Job Number: 1278; Posted: Mar 23 2001

ELECTRICAL DESIGN ENGINEER

Your Mission: Design and develop digital and analog circuitry for hi-volume electronic systems.

What You'll Do: Define and develop specification and architecture through schematic capture, PCB layout and software / hardware integration; Collaborate with engineering team to manage end-to-end system performance requirements; Optimize cost / size for volume production.

Your Skills: Experience with Microprocessor-based system design; Extensive knowledge of digital and analog circuit design; FPGA / ASIC design using VHDL; Familiarity with low-power systems and high density surface mount packaging; Prior experience taking a design through high volume production; Experience with PC-based CAD tools; Hands-on debugging and prototyping; Software experience a plus; Superior communication and interpersonal skills.

Your Nature: Creative, hands-on problem solver; Precision minded approach and eye for detail; Independent proactive thinker; Performance enthusiast with an appreciation for elegant design; Very focused on results.

Your Track Record: BS / MS in electrical engineering or equivalent experience; 3+ years experience with analog and digital design.

ENSC 204

Project Documentation
for
Electronics Design

OVERVIEW OF TOPICS

- Electrical drawing types
- Schematics symbols
- Conventional drawing styles
- Analog & Digital differences
- Netlists
- Bill of Materials
- ECAD Software

Schematics - Class 1

- Assignment expectations
- Types of electrical drawings
- Standards organizations
- Overview of schematic diagrams
- Elements of a drawing sheet
- Schematic symbol set

Assignment Expectations

- Attention to detail
  - engineering demands unrelenting attention to detail
  - in industry, small errors cost big $
  - *before* starting work, read assignments and associated support instructions very carefully
  - *double check* everything with multiple sets of eyes. Trust nothing and nobody. Use checklists.
  - minute errors *will* propagate & create big headaches

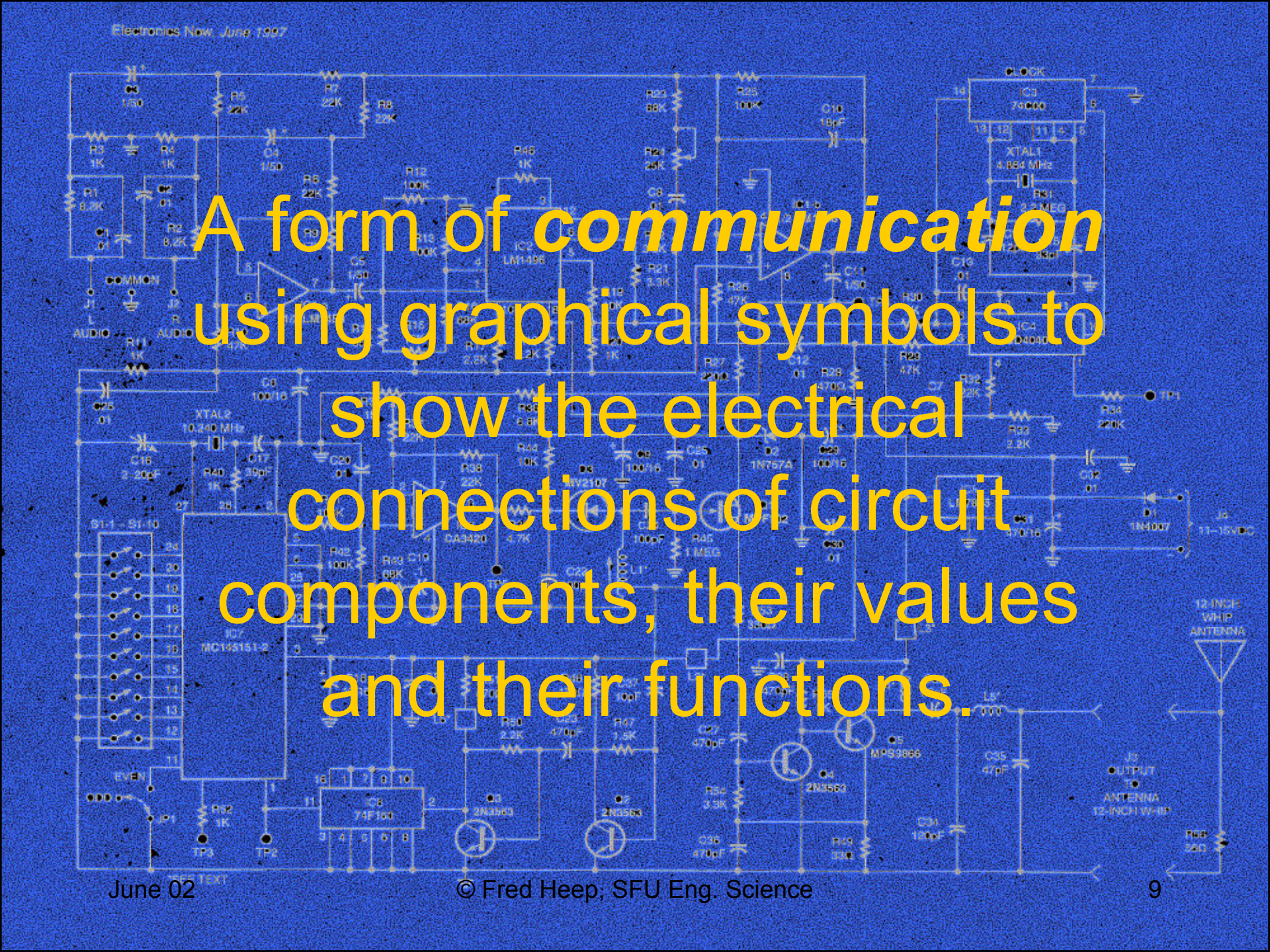
- Assessment
  - During marking, instructors seek weaknesses & inconsistencies with assignment expectations;

    no comments = good work
  - Mistakes are expected and are useful learning tools but will need to be rectified at every stage
  - Use instructors as a resource when you're stuck. Don't expect them to do your work for you.
  - Group leaders will manage task division & ensure all members develop adequate skills in each area.
  - Individual work = NO GROUP COLLABORATION
  - *You must have your own Lab Handbook!!!*
  - *Use the project documentation checklists*

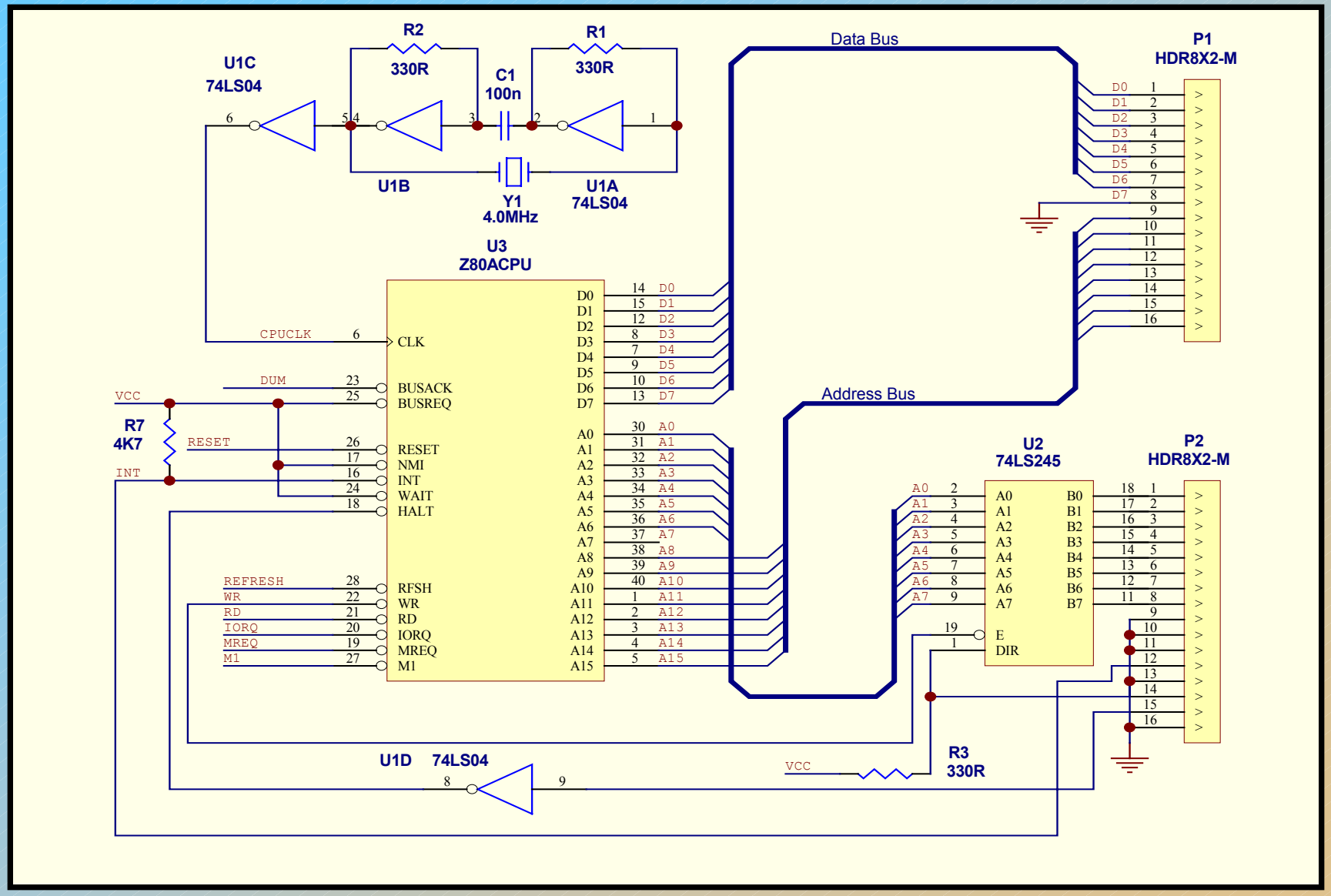
Types of Electrical Drawings

- Four main types
  - Schematics
  - Logic diagrams
  - Wiring & interconnection diagrams
  - Block diagrams

What is a *Schematic* drawing?

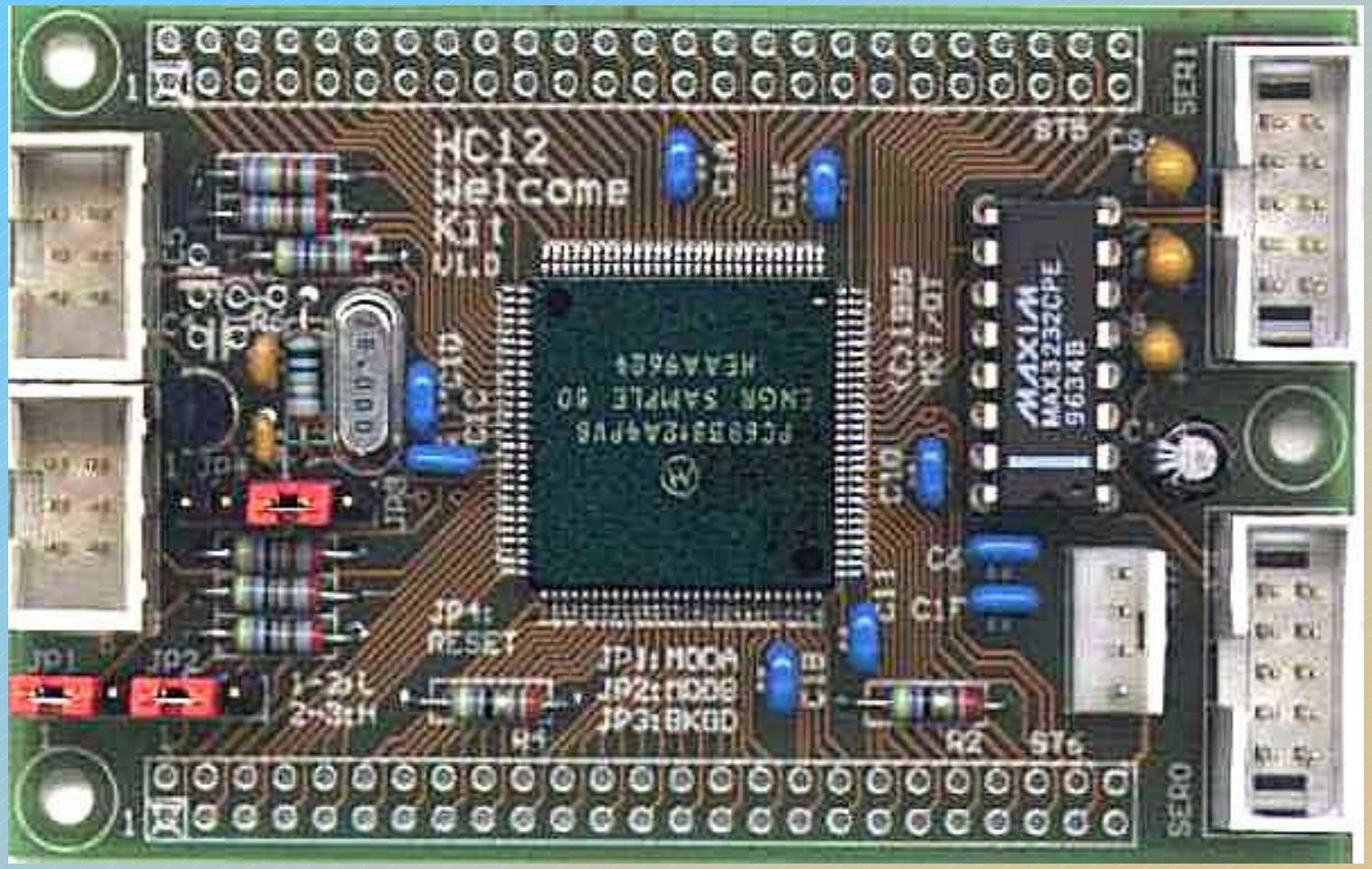


A form of ***communication*** using graphical symbols to show the electrical connections of circuit components, their values and their functions.



