprocus.com/mosfet-as-a-switch-circuit-diagram-free-circuits/>



p-MOS has an N substrate, and n-MOS has a P substrate; and they are combined to make CMOS (i.e., Complementary Metal Oxide Semiconductor) circuits

From: <https://allthingsvlsi.wordpress.com/2013/04/04/nmos-and-pmos-operating-regions/>





From: <https://www.elprocus.com/difference-between-bjt-and-mosfet/>

### **BJT Functionality:**

**Apply small current from Base(B) to Collector(C) to get larger current from Emitter(E) to Collector(C)**

### **MOSFET Functionality:**

**Apply voltage to Gate(G) to create a magnetic field that creates a conducting channel between the Source(S) and the Drain(D), allowing current to flow between S and D.**

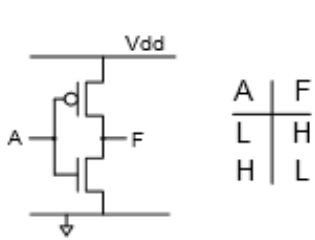
# DIGITAL LOGIC GATES

Made with either BJT's (usually in TTL circuits, i.e., Transistor-Transistor-Logic) or with FET's in CMOS circuits.

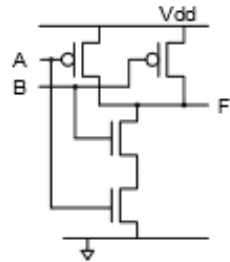
Here are CMOS Logic Gates:

( L= Low = Logic-0, H = High = Logic-1 )

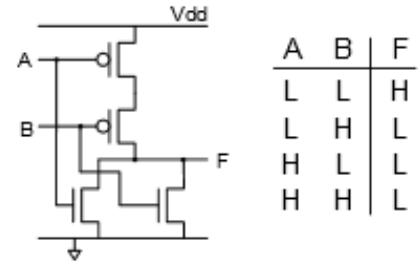
From <https://learn.digilentinc.com/Documents/313>



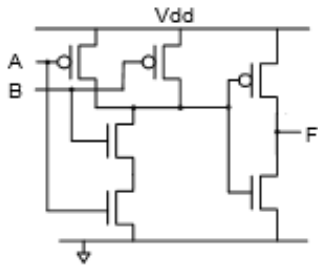
CMOS INVERTER



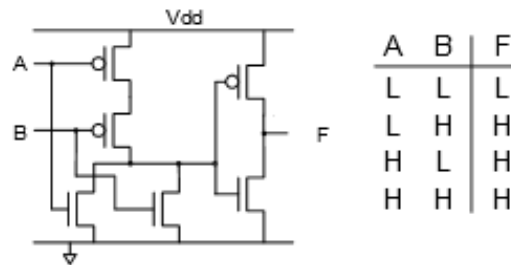
CMOS NAND



CMOS NOR

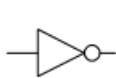


CMOS AND

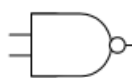


CMOS OR

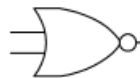
## Digital Logic Gate Symbols



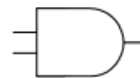
INV



NAND



NOR



AND



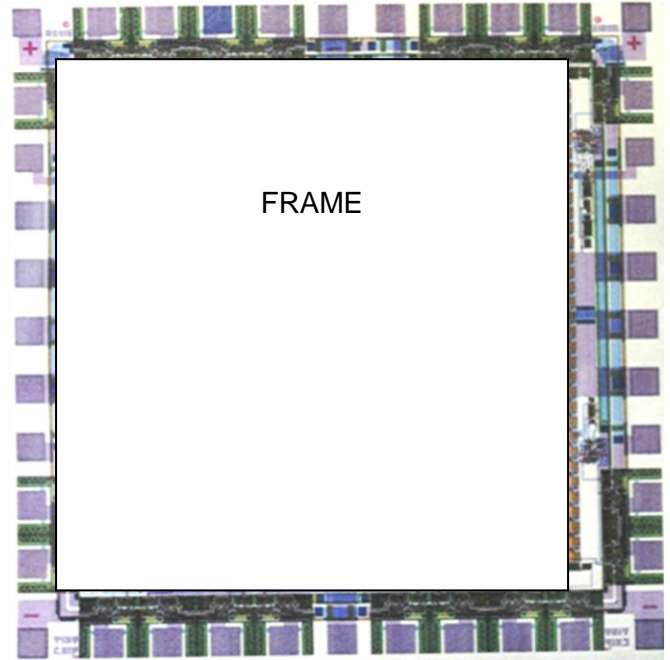
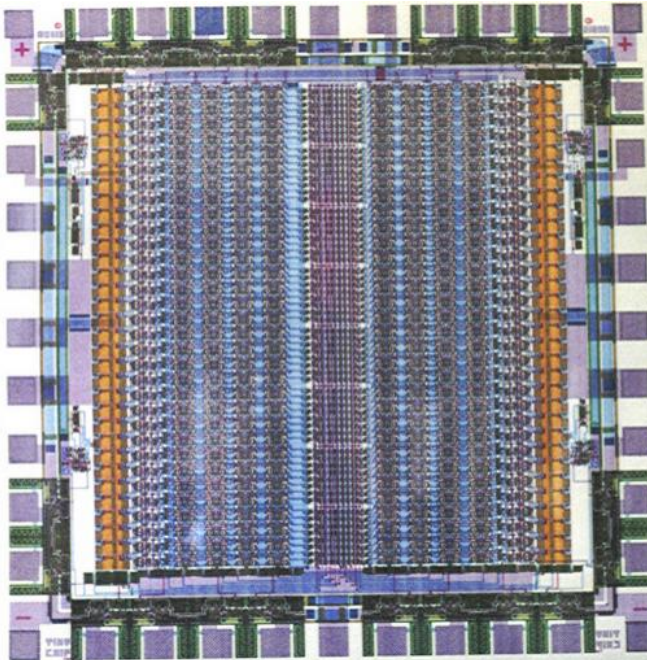
OR