Logic Schematic Diagram Example

- Schematic diagrams are *master* drawings from which many other project assembly documents are derived
  - bill of materials
  - wiring & interconnection diagrams
  - mechanical layouts
    - enclosure
    - printed wiring board (PWB)
    - computer simulation
    - N.C. production equipment
    - automated testing (ATE)



PWB - Printed Wiring Board (populated)

Standards Organizations

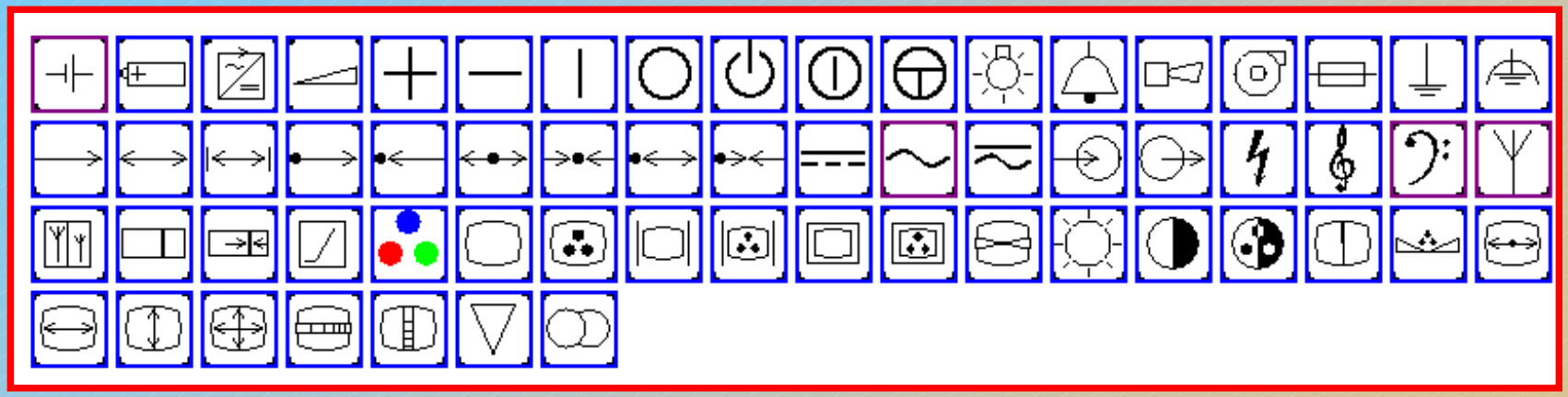
- Compile industry accepted & proven standards for
  - construction aspects
  - identification markings
  - size
  - performance
  - testing
  - component parameters

Some Standards Organizations ...

- **ANSI** (American National Standards Institute)
- **ISO** (International Standards Org.)
- **IEC** (Int'l Electrotechnical Commission)
- **EIA(J)** (Electronic Industries Alliance)(Japan)
- **IEEE** (Instit. Of Electrical & Electronics Eng's)
- **MIL** (U.S. Military/Gov't)
- **JEDEC** (Solid State Technology Assn.)
- **IPC** (Assn. Connecting Electronics Industries)

IEC

- Graphical Symbols (IEC-417)
- Int'l standards & conformity for all electrotechnical fields
- European based

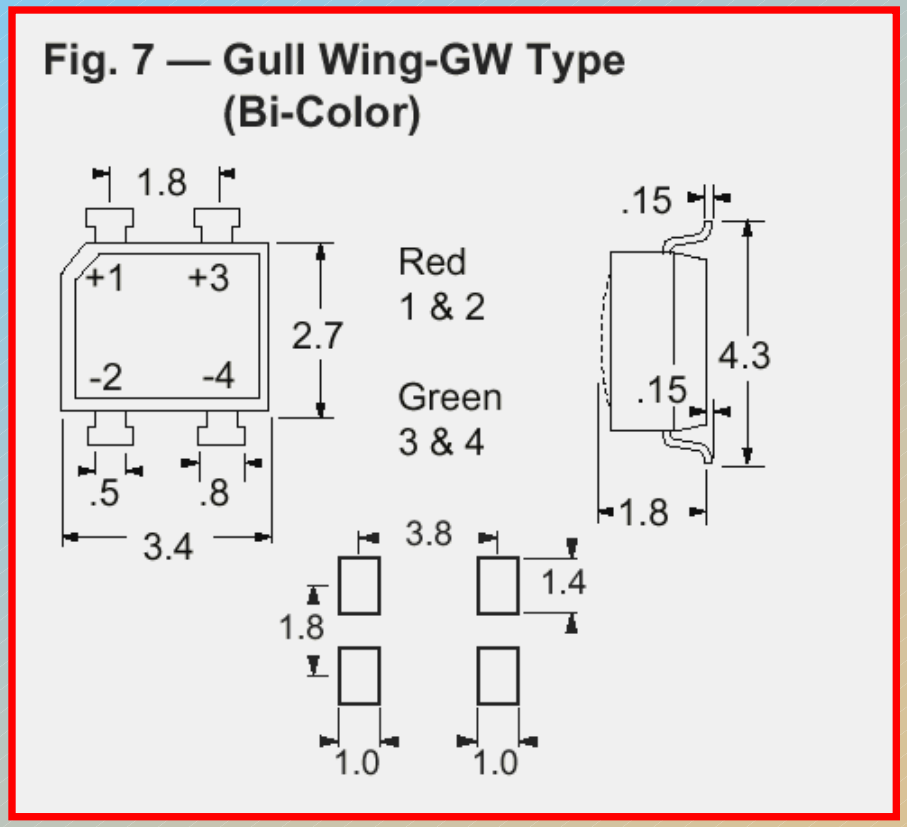


http://w3.hike.te.chiba-u.ac.jp/iec417/ver2.0/html/index.html

(http://w3.hike.te.chiba-u.ac.jp/iec417/html/index)

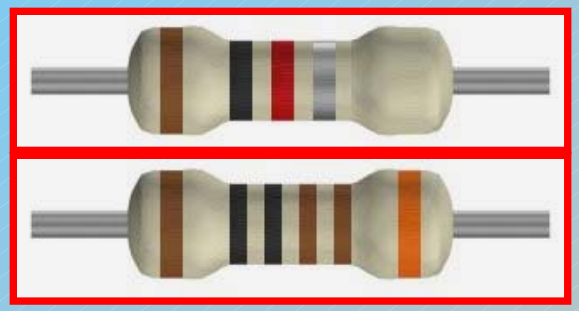
IPC

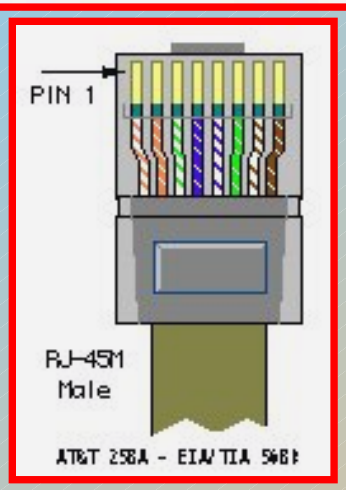
- Research, development & standardization of interconnection schemes for manufacturing & reliability.
- Strongly linked to ANSI & PWB industry.

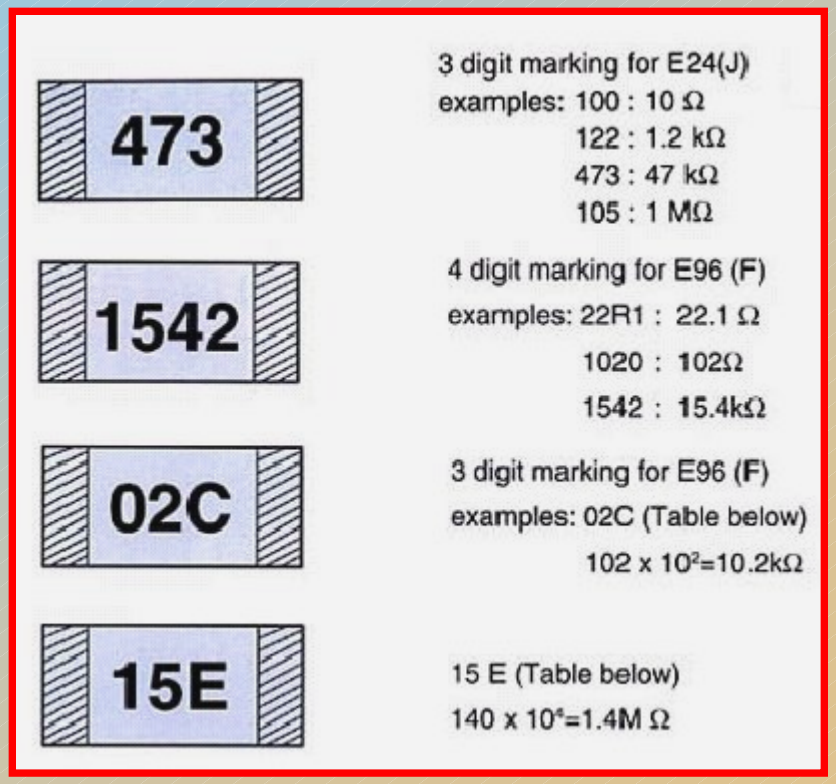


EIA

- Standards forum for components, consumer electronics, telecom, electronic information
- Accredited by ANSI







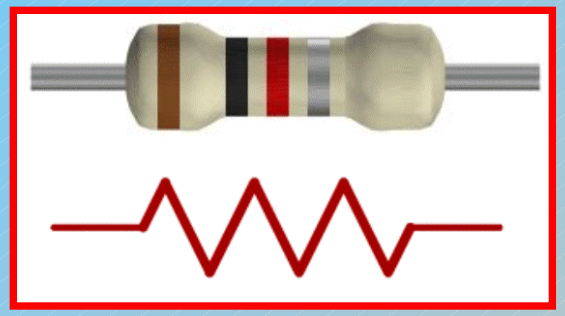
ISO

- Covers anything from Math & Natural Sciences, Healthcare, Railways, Food Technology, Paint, Electronics, etc.
- Quality Assurance (ISO9000, ISO9002)
- Document management practices
- Standards Council of Canada (SCC)

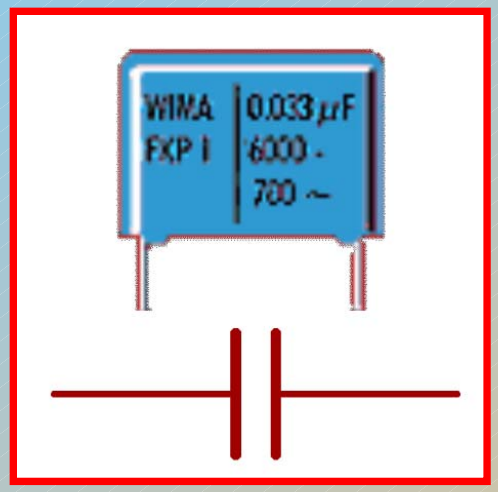
IEEE

- Information & service institute for electrical & electronics engineers
- Most standards are linked with ANSI
- Develop standards for
  - symbols
  - testing methodology & rating systems
  - user documentation
  - wiring practices
  - communications protocols
  - computer bus structures ...

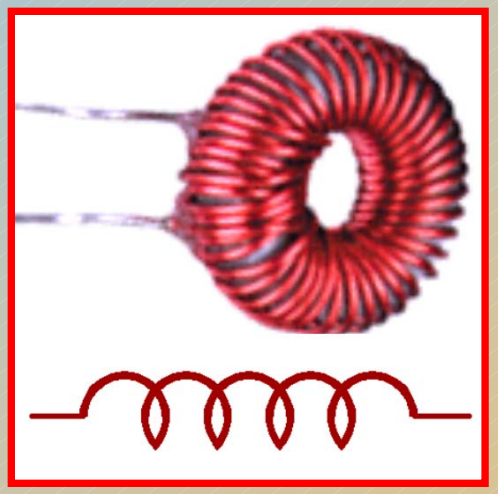
Schematic Symbols Represent Physical Components



Resistor

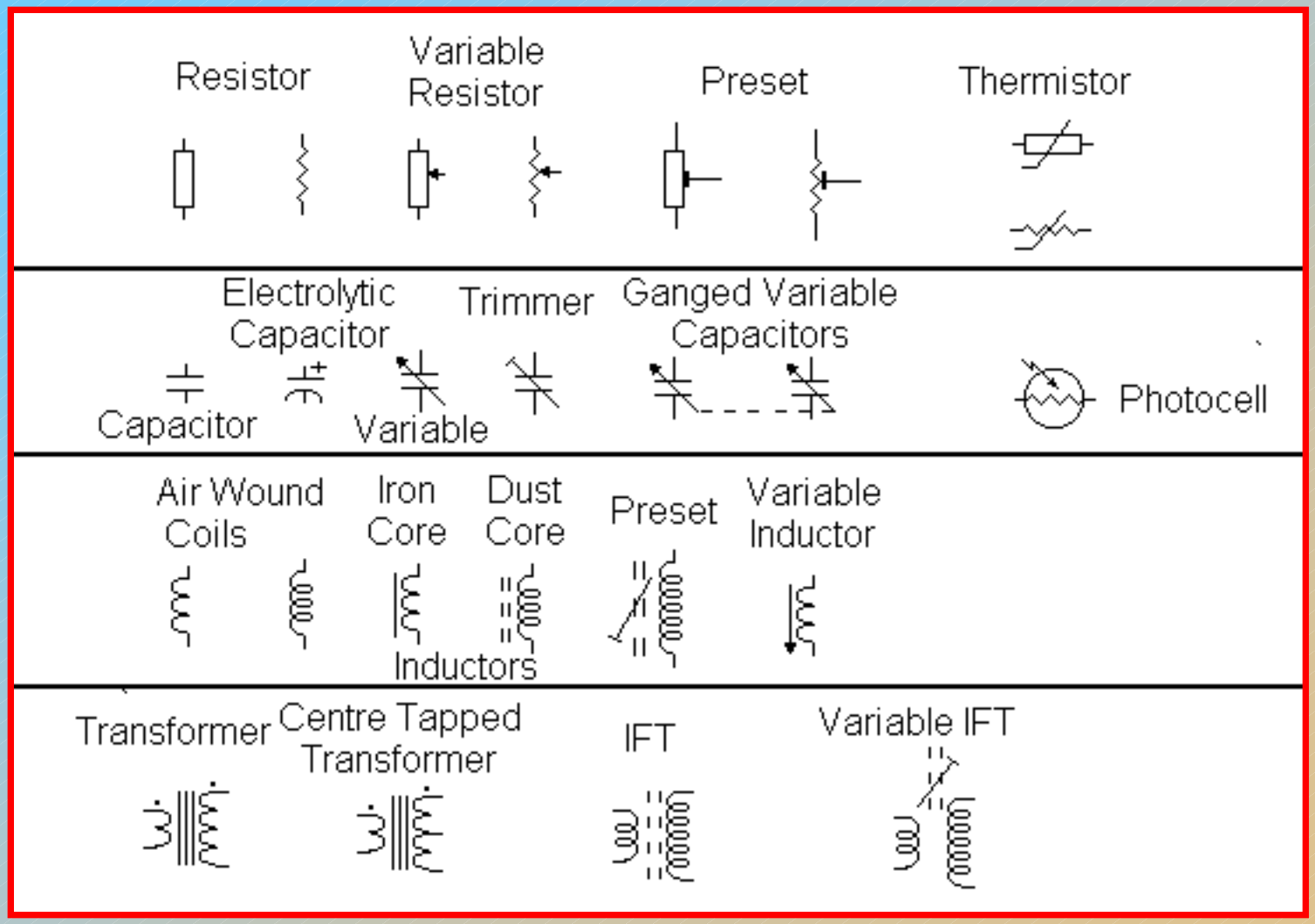


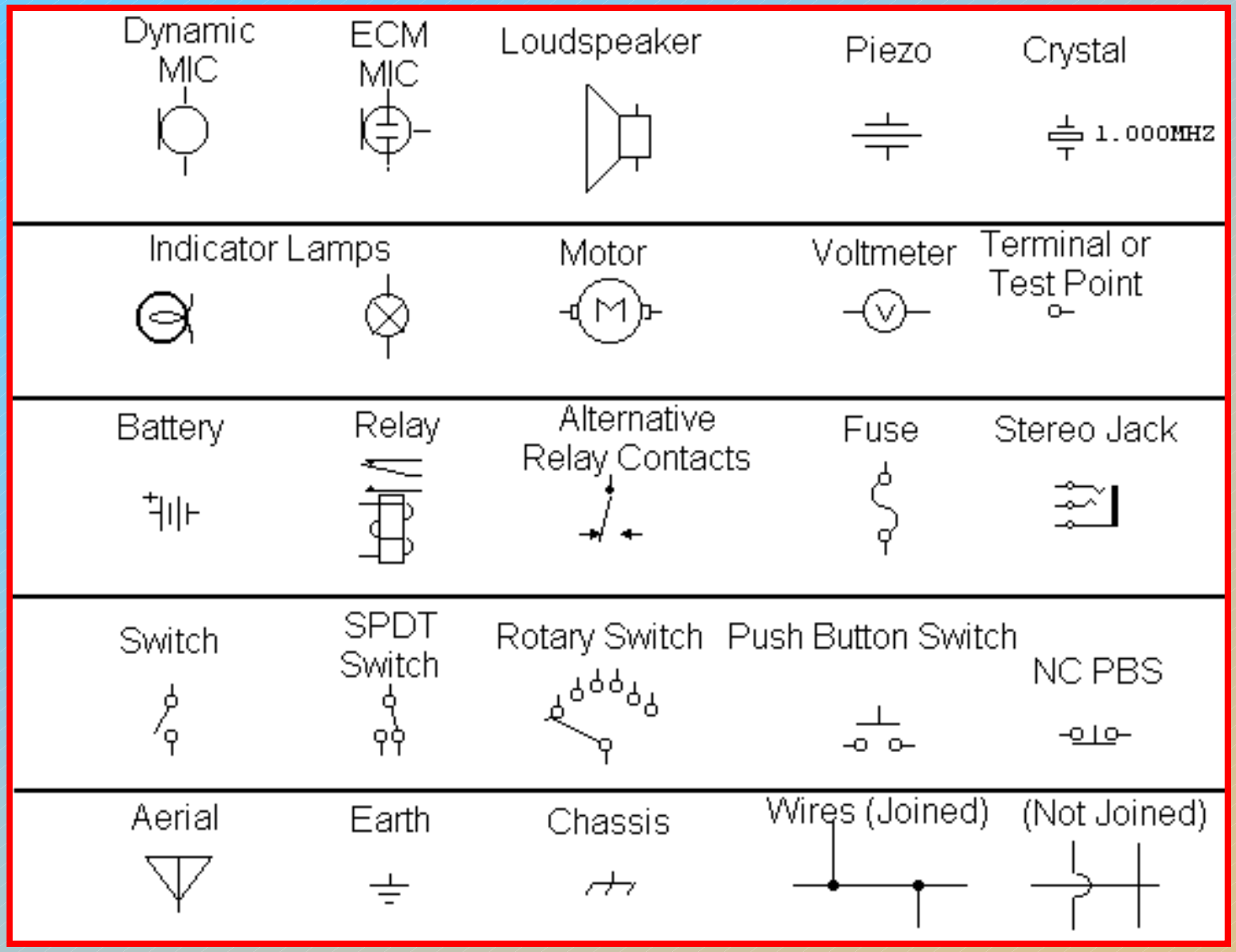
Capacitor



Inductor

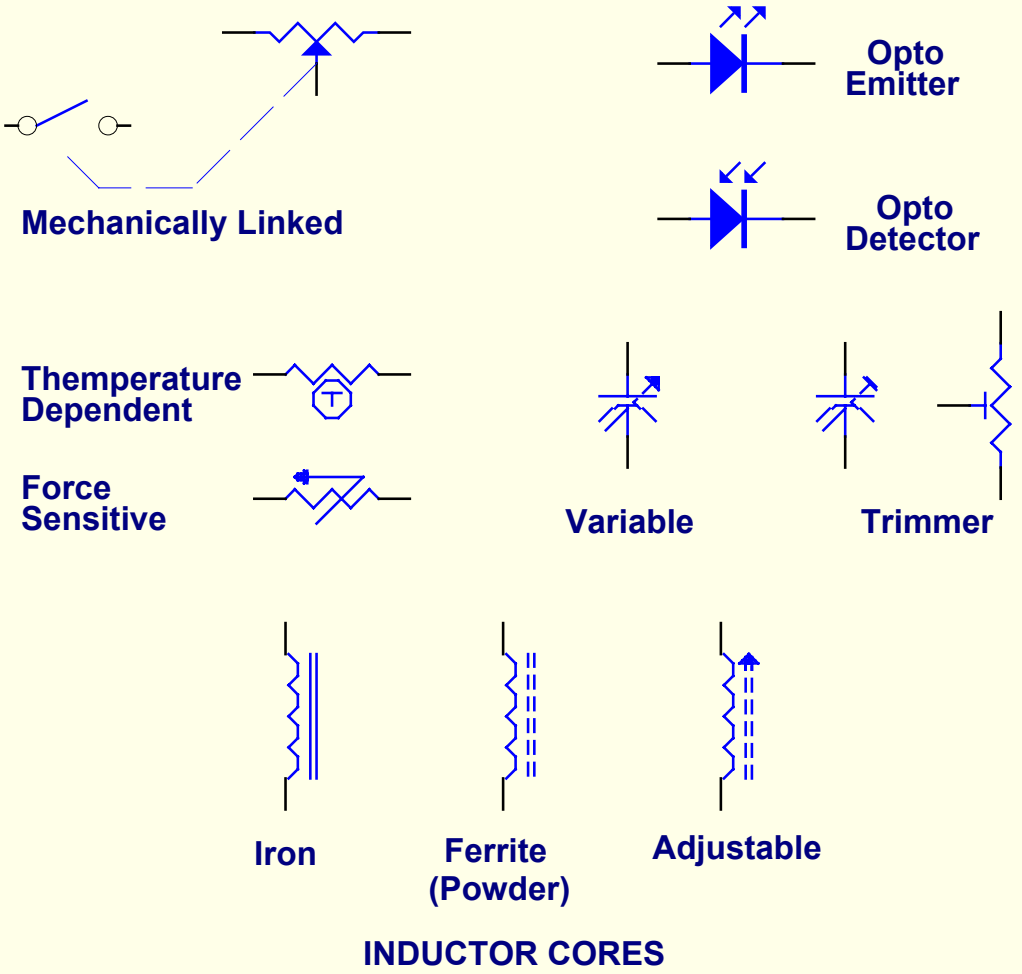
Schematic Symbol Set





* See Lab Handbook - Appendix I

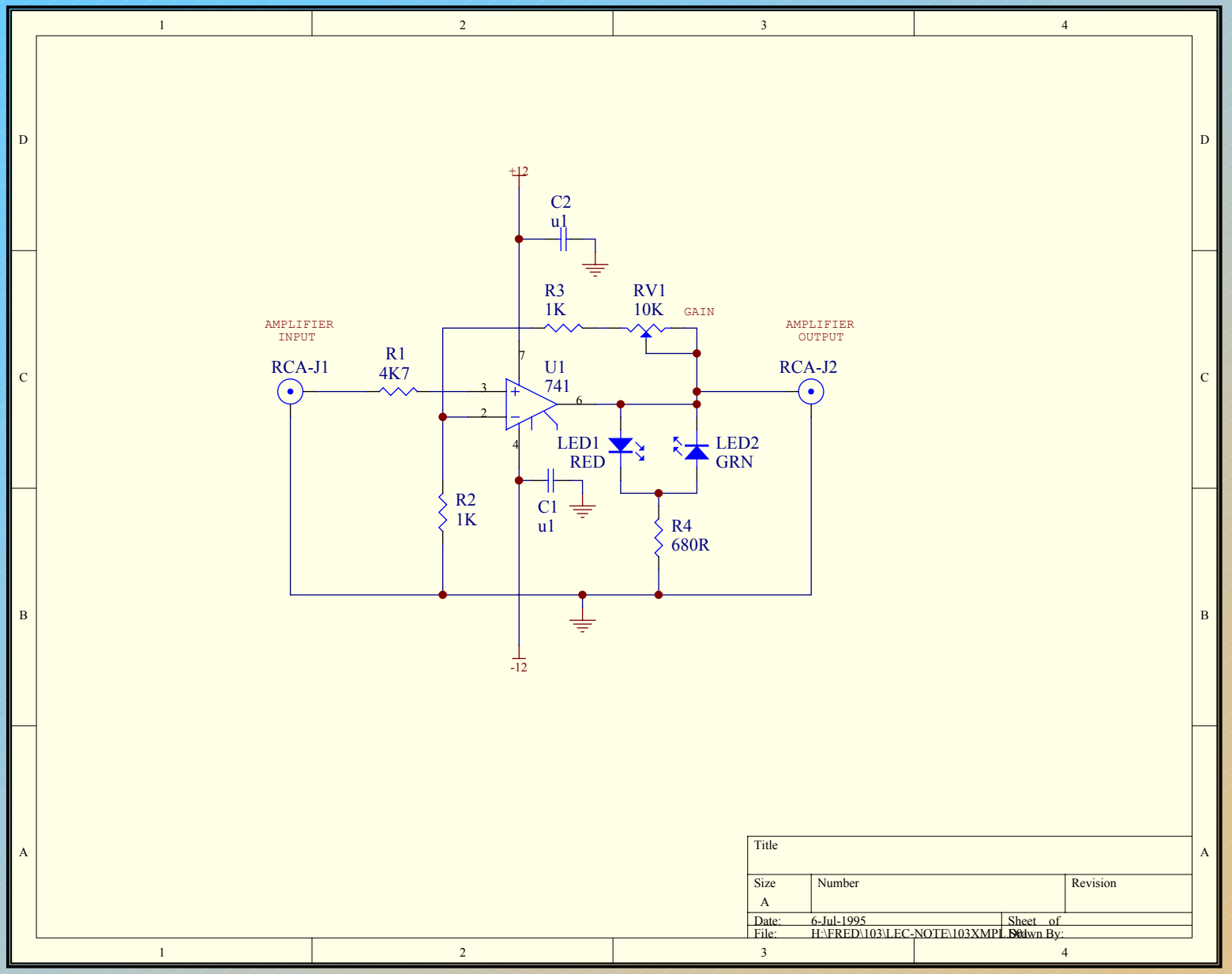
Schematic Symbol Modifiers



ANSI REFERENCE DESIGNATIONS

PART DESCRIPTION	ANSI DES.	PART DESCRIPTION	ANSI DES.
Accelerometer	A	Diode, breakdown	VR (ZD)
Alarm (visual or audible)	DS	Diode (capacitive - varactor)	CR
Antenna	E (ANT)	Diode (photo)	CR (D)
Arrestor, lightning	E	Diode (tunnel)	CR
Attenuator (fixed or variable)	AT	Electron tube	V
Autotransformer	T	Equalizer (& equalizing network)	EQ
Ballast	RT	Fan	B
Battery	BT	Ferrite bead rings	E (FB)
Bell	DS	Filter	FL
Blower	B	Flasher	DS
Buzzer	DS	Fuse	F
Cable (coaxial, assembly)	W	Fusible link	SQ (F)
Capacitor	C	Gauge, meter	M
Circuit breaker	CB	Generator	G
Coil	L	Hardware (common fasteners)	H
Connector, receptacle	J (SK)	Head, (recording or erasing)	PU
Connector, plug	P	Headphones	(HP)
Contact, rotating	SR	Heater	HR (HTR)
Contactor (magnetically operated)	K	Horn	LS
Coupler, directional	DC	Hybrid (circuit, network, coil)	HY
Crystal (oscillator, piezo or quartz)	Y	Hydrophone	MK
Crystal detector or rectifier	CR	Inductor	L
Delay line or function	DL	Instrument, meter	M

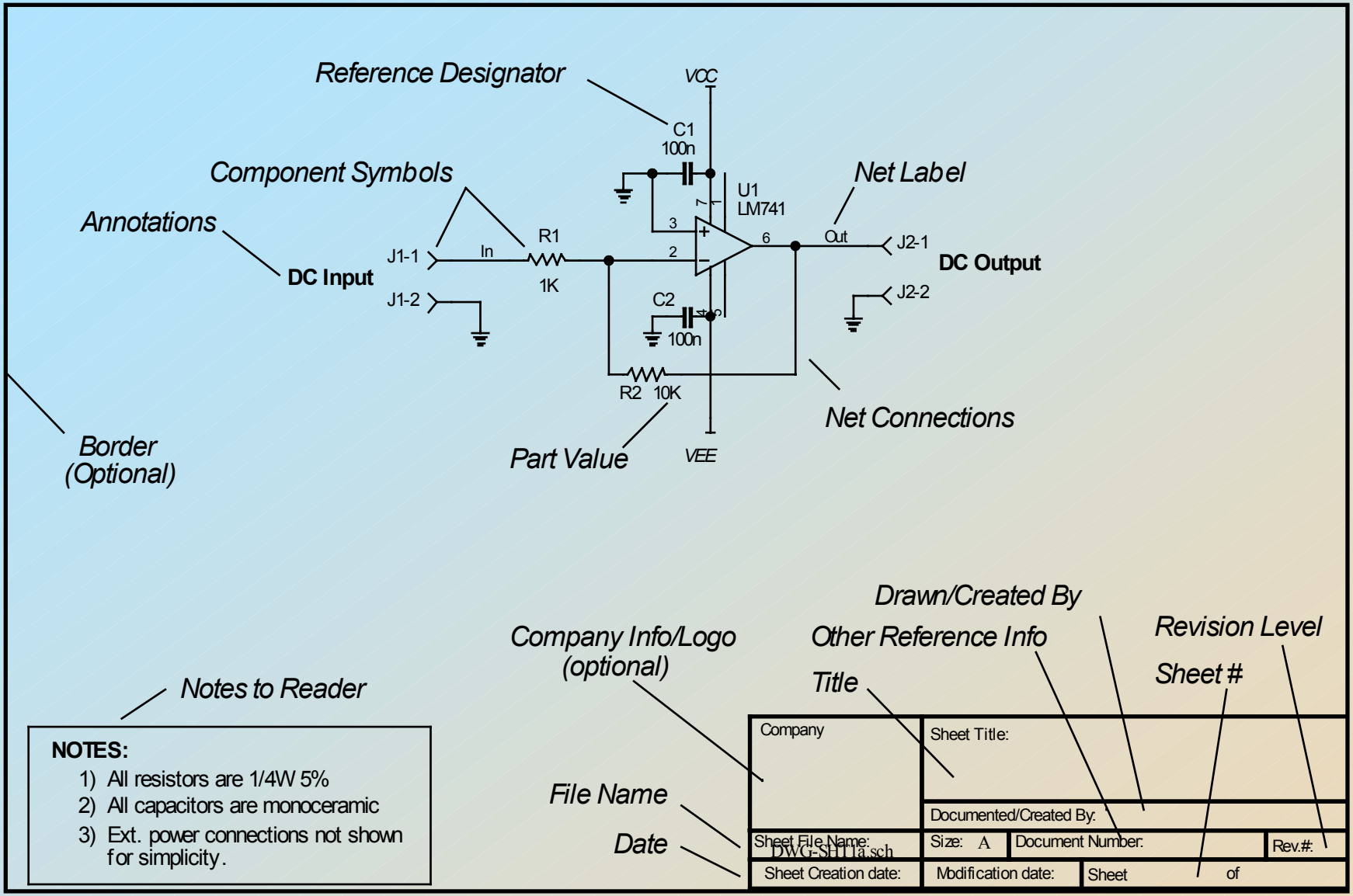
* A partial listing extracted from the ENSC Lab Handbook



What Makes a Good Schematic?