# CMOS (2.5, 3.3, 5, up to 18 volts) vs. BiPolar (5 volts) Transistor Circuits

## Artificial Dendrite Tree Neural Network Chip (J. Wunderlich et.al.1992):

(5 volt CMOS Logic) in a 5 volt Frame (pad circuits for pin connections) supplied by "Mosis Tiny-chip" Manufacturer (USC)

- Chip Pin-Out circuits can be either special CMOS (Complimentary Metal Oxide Semiconductor) FET's (Field Effect Transistors) or BiPolar BJT's (BiPolar Junction Transistors) to source more output current and to absorb more input voltage spikes

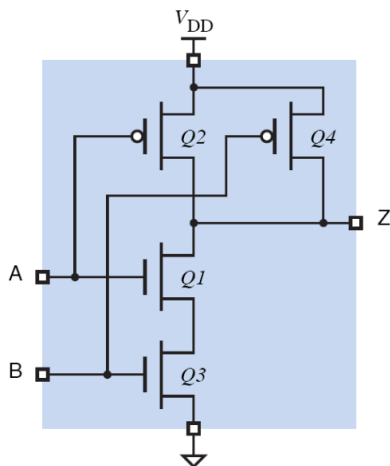


The following is from [http://www.engr.uconn.edu/~zshi/course/cse2300/lecture2\\_gates.pdf](http://www.engr.uconn.edu/~zshi/course/cse2300/lecture2_gates.pdf) :

CMOS families:

- 4000 series
- 7400 series:
  - 74HC (high-speed CMOS),
  - 74HCT(High-speed CMOS, TTL compatible)
  - 74AC(Avanced CMOS)
  - 74ACT(Advanced CMOS, TTL compatible)
  - 74FCT(Fast CMOS, TTL compatible)
  - 74FCTT(Fast CMOS, TTL compatible with TTL)

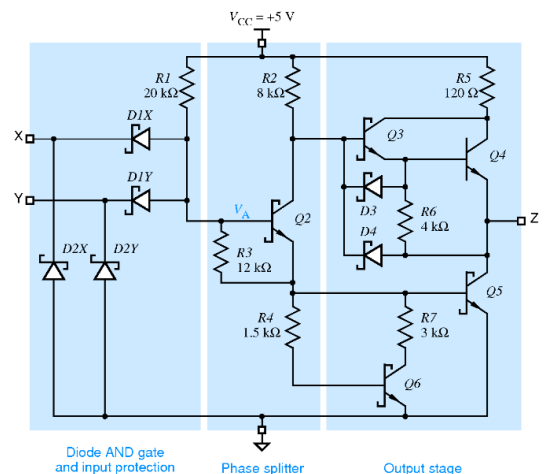
### CMOS NAND gate



A	B	Q1	Q2	Q3	Q4	Z
L	L	off	on	off	on	H
L	H	off	on	on	off	H
H	L	on	off	off	on	H
H	H	on	off	on	off	L



### Example of LS-TTL gates: 2-input NAND



# FOR THIS COURSE USE ONLY THE 5 VOLT SUPPLY TO POWER CHIPS

The Following information is excerpted from [http://www.elexp.com/tst\\_234.htm](http://www.elexp.com/tst_234.htm)

## PAD - 234 ANALOG / DIGITAL TRAINER



1. This manual should be read thoroughly before engaging in any experimentation.
2. As a general rule, NEVER construct a circuit or insert any wiring with the PAD unit ON.
3. Construct the circuit. Double check your wiring. Then apply power to the circuit.
4. Should a problem occur. Turn the unit off immediately. Unplug the PAD and notify your instructor.
5. In the event this unit needs repairs, notify your instructor.

**DO NOT ATTEMPT TO REPAIR THIS UNIT YOURSELF!!!**



# MAINTENANCE OF THE PAD 234 ANALOG DIGITAL TRAINER

**\*\*\* CAUTION \*\*\***

## FUSE REPLACEMENT

1. Before replacing the fuse be sure that the power switch is in the off position and unplug the pad !!
2. Use only MDL 0.5 amp fuses.
3. Unscrew the black cap on the right side panel of the PAD unit and remove bad fuse. Replace with the correct fuse in the same manner.

**\*\*\*\*\* WARNING \*\*\*\*\***

**Do not use all sources simultaneously !!**

**keep liquids away from the PAD unit !!**

**Do not use near flammable materials !!!**

## POWER SUPPLY

- (+) and (-) 12 volt regulated power supply, with 500 ma short circuit protection.
- (+) 5 volt regulated power supply, with 1 amp short circuit protection.
- (+) and (-) 15 volt variable supply (from 1.5 V to 15V) with 1.5 amp short circuit protection.
- (+)12.6 Volt AC center tap power supply.

## FUNCTION GENERATOR

- Sine, square, and triangle output wave shape.  
1 Hz to 100 Khz in 5 ranges, uncalibrated, buffered, adjustable output 0 to 15 volts peak to peak.

## CLOCK OUTPUT (TTL)

- Frequency determined by COARSE FREQUENCY FINE FREQUENCY adjustment knob. Rise and fall time is 400 ns.

## INDICATORS

- 8 BUFFERED TTL compatible LED'S.