Elements of a well drawn schematic

- easy to read, understand & troubleshoot from
- functions of components are clear
- components and drawing elements are arranged into distinct functional groups
- potentially ambiguous items are clearly labeled or identified in Notes Section
- parts, values, pin numbers, polarities, nets, etc. are labeled clearly
- white-space, balance & eye pleasing
- consistency



Elements of a Schematic Drawing Sheet

Elements of a Schematic Drawing Sheet

- Page layout, border & sheet size
- Circuit element arrangement
- Input - left // output - right
- White space & balance
- Title block info
- Notes to reader
- Annotations, function & net labels
- Circuit element arrangement

* See checklist in Lab Handbook Rev.7+

Mind Your Revision Levels

Go ahead. . .it's an old schematic.

Labeling & Notation Conventions

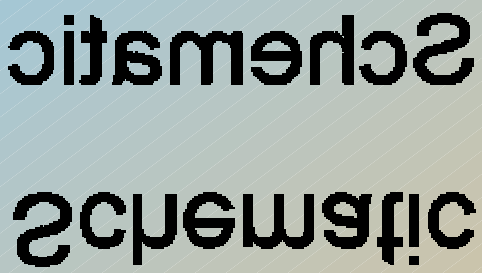
- ANSI reference designations
  - Lab Handbook (Appendix I)
- Values & Units
  - µF, K, R, M, V
  - ***Avoid decimals*** (6K8 = 6.8K, 0R82 = 0.82Ω)
- Tolerance
  - Label near symbol for special parts (10R 1%)
  - Notes - *All resistors 1/4W 5% carbon film unless …*
- Component type/construction
  - Capacitors - film, tantalum, electrolytic, ceramic …
  - Resistors - carbon film, metal film, wirewound ...

Conventional Writing Style

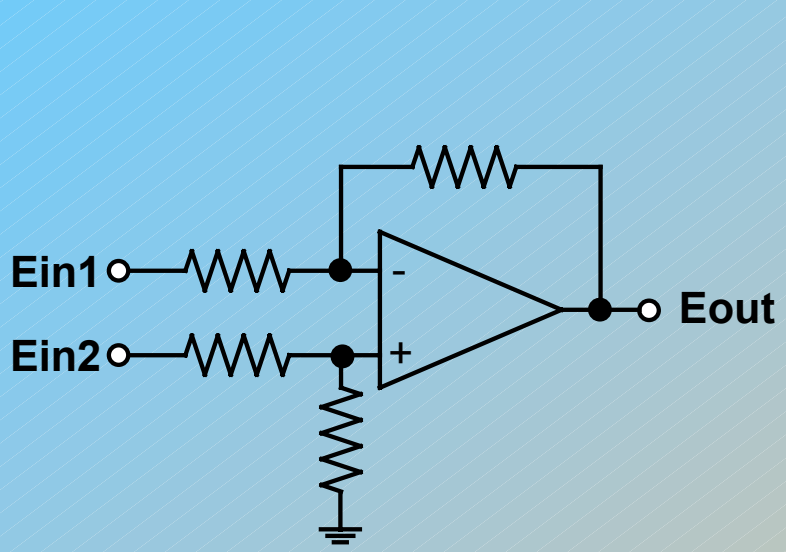
Schematic

citamehcS

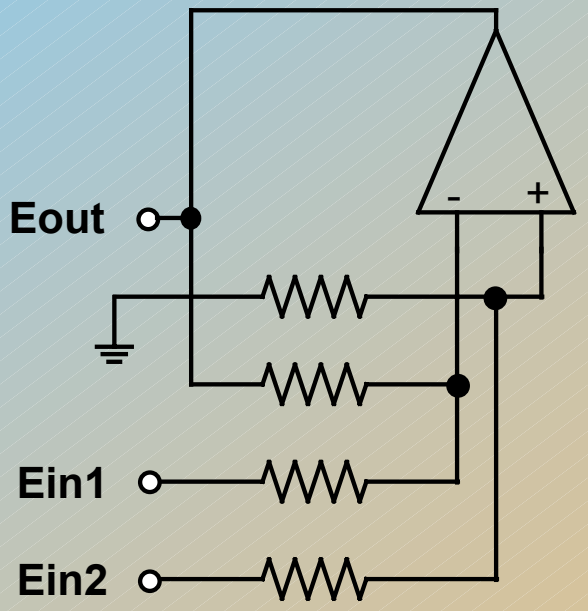
$S_c he^m atic$



Conventional Drawing Styles



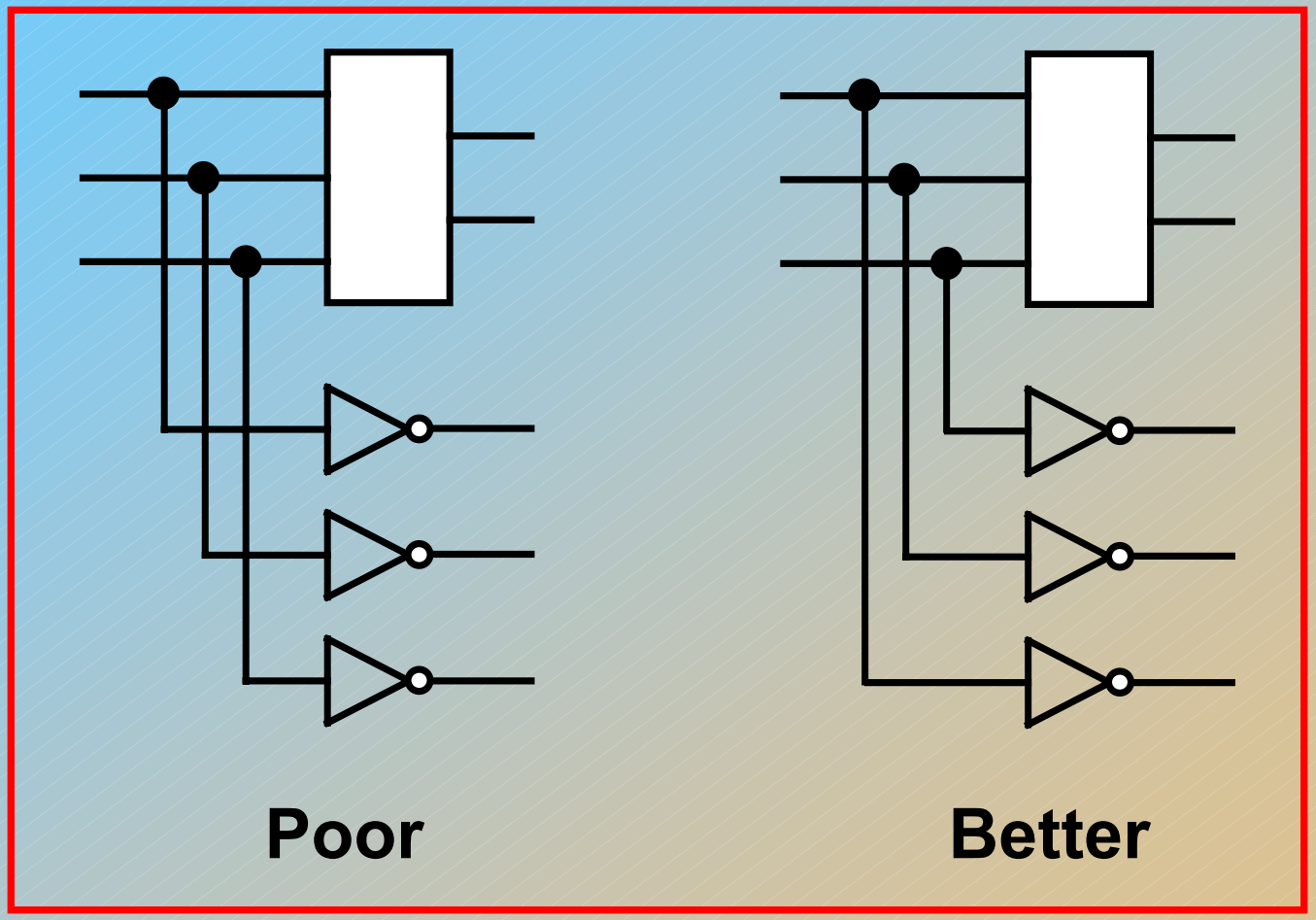
Conventional

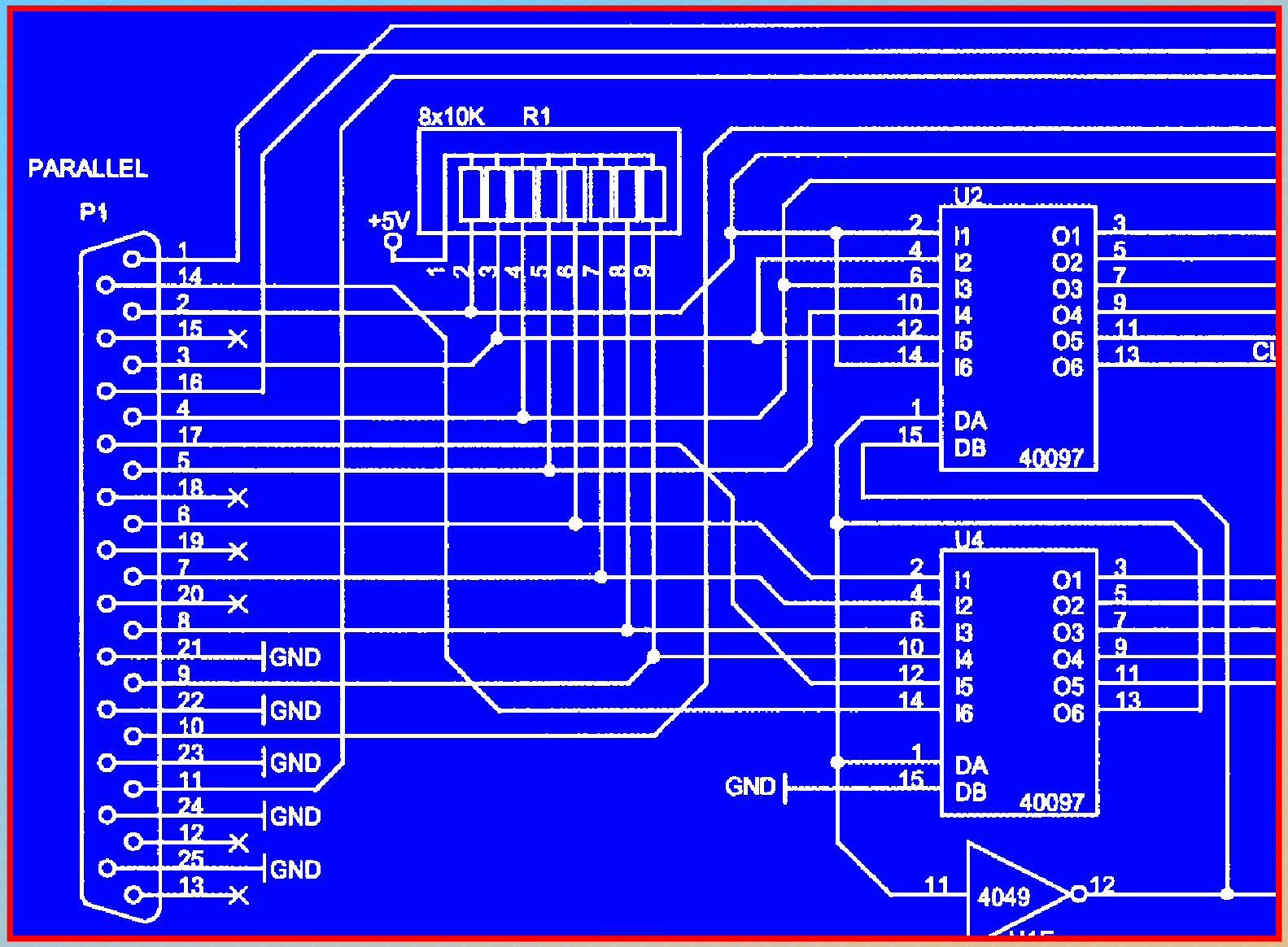


Unconventional

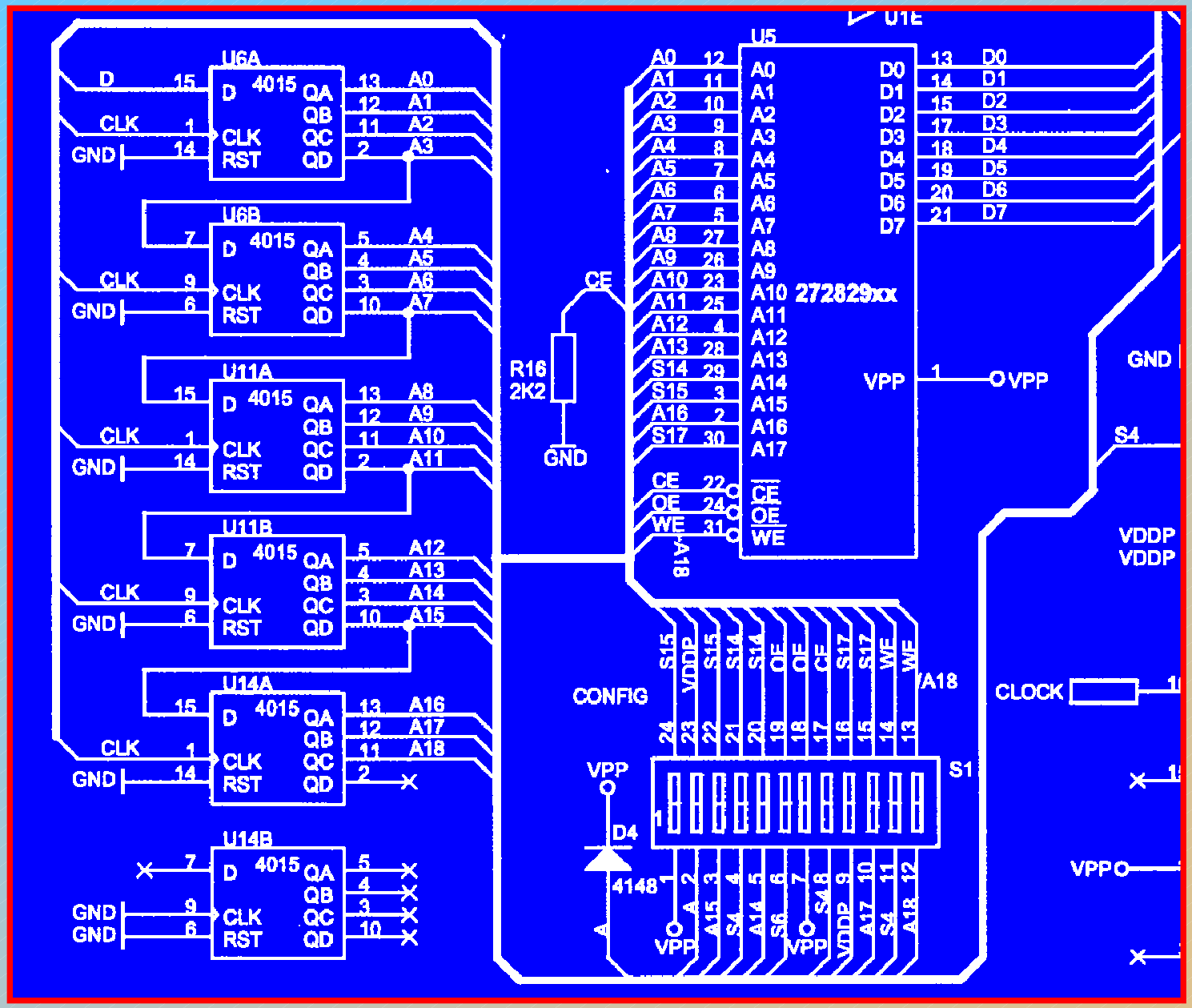
"Conventional Drawing Style" refers to the standardized arrangement of component symbols in an electronic circuit or subcircuit.

Net Routing Management

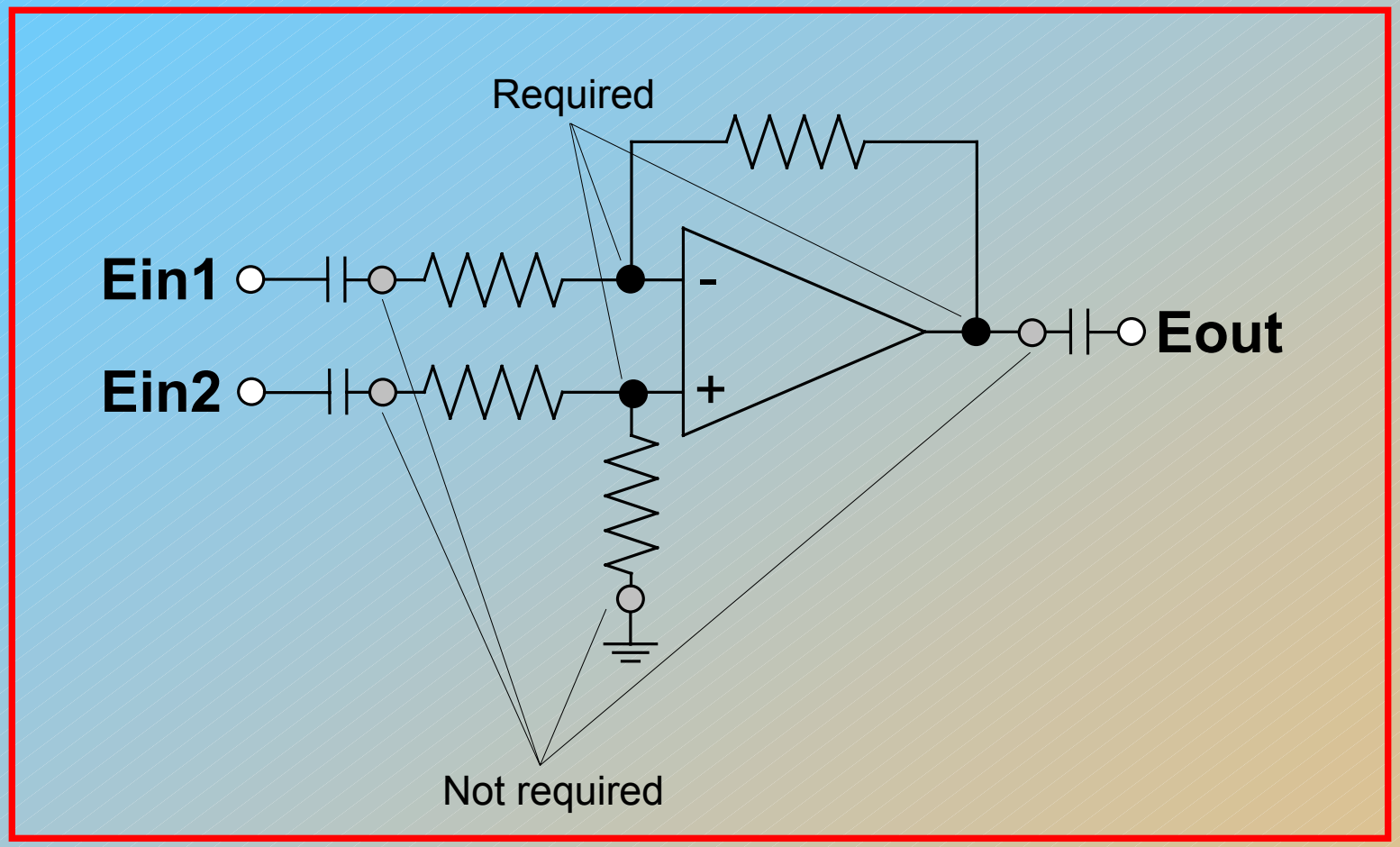




Poor method of net management



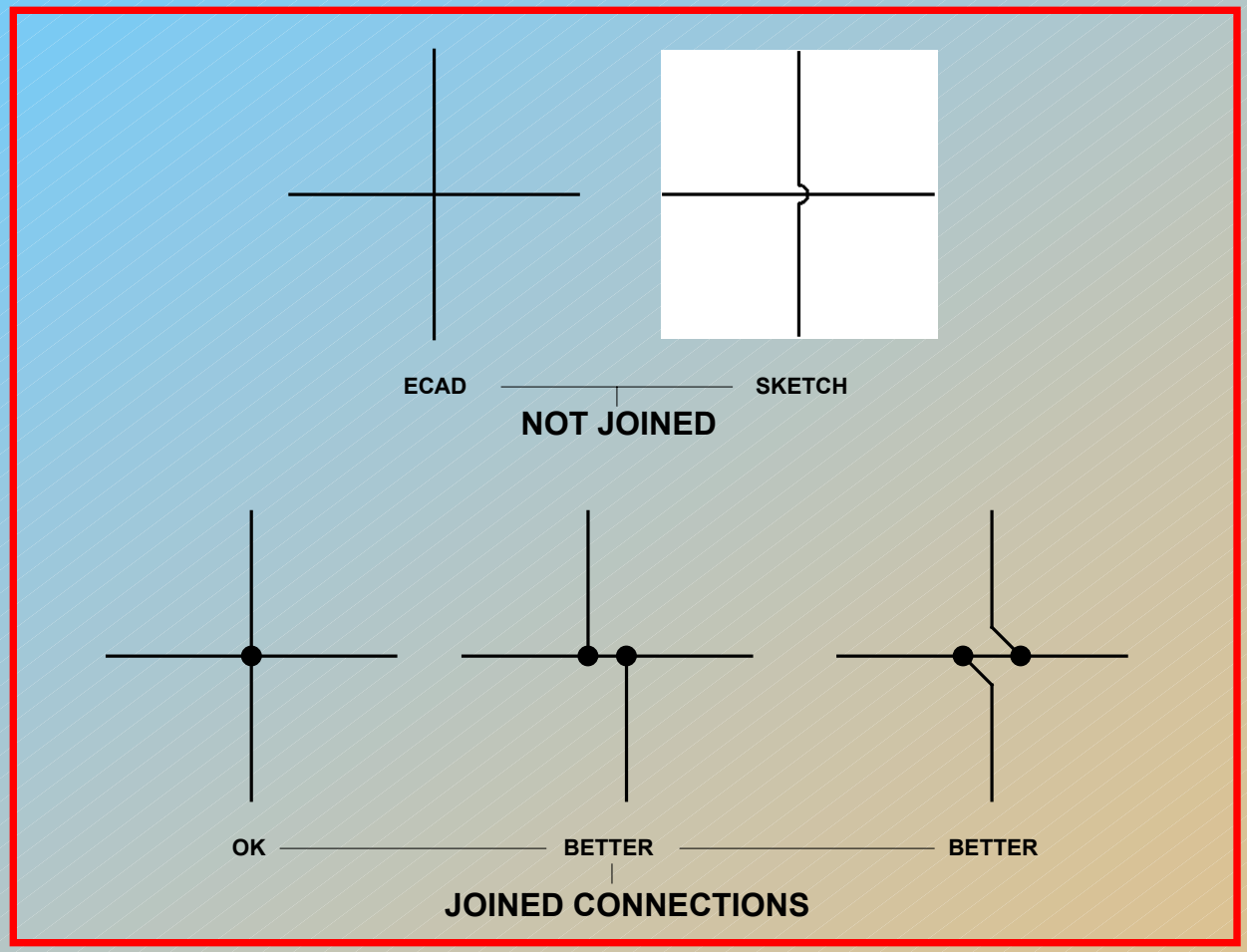
Appropriate Use of Junctions



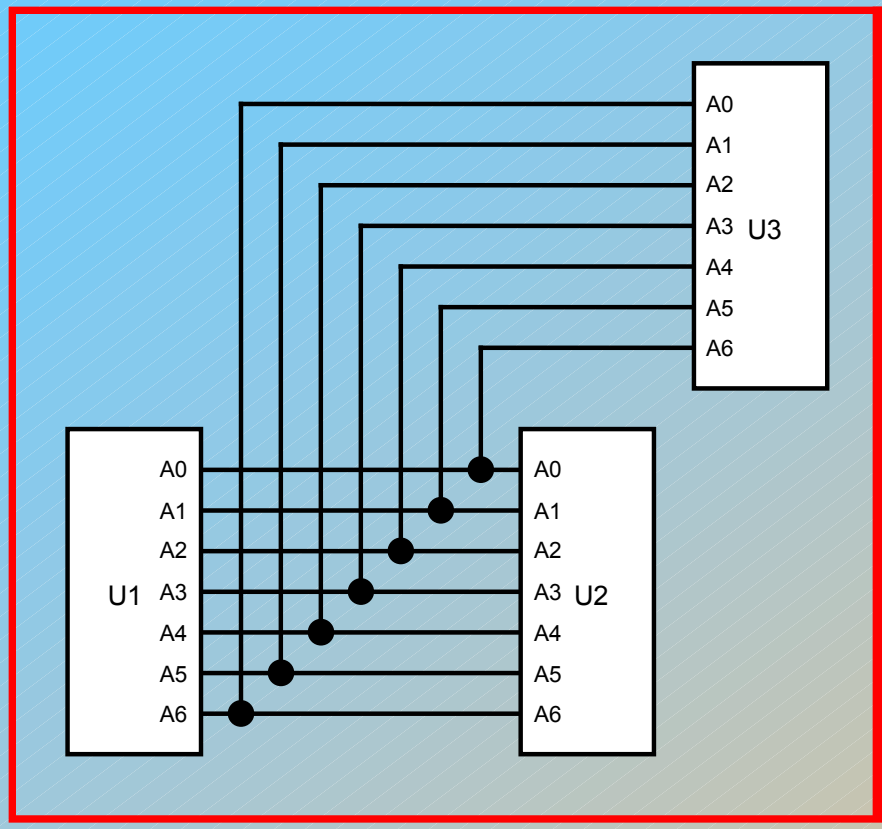
Junctions confirm the electrical connection of two intersecting *wires* (lines).

Junction symbols are not used as *circuit nodes* in schematic diagrams.