## SWITCHES

- 8 binary toggle switches (0 or 5 Volts)  
2 momentary pulse switches, debounced with complimentary outputs

## BREADBOARDS

- 2 breadboards with 840 plug-in tie points each.

## POWER CONSUMPTION

- 117 Volts at .5 Amps

## ADDITIONAL FEATURES

- High impact plastic case with a 3-wire grounded line cord. Fuse protected AC line.

## OPERATION

- DC POWER SUPPLY**
- +5, +12, -12, located in the vertical row of binding posts, positioned along the left side of the breadboards.
- Use of 5V Supply
- Connect the load between the binding post and the GND (ground).
- Use of + 12V
- Connector the load between the Binding Post marked + 12V and the Binding Post marked GND (ground).
- Use of -12V
- Connect the load between the Binding Post marked - 12V and the Binding Post marked GND (ground) .
- VARIABLE DC SUPPLY**
- Located above left to the main breadboards and identified as + 15V, controlled by the appropriate knobs. (Lower left hand corner of the top plate.)
- Using the + 15V
- Connect the load between the tie blocks identified as + 15 V and OV (ground). Use the knob marked + 15V to control the output voltage of this tie block.
- Using the -15V
- Connect the load between the tie block identified as - 15V and OV (ground). Use the knob marked - 15V to control the output voltage of this tie block.
- AC POWER SUPPLY**
- Located above right to the main breadboards and identified as AC Volts.
- Using the 6.3 VAC
- Connect the load between the tie block identified as 6.3 and 0 (ground).
- Using the 12.6 VAC
- Connect the load between the tie blocks marked 6.3 and 6.3.
- FUNCTION GENERATOR**
- The output for the GENERATOR and CLOCK are located in the top two Binding posts in the vertical row, on the left hand side of the breadboards marked GEN and CLOCK.
  - The generator and clock outputs are controlled by the five knobs located on the far left hand side of the PAD unit and marked accordingly.

Before using the Generator or Clock output in an actual circuit, familiarize yourself with the functions of the five control knobs and the effects they have on the output waveforms.

Connect an oscilloscope to the GEN Binding post and GND Binding post as described above. Adjust the O-scope as necessary to observe a clearly visible waveform.

By using the five control knobs observe how you are able to adjust the output waveforms, by using these controls. *(See the section below labeled "Using the Generator".*

### Using the CLOCK

- Connect the load between the Binding posts . marked CLOCK and GND (ground).
- Select the appropriate frequency using the knob marked COARSE FREQUENCY.
- Adjust to the exact frequency using the knob marked FINE FREQUENCY.

### Using the GENERATOR

- Connect the load between the Binding Posts marked GEN (Function Generator) and GND (ground) .

1. Select the type of waveform required by using the top left knob.
2. Set the COARSE FREQUENCY knob to the correct range.
3. Fine tune the frequency (using the knob marked FINE FREQUENCY) to the exact frequency required.
4. Adjust the amplitude (using the AMPLITUDES) knob to adjust the output voltage maintaining a clear waveform.
5. Adjust the offset as needed with the bottom control knob marked OFFSET.

### DIGITAL SECTION

- Located across the top of the PAD
- This section includes eight manual toggle switches, eight LED tie blocks and two pulse switches.

### Using the Toggles

- Connect the device between the tie block to be used (numbered 0 to 7) and GND (ground) .
- When the toggle switch is in the up position, +5 volts is supplied to the device. When the switch is in the down position 0 volts is applied.

### Using the LED Tie

- Connect the device to the tie block directly under the LED to be used. When + 5V is applied the LED will light, when 0 is applied it will be off.

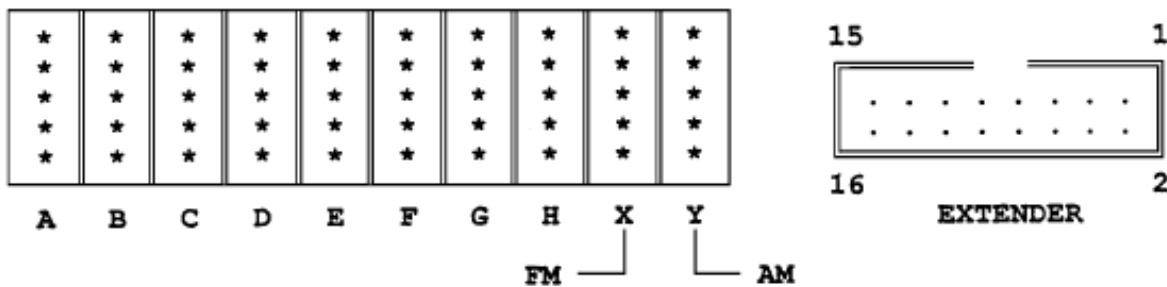
### Using the Momentary

- For + 5V pulse connect the device to the tie block marked 0. When the switch is pulsed the output at the tie block will be +5V. For 0 V pulse, connect the device to the tie block marked 1. +5 V will be applied to the point block till the switch is pulsed, then the output will be 0 V.

To become more familiar with the toggle switches and LED tie points, take a piece of wire and connect between one of the Toggle tie point blocks and one of the LED tie point blocks. Flip the switch and observe that voltage is being applied, lighting the LED.

Repeat this procedure using the momentary pulse switches.