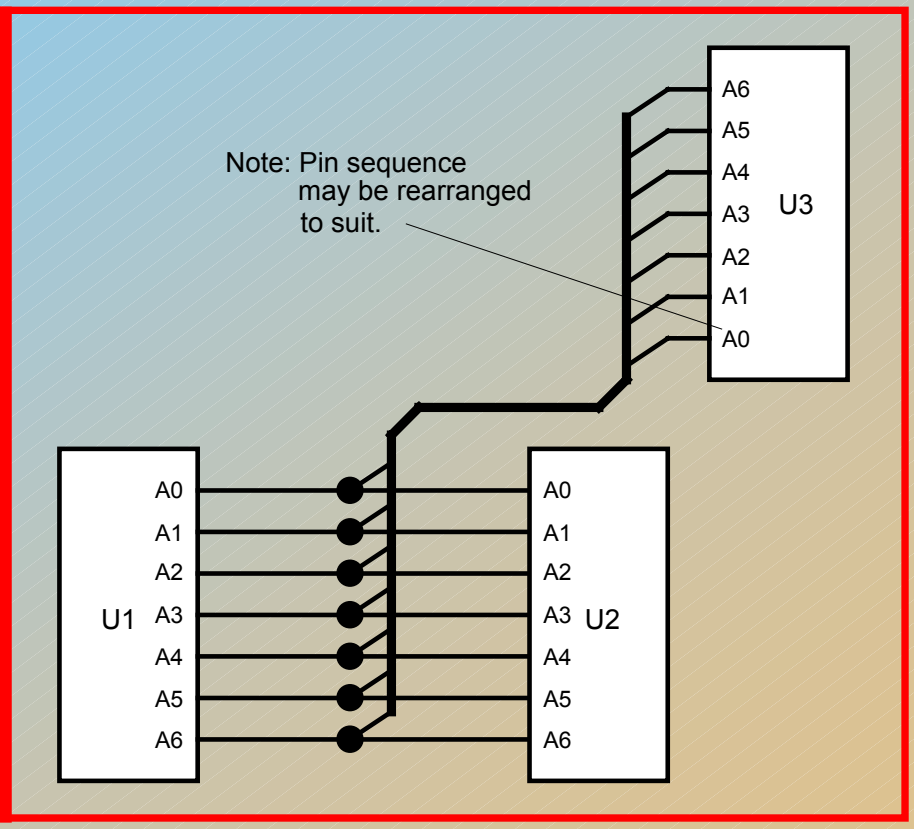
Notation Forms for Wire Interconnection



Separate Vs Bussed Interconnects



Separate Connection Scheme

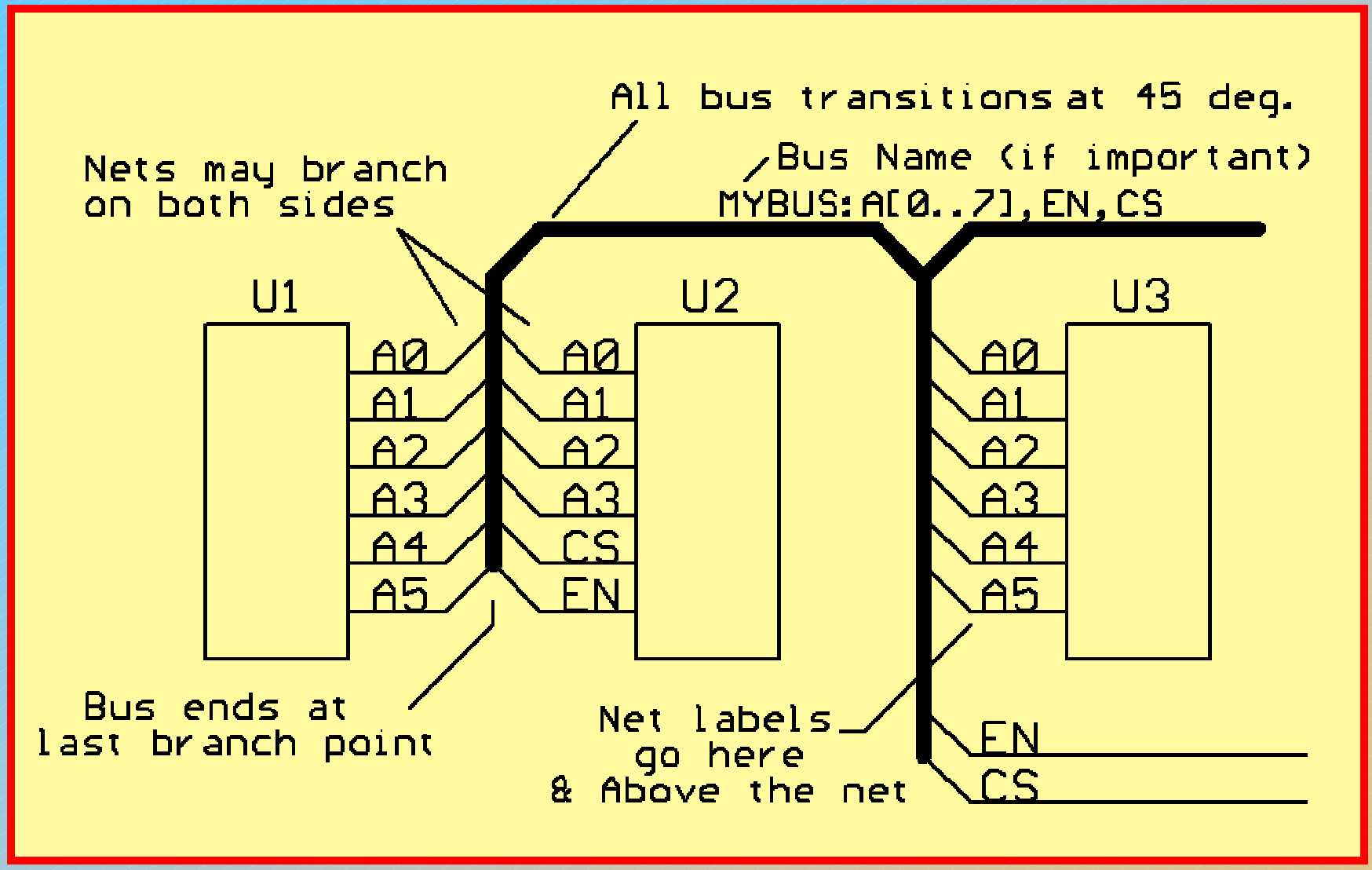


Bus Interconnection Scheme

(shown w/o net labels for simplicity)

Using Busses

- Advantages of using of busses
  - significantly improves readability
  - Less chance of interpretation errors
  - Faster to draw and modify
  - Much easier management on multi-sheet drawings
- Other comments
  - Excellent for logic drawings
  - Rarely used for analog circuits

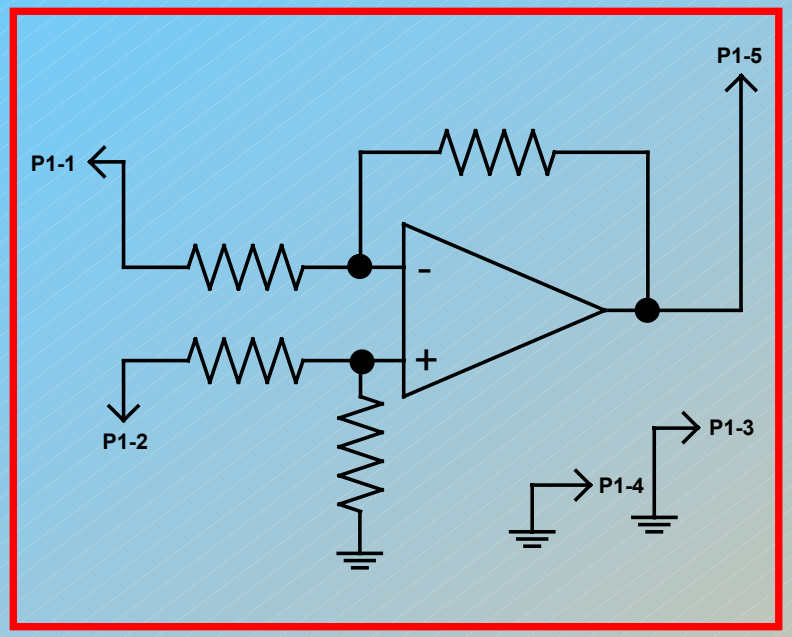


Effective use of Busses

Busses – General Notes

- Busses generally carry signals belonging to a related set; i.e. Address bus, Data bus
- Most logic schematics use many different busses
- Signal busses *don't* distribute power
- All bus & net branch transitions = *45°*
- Heavy bus line ends at last net branch
- Net labels are placed *above* and *clear* of the net & aligned between the branch point & destination

Managing Connectors



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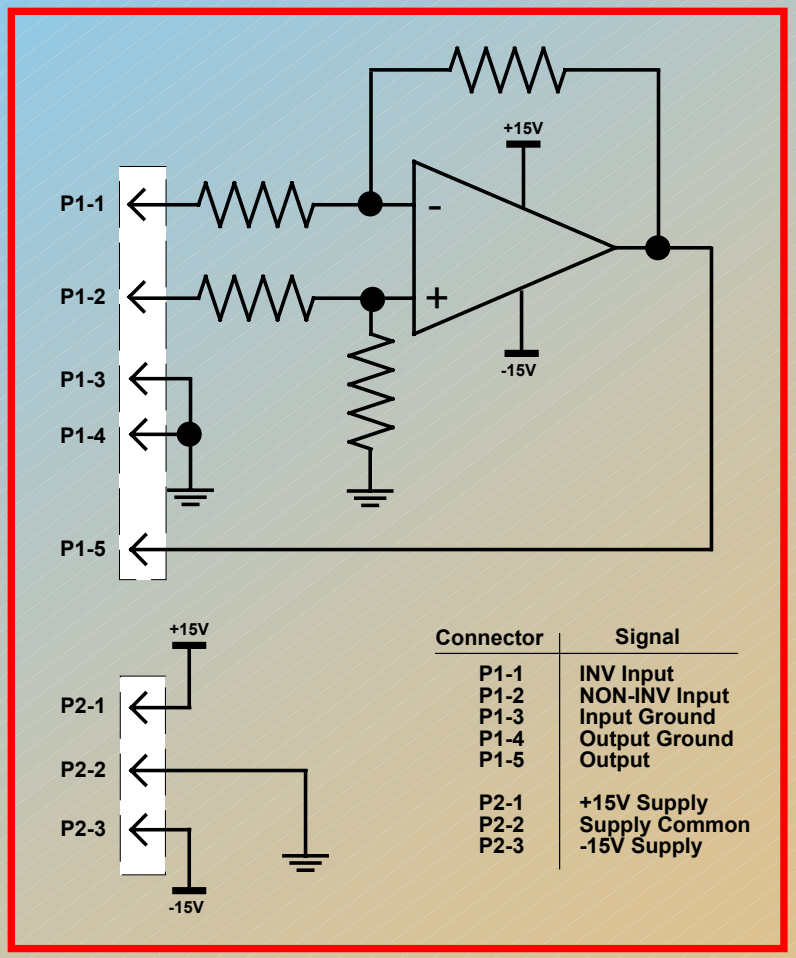
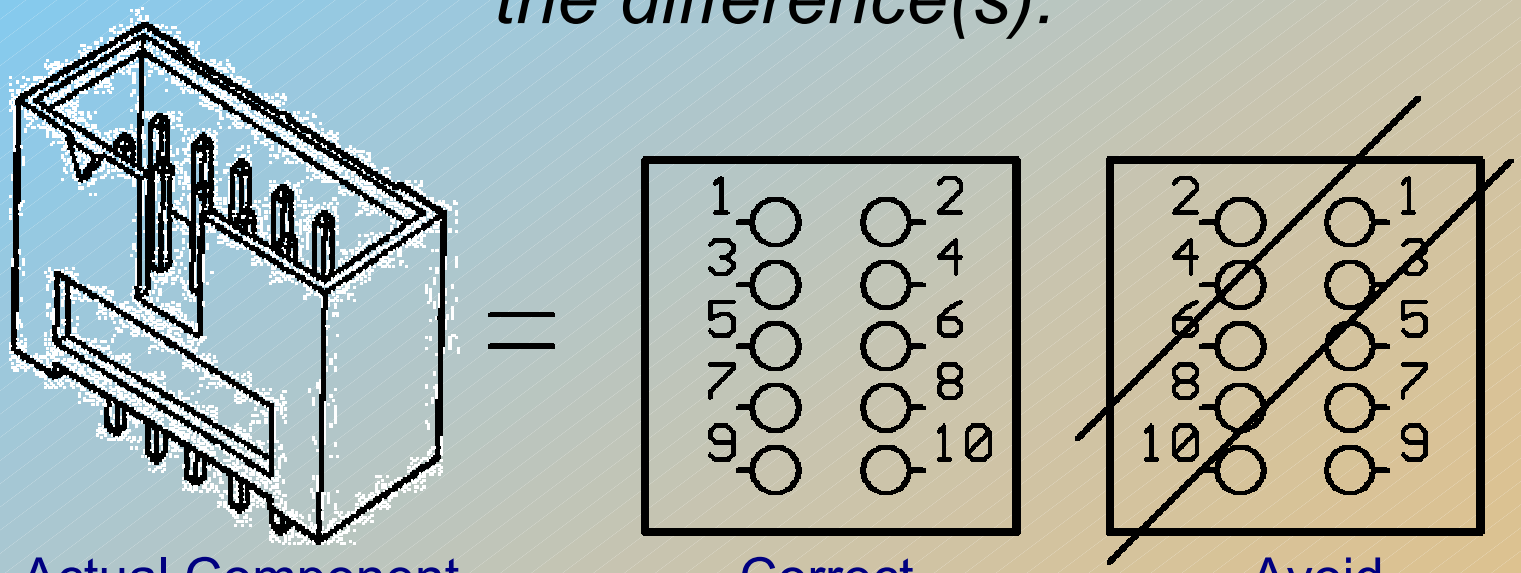


Connector	Signal
P1-1	INV Input
P1-2	NON-INV Input
P1-3	Input Ground
P1-4	Output Ground
P1-5	Output
P2-1	+15V Supply
P2-2	Supply Common
P2-3	-15V Supply

Better

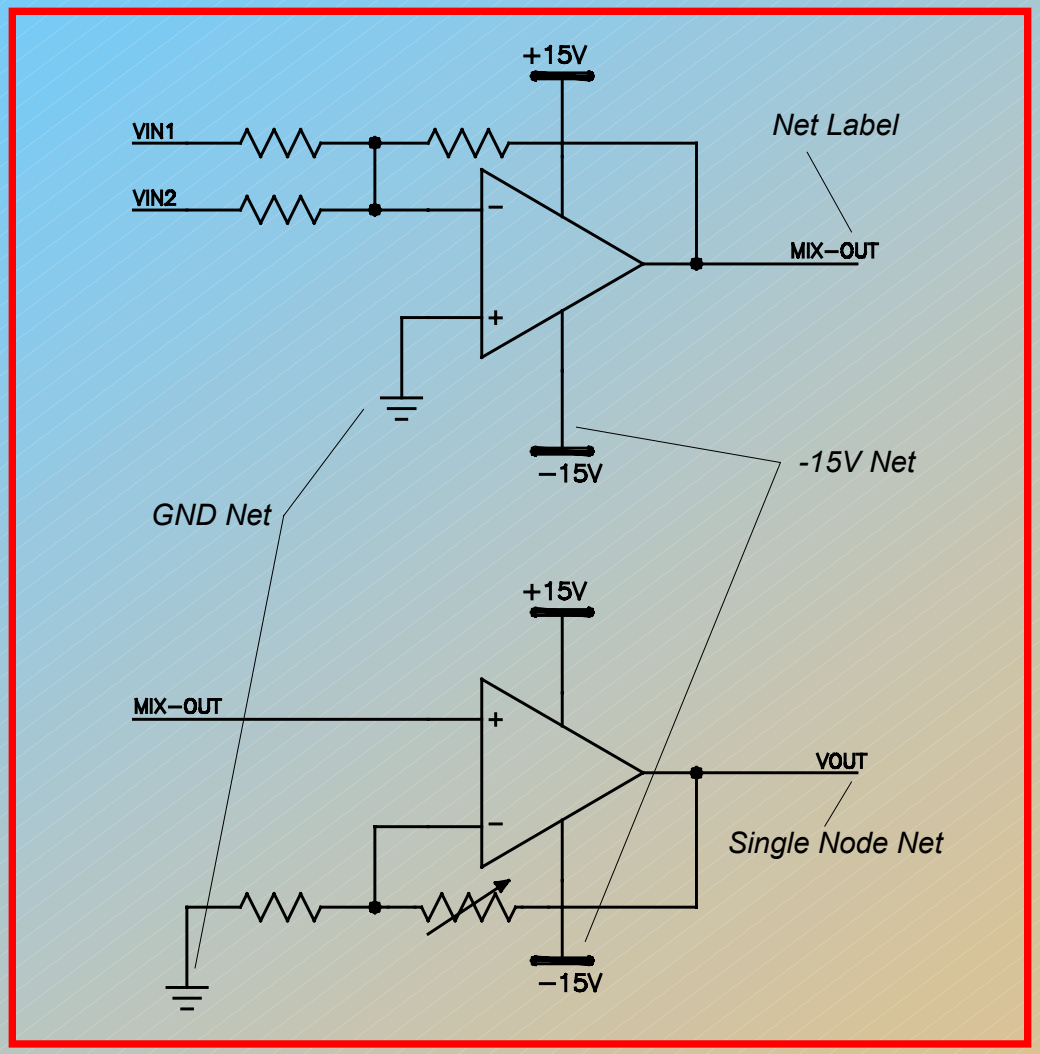
To avoid $ confusion, orientate connector symbols so that the pins and their numbering sequence is shown the same way they would be viewed & arranged in the actual part or assembly.

If otherwise, make the reader clearly aware of the difference(s).

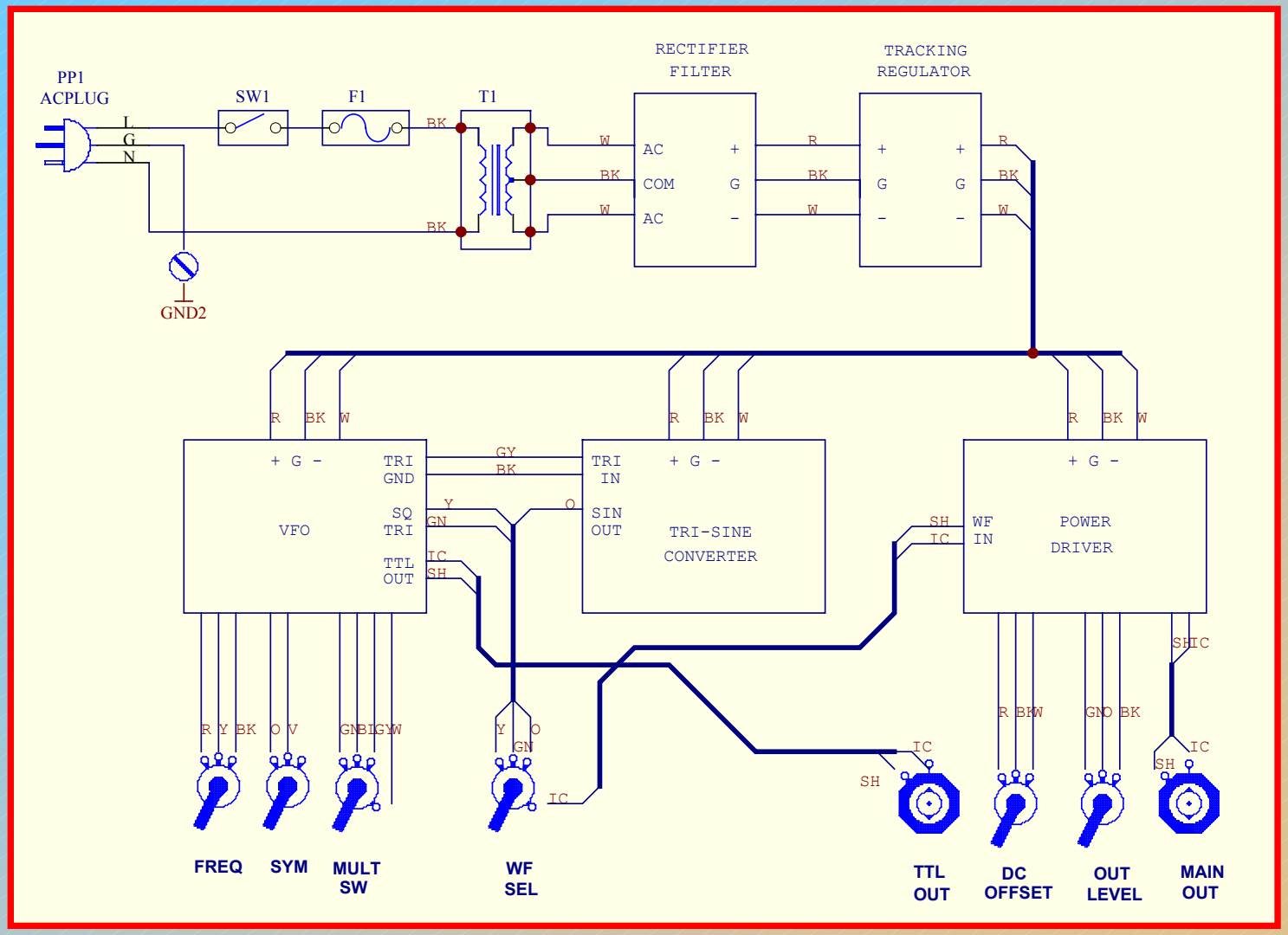


Actual Component Correct Avoid

Using Net Connections



The Wiring Diagram

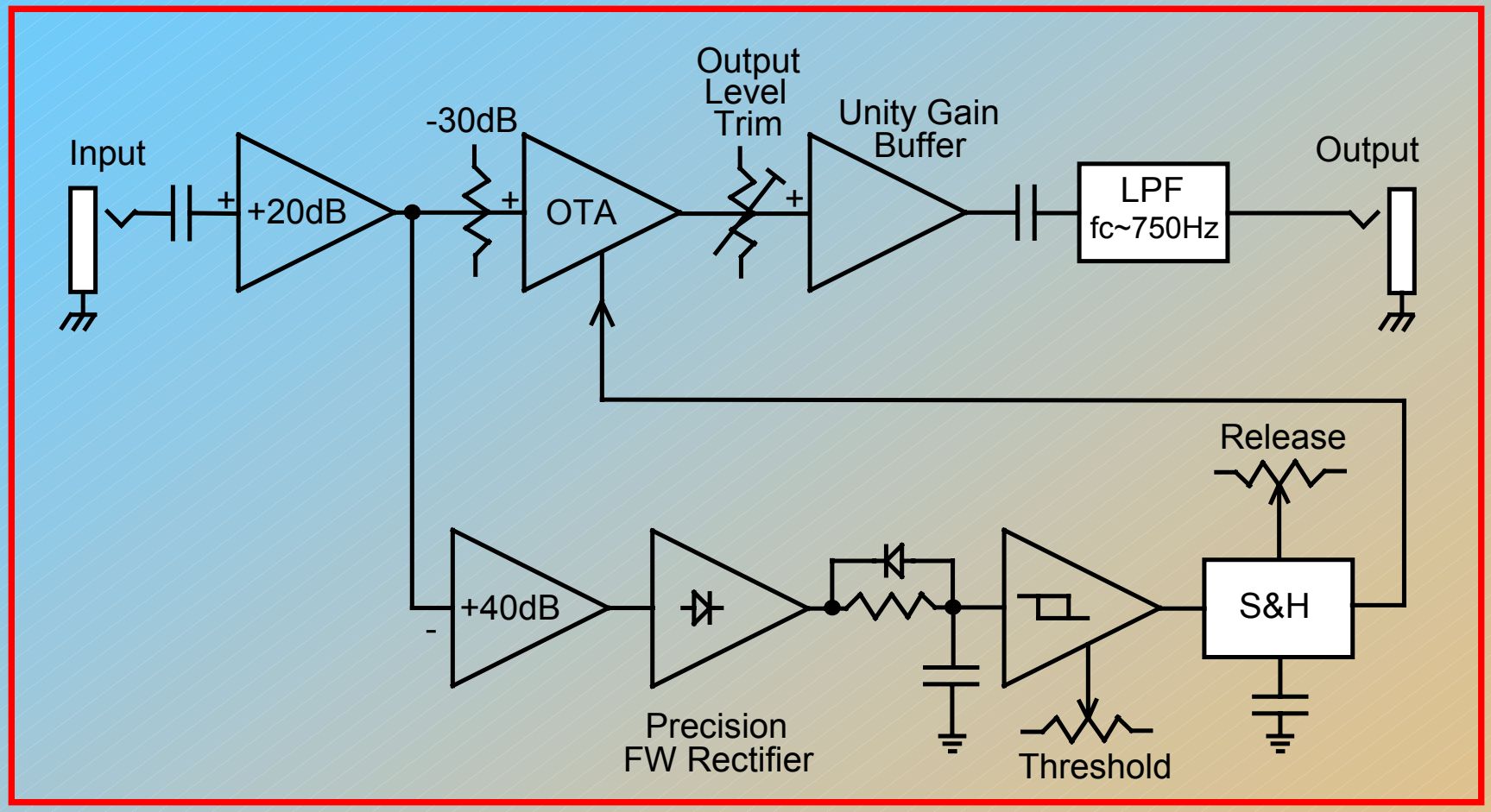


The Block Diagram

A method of simplifying and explaining a complex system using labeled block symbols logically arranged and joined by lines.

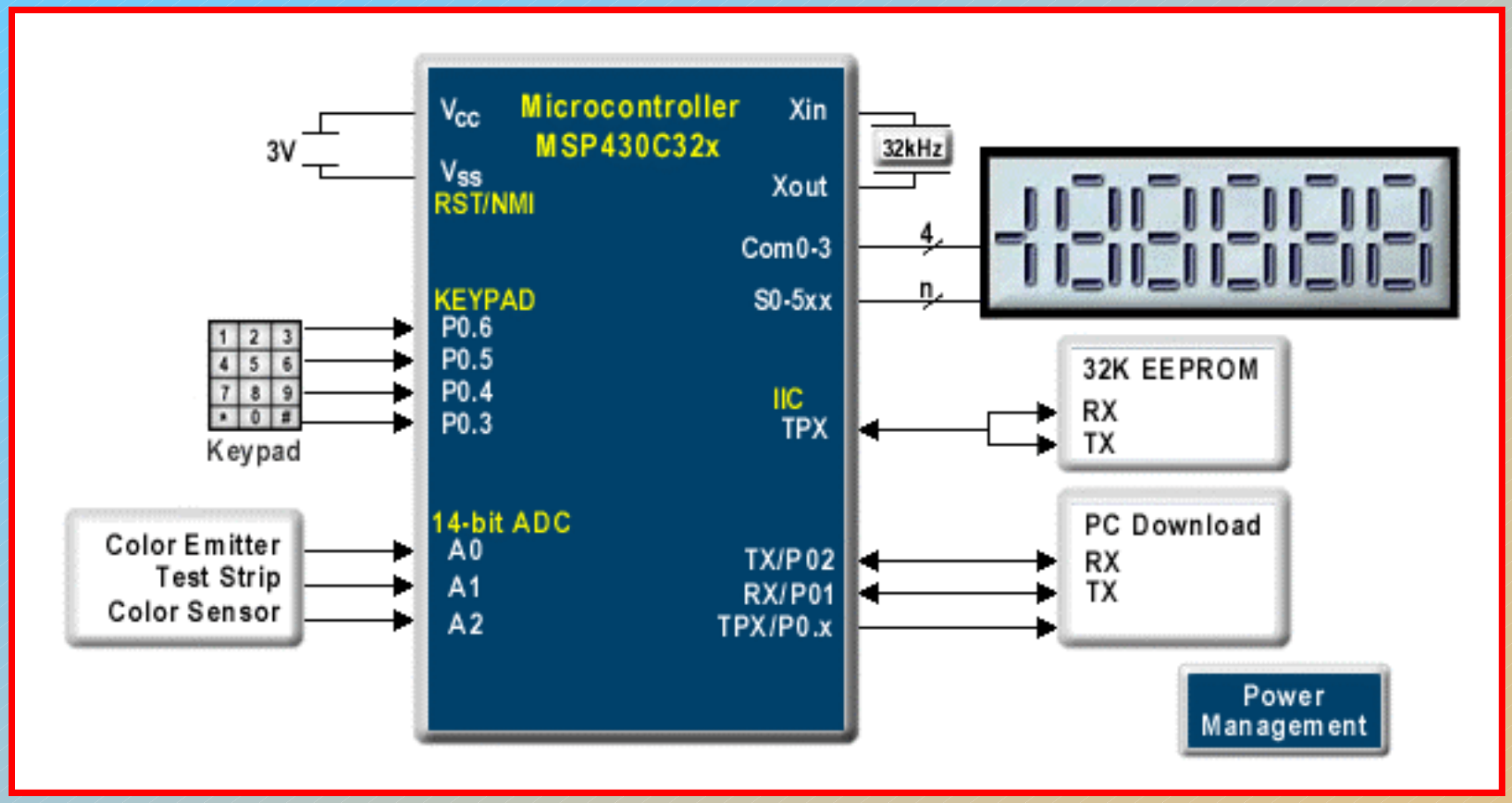
- Arrows illustrate (process) flow as well as I/O's.
- In electronics, each block may represent a group of components (R/C/L's, IC's, etc.) performing a dedicated function.
- B.D.'s explain what a group of parts does, not how it does it.
- Useful for fault finding & debugging.

Block Diagram Example



Audio Signal Processor - Noise Gate

Digital System Block Diagram



Glucose Monitor - (Texas Instruments)

Block Diagrams should include:

1. A block symbol which best represents each signal processing stage or sub-stage in the circuit or system.

2. Left to right flow, organized with *inputs - leftmost* and *outputs - rightmost*.

3. Standardized schematic symbols may be used (sparingly) for user controls, indicators, or simple circuitry performing noteworthy functions.

4. Function labels for each stage, component and input or output connections.

Block Diagrams Should Include:

5. Important signal levels.
6. Symbols such as (-) or (+) to indicate inverting or non-inverting inputs/stages.
7. Standardized signal waveform shapes, signal processing modifiers (esp. for filters or passband control), or annotation symbols.
8. A title (and other appropriate credits or annotations).