## PAD 234 EXTENDER DESCRIPTION

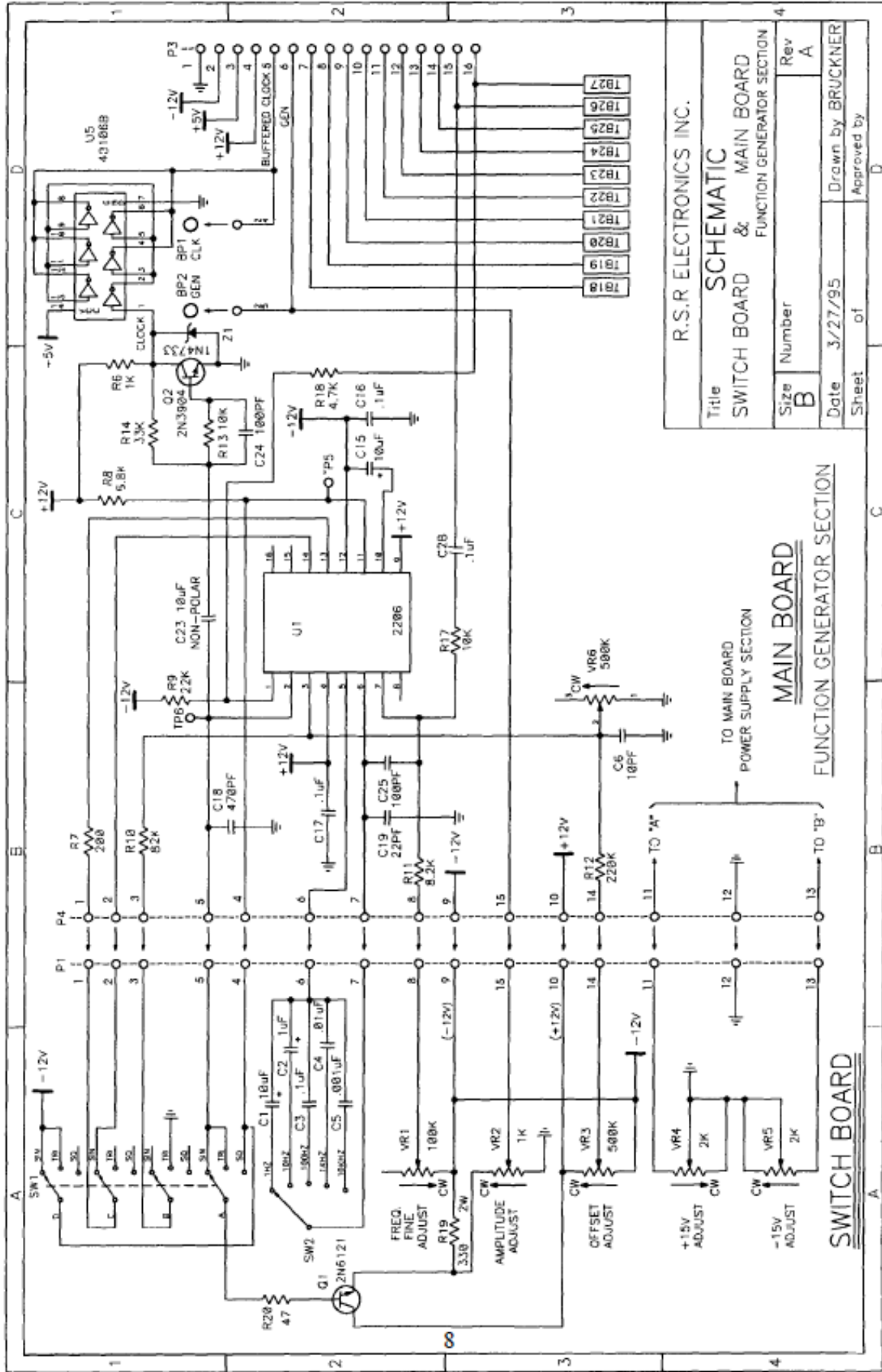


EXTENDER PIN	TIE BLOCK	FUNCTION
1	-	GROUND
2	-	- 12 V
3	-	+ 5 V
4	-	+ 12 V
5	-	CLOCK
6	-	GEN
7	A	-
8	B	-
9	C	-
10	D	-
11	E	-
12	F	-
13	G	-
14	H	-
15	X	FM INPUT
16	Y	AM INPUT

A 16-pin Insulation Displacement Connector (IDC), labeled **EXTENDER** on the top plate of the **PAD 234**, allows ribbon-cable connection to personal computers and other electronic equipment.

The user can supply power, analog, and digital signals to add-on boards via a ribbon cable. The **EXTENDER** has eight uncommitted bidirectional lines which can be easily connected via tie-blocks to the LEDs and switches of the **PAD 234**. Also, add-ons or external equipment can be interfaced to circuits already breadboarded on the trainer.

In addition, the function generator built into the **PAD 234** can be either AM or FM modulated by applying signals to either pins 15 and 16 of the IDC or tie-blocks X and Y. Since pin 15 (FM) is capacitively coupled to the function generator, it may be used as an additional DC-level signal in certain applications.



R.S.R. ELECTRONICS INC.

Title  
**SCHEMATIC**  
 SWITCH BOARD & MAIN BOARD  
 FUNCTION GENERATOR SECTION

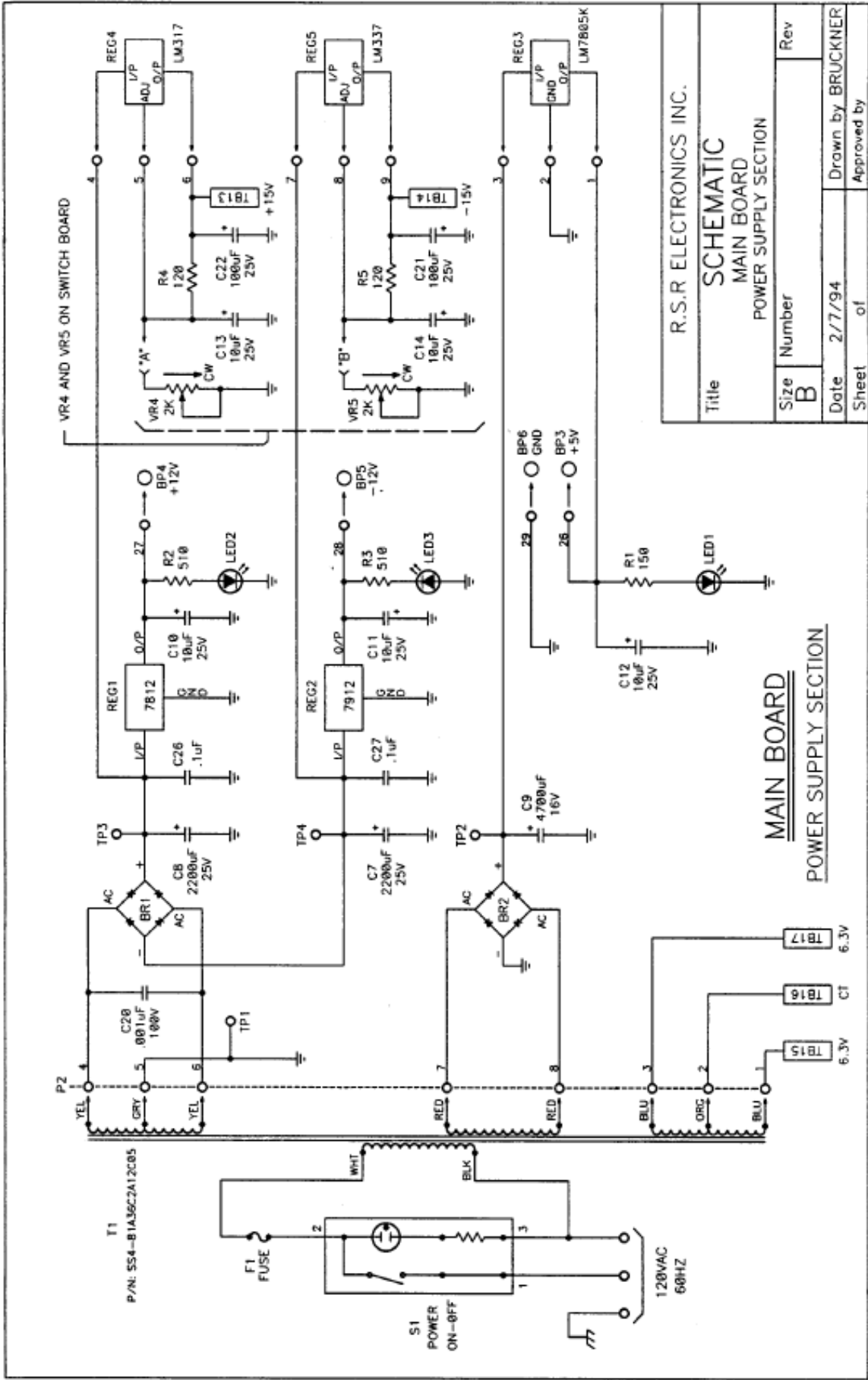
Size  
**B**  
 Number

Date  
 3/27/95  
 Sheet of

Rev  
 A  
 Approved by  
 BRUCKNER

TO MAIN BOARD  
 POWER SUPPLY SECTION  
**MAIN BOARD**  
 FUNCTION GENERATOR SECTION

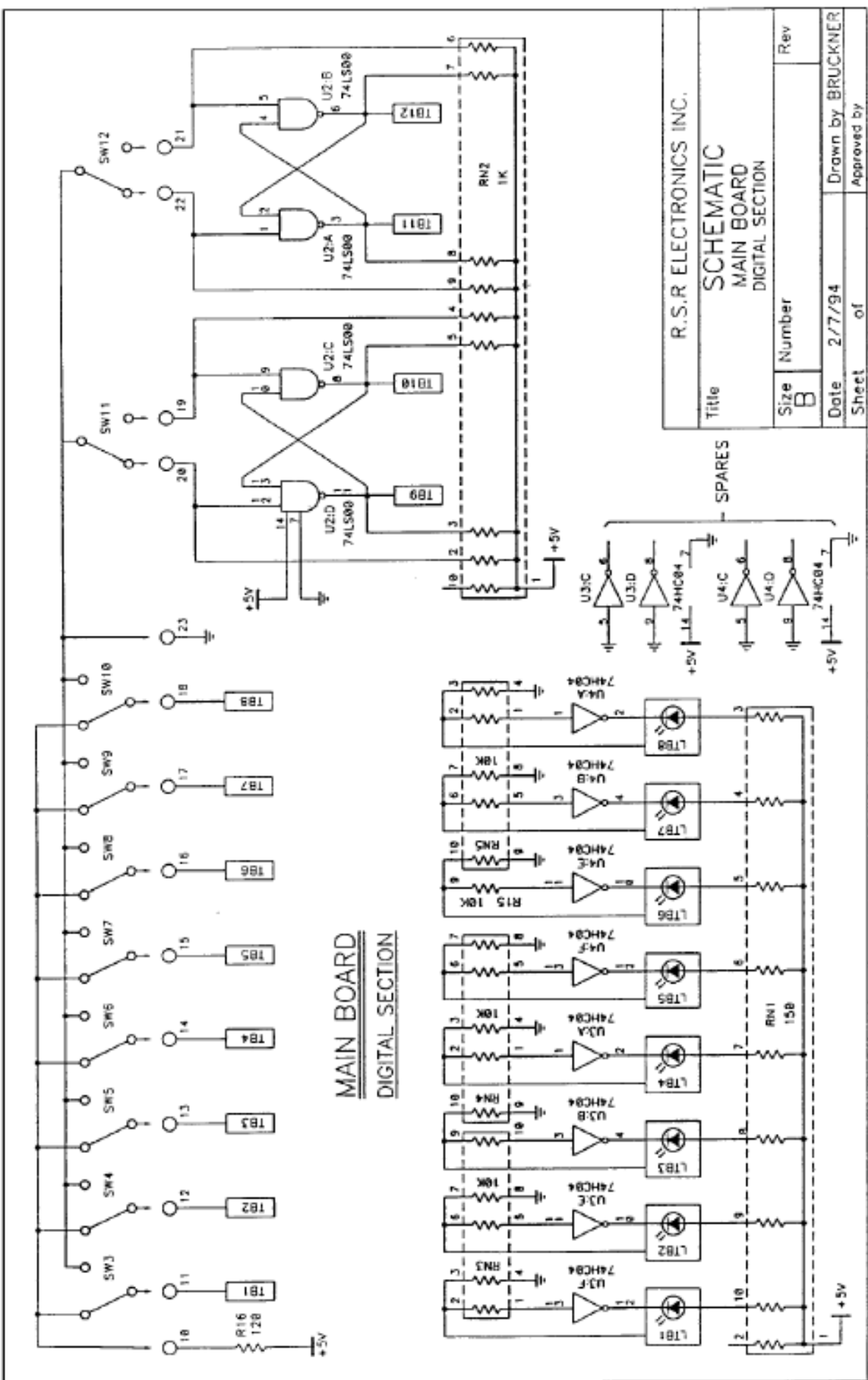
**SWITCH BOARD**



VR4 AND VR5 ON SWITCH BOARD

**MAIN BOARD**  
POWER SUPPLY SECTION

R.S.R ELECTRONICS INC.	
Title <b>SCHEMATIC</b> MAIN BOARD POWER SUPPLY SECTION	
Size <b>B</b>	Number
Date 2/7/94	Rev
Sheet of	Approved by BRUCKNER



**MAIN BOARD**  
**DIGITAL SECTION**

R. S. R ELECTRONICS INC.	
Title <b>SCHEMATIC MAIN BOARD DIGITAL SECTION</b>	
Size <b>B</b>	Rev
Date 2/7/94	Drawn by BRÜCKNER
Sheet of	Approved by

## **Circuit Trainer General Tips**

- Never construct circuitry or wire an interface with PLC/FPGA with the circuit trainer powered on.
- Construct circuit first. Double check your wiring second. Apply power and test third.
- If something goes wrong, shut off power immediately and inform Dr. Wunderlich of any damage to the circuit trainer
- If interfacing with other devices, make sure to tie your grounds together
- Be aware of potential fan-out issues when designing your circuits

## **Circuit Trainer Function Specifications**

- Power Supply
  - (+) and (-) 12v regulated power supply, with 500ma short circuit protection
  - (+) 5v regulated power supply, with 1a short circuit protection
  - (+) and (-) 15v variable supply, with 1.5a short circuit protection
- Function Generator