Some Useful Block Diagram Function Symbols

Hysteresis

Bandpass

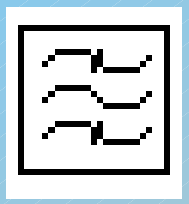
Low Pass

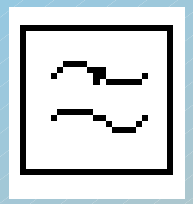
High Pass

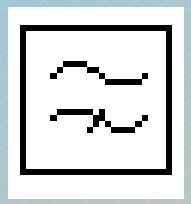
Falling Edge Pulses

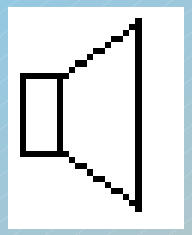
Rising Pulses

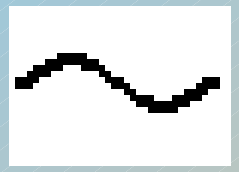
Signal Direction Arrow

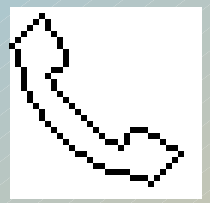


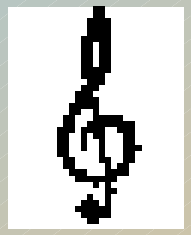


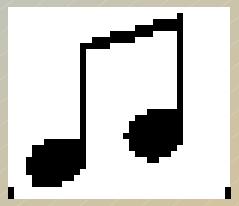


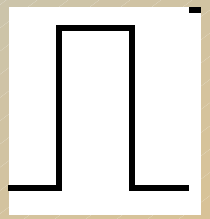


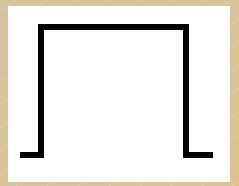


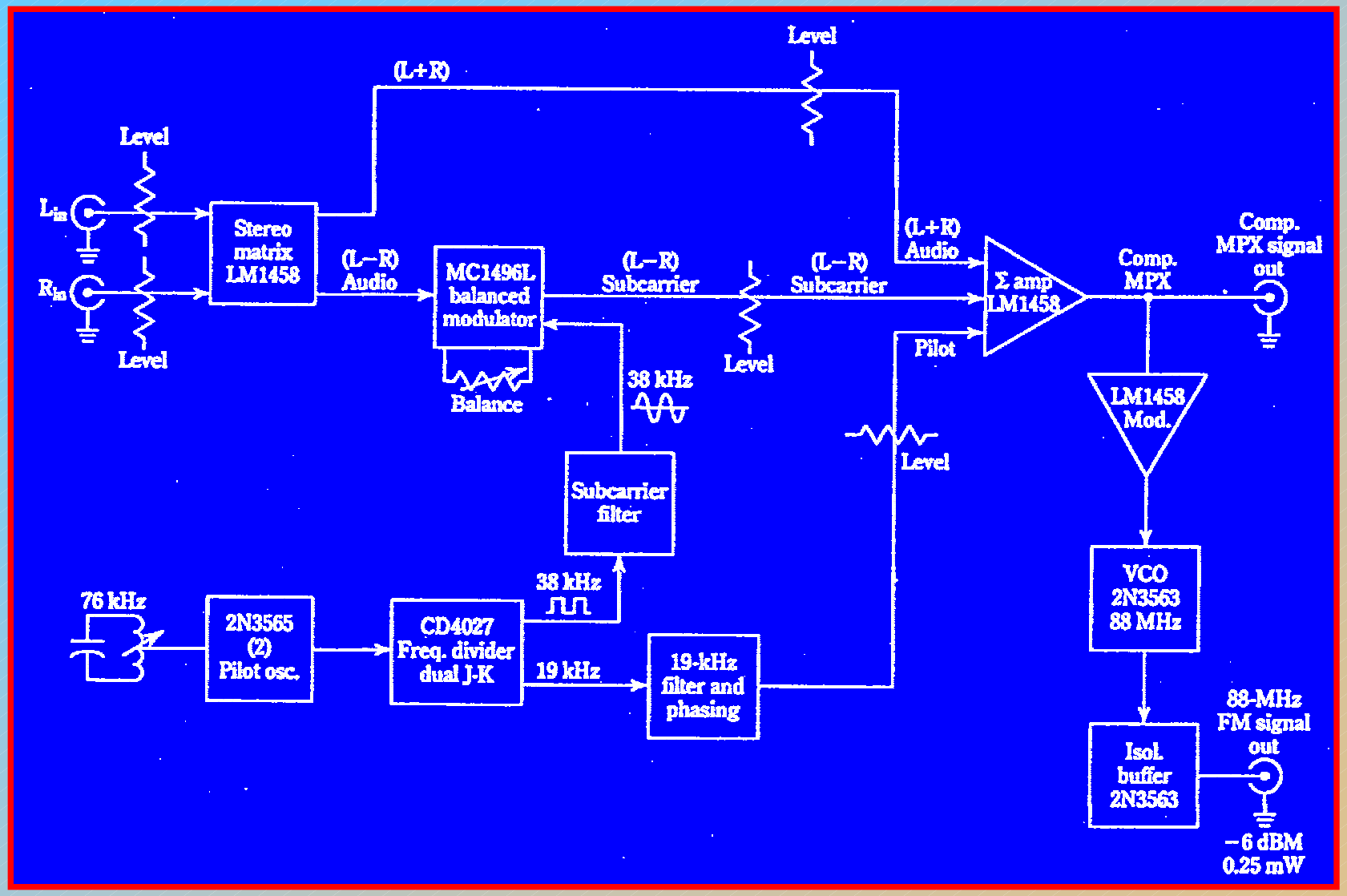




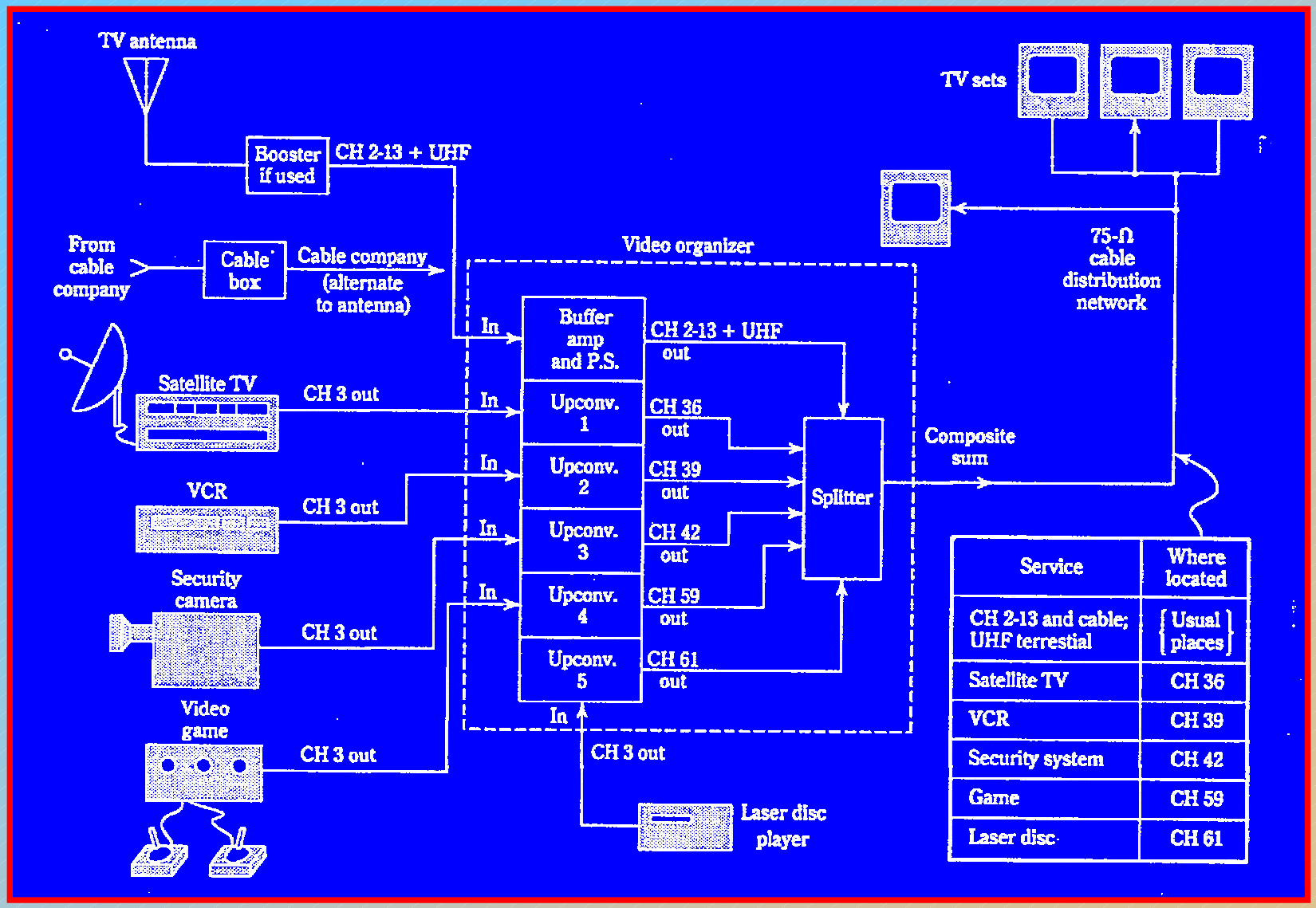






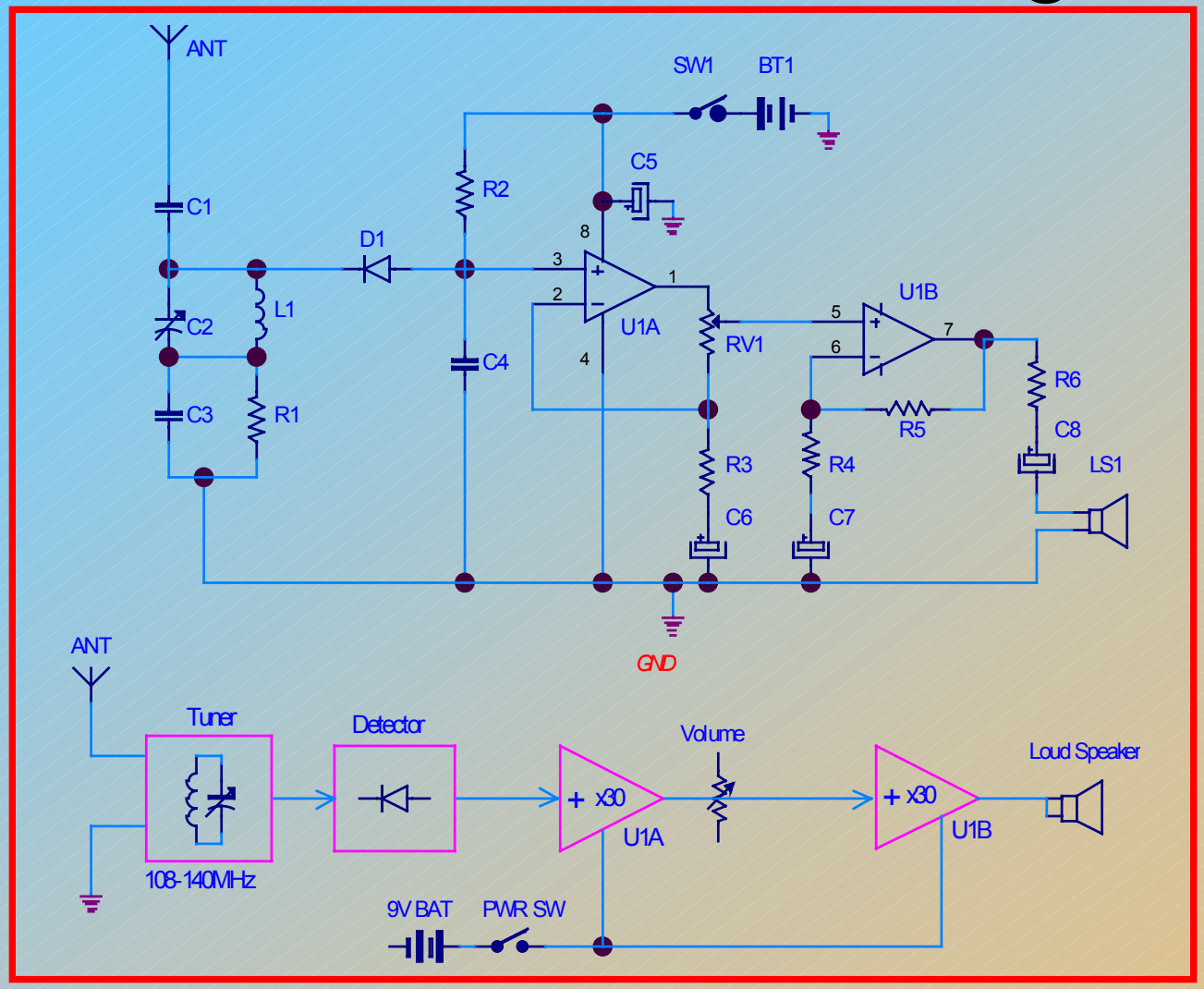


88 MHz FM Stereo Wireless Transmitter



Small Cable Distribution System Diagram

Schematic -> Block Diagram



Aircraft Receiver

Aircraft Receiver Netlist - Generic Format

```
[                ]                ]                ]                (N00011
ANT              [                [                [                C4-1
                 C7               U1               LS1              R2-2
ANTENNA          RAD-197          8DIP300                           U1-3
                 CAP_POL          LM358            SPEAKER          D1-1
                                                                    )
]                                                                   (N00012
[                ]                ]                ]                C6-2
C1               [                [                (N00000          R3-2
TAJ-A            L1               D1               ANT-1            )
CAP_NP                            DO-7             C1-1             (N00007
                 INDUCTOR         DIODE            )                C7-2
                                                   (N00010          R4-2
]                                                  C1-2             )
[                ]                ]                C2-1             (N00005
C2               [                [                L1-1             R2-1
TAJ-A            R2               RV1              D1-2             U1-8
CAP_VAR          RC05             3059Y            )                SW1-COMM
                 R                R_POT            (N00001          C5-2
]                                                  C3-1             )
[                                                  C2-2             (N00002
C3               ]                ]                L1-2             R3-1
TAJ-A            [                [                R1-1             U1-2
CAP_NP           R1               BT1              )                RV1-2
                 RC05                              )
                                  BATTERY
                 R
```

(Edited example only - not a complete listing)

Netlists

Listing of the *names* & *parts symbols* used in an ECAD circuit drawing as well as their *connection points* on each *net*.

- Used to create or verify a link between a schematic and a PWB design.
- ASCII text file
- Many formats for compatibility with different PWB design software packages.
    - EDIF, Cadstar, Protel, Tango ...

What is a BOM

- BOM = Bill of Material(s)
- A BOM details *all* the individual items needed to complete an assembly
  - Part number
  - Part value
  - Description (in detail)
  - Quantity
  - Manufacturer
  - Comments to the buyer
    - Substitution options
    - Critical characteristics, etc.
  - Supplier, price … (optional)

Bill of Materials for VCHIP3 REV2 - Jerrold

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#	DESCRIPTION	VALUE/PN	MAKE	QTY	DESIGNATION
1	Capacitor, 10pF/50V (pref NPO or min 10%), ceramic, radial, 0.2"ls	C322C100M5U5CA	Kemet	1	C20
2	Capacitor, 100nF/50V, Z5U, 20%, monoceramic, radial, 0.2" ls	C322C104M5U5CA	Kemet	9	C1, C2, C3, C5, C7, C11, C12, C15, C16
3	Connector, 4 pin locking straight header	640456-4	Amp	3	J1, J2, J4
4	Crystal, 14.31818MHz, HC49, parallel res.	14.318MHz-HC49 20/50/10S	IQD (Farnell)	0	Y2 (not required)
5	Crystal, 20.0000MHz, HC49S (short), parallel res.	A-20.000000-18-FUND	Raltron	1	Y1
6	Diode, signal	1N4148/1N914A	any	0	D1 (not required))
7	IC, EEPROM, serial, CMOS, DIP8, plastic	24C01-10PC	Atmel	1	U7
8	IC, CMOS multiplexer, DIP16, plastic	4053	any	1	U3
9	IC, voltage controller, TO-92	MC34064P	Motorola	1	U6
10	IC, microcontroller, OTP, DIP18, plastic	PIC16C56-20 HS/P	uCHIP	1	U4
11	Inductor, RF choke, 47uH, radial, 0.3 or 0.4, or 0.5" ls	AL03-47K	RCD	1	L1
12	PWB, VCHIP3 Rev2, BHE-02-0795			1	
13	Resistor, 1K, 1/4W, 5%	1K, 1/4W, 5%		2	R7, R15 (not required), R22
14	Resistor, 820R, 1/4W, 5%	820R, 1/4W, 5%		1	R20
15	Socket, IC, DIP8, solder	640463	Amp	2	U1, U7
16	Spacer, 0.625", polyamide	115-0260-009 MSPM-4-01	Johnson Richco/Intek	2	
17	Standoff, PWB, SS, #6-32 threaded, press-fit	KF(S)E-632-12	PEM, Interfast	1	
18	Transistor, NPN, TO-92	2N3904	any	1	Q1

ECAD & the BOM

- Generated from your ECAD software
  - Basic column headings, parts values, reference designators, etc.
  - Information output is typically limited
- Its format and complexity varies with ECAD program
- Newer, up-to-date software permits a higher degree of integration, flexibility and customization
- Commonly exported to a spreadsheet; eg. MS Excel
  - Easier to send by email to parts suppliers/buyers
  - Anyone can read them easily in this format
  - Columns can be added, hidden or sorted to suit needs of user
  - Once built and accurate, other project BOMs can be built quickly cutting and pasting info from one sheet to another

How to Build a BOM

- From your ECAD software, generate your BOM output
  - *do this after all ECAD details are finalized*
- BOMs are generally highly developed - manually.
  - *research, specify and check each line-item carefully for accuracy (get a datasheet for each semiconductor & special part)*
  - *Don't forget all the misc. stuff…(screws, nuts, washers, heatsinks, standoffs, PWBs, enclosures, etc.)*
- Be certain that your BOM matches your revision level
  - *Ensure that both BOM and related drawings reflect the same Rev. #*
  - *Ensure data between ECAD & BOM correlate after each change*
- REF column is sequential; sort others on the Description column
- Use Lab Handbook examples or 'Project Documentation' info
- Most companies have set practices for managing documents