  - Sine, square, and triangle output wave shape
  - 1Hz to 100Khz in 5 ranges
  - Uncalibrated, buffered, adjustable output (0v to 15v peak to peak)
- Clock Output (TTL)
  - Frequency determined by “coarse frequency fine frequency” adjustment knob, rise and fall time of 400ns
- Indicators
  - 8 buffered TTL compatible LEDs
- Switches
  - 8 binary toggle switches (0v or 5v)
  - 2 pulse switches (debounced)
- Breadboards
  - 2 breadboards with 840 plug-in tie points each
- Power Consumption
  - 117v at .5a
- Additional Features
  - Protective plastic case, with a grounded line cord



# Computer Power Supplies

and how to convert to bench power supplies  
J Wunderlich PhD

## Linear Power Supply

The traditional way of converting from 120V or 240 V AC to lower DC voltages

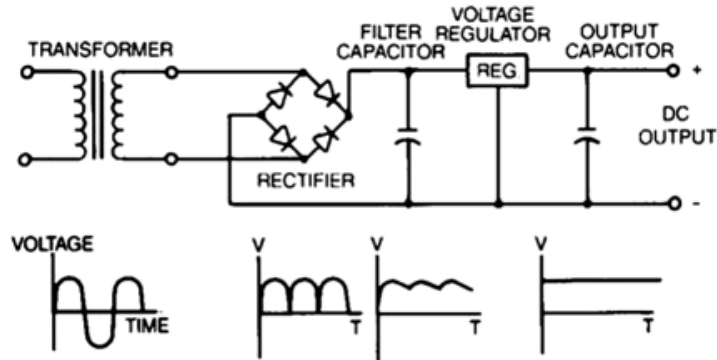


Image from:  
<http://williamson-labs.com/powersupply.htm>

For personal computers this converts to 12 V for hard drive and fan motors, 3.3 V for CMOS circuits, and 5V ifor TTL bipolar circuits

Process of converting to a bench power supply for experimenting with digital circuits

- 1: Cut off all connectors
- 2: Strip the ends of all the wires
- 3: Bundle them together by color (Yellow=12V, Red=5V, Orange= 3.3V, Black=ground)
- 4: Solder each color together to one wire and connect them to separate screw on a terminal block
- 5: Test each voltage with the multimeter and label masking tape with the voltage of each
- 7: Connect a toggle switch between the green and black-wire screws on the power supply side of the terminal block

## Switch Mode Power Supply

The modern way of converting from 120V or 240 V AC to lower DC voltages

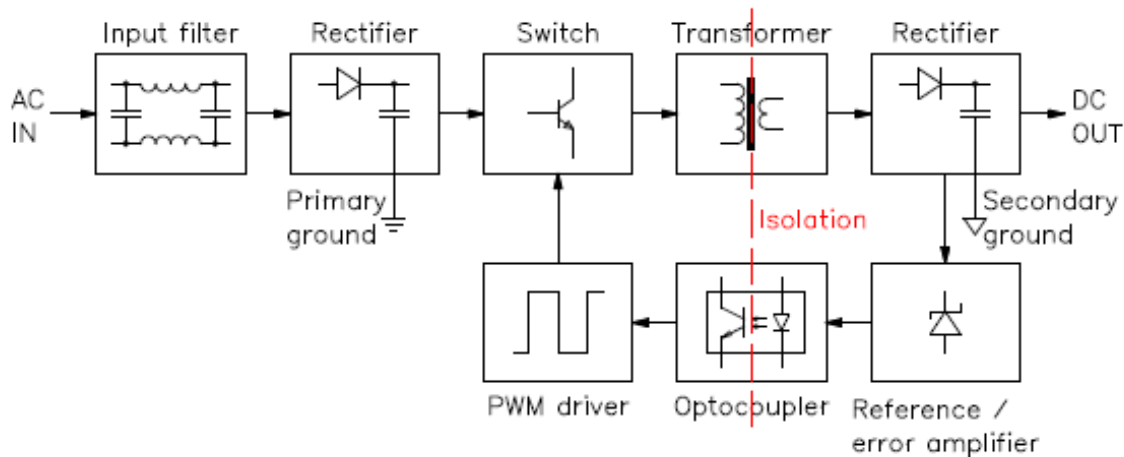


Image from: <http://www.giangrandi.ch/electronics/smfix/smfix.shtml>

For personal computers this converts to 12 V for hard drive and fan motors, 3.3 V for CMOS circuits, and 5V ifor TTL bipolar circuits

Process of converting to a bench power supply for experimenting with digital circuits

- 1: Cut off all connectors
- 2: Strip the ends of all the wires
- 3: Bundle them together by color (Yellow=12V, Red=5V, Orange= 3.3V, Black=ground)
- 4: Solder each color together to one wire and connect them to separate screw on a terminal block
- 5: Test each voltage with the multimeter and label masking tape with the voltage of each
- 6: **CONNECT "DUMMY LOAD" 10 OHM 10 WATT RESISTORS BETWEEN THE GROUND WIRE AND EACH OF THE VOLTAGES ON THE POWER SUPPLY SIDE OF THE TERMINAL BLOCK BEFORE YOU TURN ON POWER SUPPLY !!**
- 7: Connect a toggle switch between the green and black-wire screws on the power supply side of the terminal block

# Rationale for evolution of Power Supplies from Linear to Switch Mode

source: <http://www.informit.com/articles/article.aspx?p=30273&seqNum=6>

## Power Supply Loading

Now, most PC power supplies are of a **switching** rather than a **linear** design. The switching type uses a high-speed oscillator circuit to convert the higher wall-socket AC voltage to lower DC voltages for PC components. Switching type power supplies are very efficient in size, weight, and energy in comparison to linear design, which uses a large internal transformer. This type of transformer-based design is inefficient in at least three ways:

1. First, the output voltage of the transformer linearly follows the input voltage (hence the name *linear*), so any **fluctuations in the AC power going into the system can cause problems with the output.**
2. Second, the **high current-level (power) requirements of a PC system require the use of heavy wiring in the transformer which INCREASES the SIZE, WEIGHT, and USE OF ENERGY.**
3. Third, the **60Hz (hertz) frequency of the AC power supplied from your building is difficult to filter out inside the power supply, requiring large and expensive filter capacitors and rectifiers which INCREASES the SIZE, WEIGHT, and USE OF ENERGY**

The switching supply, on the other hand, uses a switching circuit that chops up the incoming power at a relatively high frequency. This enables the use of high-frequency transformers that are much smaller and lighter. Also, the higher frequency is much easier and cheaper to filter out at the output, and the input voltage can vary widely. **Input ranging from 90 volts to 135 volts** still produces the proper output levels, and many switching supplies can automatically adjust to 220v input.

**One characteristic of all switching-type power supplies is that they do not run without a load.** This means that you must have the supply plugged into something drawing power for the supply to work. If you simply have the power supply on a bench with nothing plugged into it, either the supply burns up or its protection circuitry shuts it down. Most power supplies are protected from no-load operation and shut down automatically. **Some of the cheap clone supplies, however, lack the protection circuit and relay. They are destroyed after a few seconds of no-load operation.** A few power supplies have their own built-in load resistors, so they can run even though no normal load is plugged in.

According to **IBM specifications** for the standard 192-watt power supply used in the original AT, a minimum load of 7.0 amps was required at +5v and a minimum of 2.5 amps was required at +12v for the supply to work properly. Because floppy drives present no +12v load unless they are spinning, systems without a hard disk drive often do not operate properly. Some power supplies have a minimum load requirement for both the +5v and +12v sides. If you fail to meet this minimum load, the supply shuts down. Because of this characteristic, when IBM used to ship the original AT systems without a hard disk, they plugged the hard disk drive power cable into a large 5-ohm, 50-watt sandbar resistor, which was mounted in a little metal cage assembly where the drive would have been. The AT case had screw holes on top of where the hard disk would go, specifically designed to mount this resistor cage.

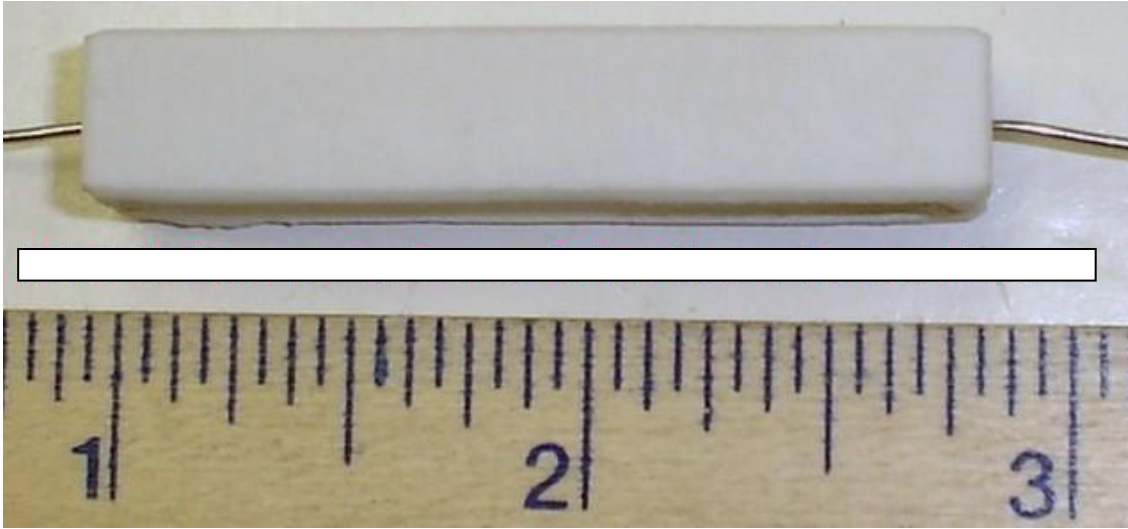
This resistor would be connected between pin 1 (+12v) and pin 2 (Ground) on the hard disk power connector. This would place a 2.4-amp load on the supply's +12v output, drawing 28.8 watts of power (it would get hot!) and thus enabling the supply to operate normally.

Note that the cooling fan in most power supplies draws approximately 0.1–0.25 amps, bringing the total load to 2.5 amps or more. If the load resistor were missing, the system would intermittently fail to start up or operate properly. The motherboard would draw +5v at all times, but +12v would normally be used only by motors, and the floppy drive motors would be off most of the time.

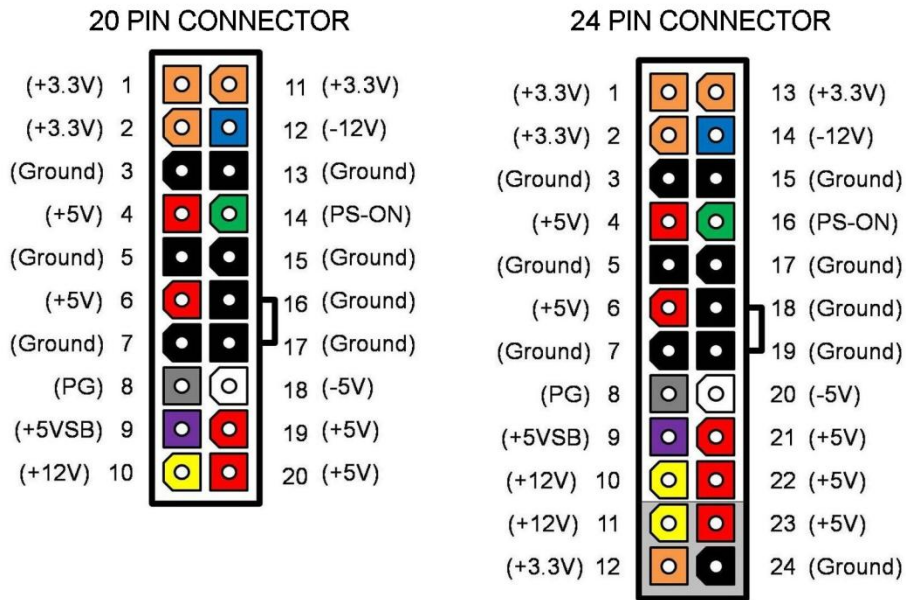
Most of the power supplies in use today do not require as much of a load as the original IBM AT power supply. In most cases, a minimum load of 0–0.3 amps at +3.3v, 2.0–4.0 amps at +5v, and 0.5–1.0 amps at +12v is considered acceptable. Most motherboards easily draw the minimum +5v current by themselves. The standard power supply cooling fan draws only 0.1–0.25 amps, so the +12v minimum load might still be a problem for a diskless workstation. Generally, the higher the rating on the supply, the more minimum load required; however, exceptions do exist, so this is a specification you want to check when evaluating power supplies.

Some high-quality switching power supplies have built-in load resistors and can run under a no-load situation because the supply loads. Other high-quality power supplies, such as those from PC Power and Cooling, have no internal load resistors. They require only a small load on the +5v line to operate properly. **Many of the cheaper clone supplies, which often do not have built-in load resistors, might require +3.3v, +5v, and +12v loads to work.**

# USE A 10 OHM 10 WATT RESISTOR BETWEEN EACH VOLTAGE AND THE GROUND !!



## ATX Pinout



- PSU in Lab (as of Spring 2018) follow 20 Pin ATX layout, described above.
  - Only used in old and low power PSU, obsolete today
  - Labels for wiring grouping should follow the above labels