Technical Materials

Electrical Components

Components

- Common Components used in electronics:
  - Resistors
  - Inductors, Transformers
  - Capacitors
  - Diodes
  - Transistors
  - Functional ICs
  - LCDs
  - Switches/Relays
  - Connectors

Resistors

- value
- stability (temperature coefficient)
- tolerance
- power rating

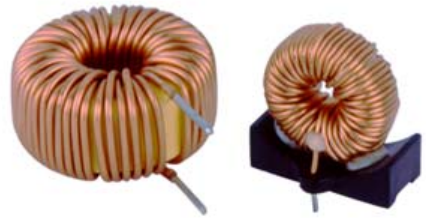
Molded carbon	low cost, 5-10% tolerance, -ve temperature coefficient
Carbon film resistor 	small size, more stability, low cost, 1-5-10% tolerance, -ve coefficient
Metal film resistor 	+ve temperature coefficient
Wire wound resistor 	very low resistance values are available. Also available for higher power rating.

Inductors

- Three types of inductors are used:
  air core, iron core and ferrite core.

- Air core inductors are used for very high frequencies: 100kHz to 1 GHz. Available in a few uH to several hundred uH.

- Iron core inductors are available from 0.1 to 120mH.
  Max DC current about 100mA.



More on inductors

- For tuned and timing circuits, tighter tolerance of inductance values and Q-factor are important. Q value for inductor is R/XL.

- Transformers are used for :

  1) step up 2) step down

  3) isolation 4) impedance matching

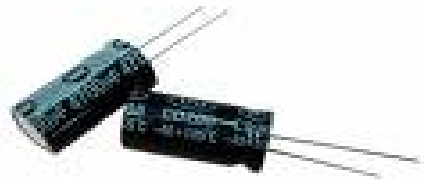
Capacitors

- Value, tolerance, working voltage, temperature coefficient, insulation resistance, quality factor, dielectric absorption.
- Equivalent series resistance (ESR)
- Dissipation Factor(DF) = ESR/Xc
- Quality Factor(QF)=1/DF

So most commonly selected capacitors are:

ceramic disc

aluminum electrolytic



Capacitor Table

	Ceramic	**Mica**	**Plastic Film(polyester, polypropylene,etc)**
Capacitance range	1pF to 1 uF	2.2pF to 0.01uF	20pF to 500uF
Working voltage	25V to 30 kV	50V to 5 kV	30V to 10kV
Tolerance	5% to 50% and -20%	0.5% to 20%	+/-1% to +/-20%
Temp coefficient	+/-15%	+/-200 ppm	
Relative size	Small	Mid to large	Medium to large
Relative cost	Inexpensive	Medium	Medium to high
Typical use	Mid-to-high frequency bypass, coupling, filter	Above 200MHz	Low to medium frequency range, with good tolerance, high Q-factor

Electrolytic Capacitors

- high capacitance, low working voltage, polarized (as plates are made of different metals). Reversing the polarity will destroy them if voltage is high.

- Two type of dielectrics are used: aluminum and tantalum. Aluminum electrolytics are more common, physically larger, and have a wider range of values. 0.1 uF to 5700uF. 10V DC to 500V DC. Tolerances -10% to 50%. Common use is power supply rectifier filter.

- Tantalum electrolytic are relatively smaller, in narrow range of capacitance and voltage rating. 0.1uF to 100uF, 10V DC to 35V DC.

- For both positive and negative varying voltages, two electrolytic caps can be put in series, in back-to-back position(-ve to -ve). Total cap is the series equivalent of the two polarized caps. Wet anode tantalum caps are advised against this configuration.

Application example of Capacitors

- For bypass filters in power supplies:

  2 caps (100uF(electrolytic) and 0.1uF(ceramic disc)) are paralleled.

  It is because at high frequency, the ESR of electrolytic cap is high but that of ceramic cap is less.

Application example of Capacitors

- Decoupling Capacitors:

  In digital circuits, a 0.1uF ceramic disc capacitor is used for the power supply near the ICs.

  This stores enough charge to supply the requirements of the switched component

Switches

- Switches are of two types :
  - maintained or momentary
  - contacts are normally open (NO), normally closed (NC).

    (Normal state is the mechanical ‘off’ position)
- Relays are like voltage-controlled switches and are used for interlocking or driving high-power loads from logic.
  - They are of two types:
    - electromagnetic or solid-state.
  - Relays can be panel mounted/ plug-in/direct soldered
  - Selection depends on mechanical size, configuration, coil voltage, contacts arrangement, contact voltage and key parameters.

Connectors

Types

- Wire-to-wire, wire-to-PCB, PCB-to-PCB.
- Wire could be flat cable, coaxial cable, conventional wire.
- Mounting can be panel or PCB type.

Sizes

What is the voltage across the contacts and what is the current through the contacts, what is the contact resistance.

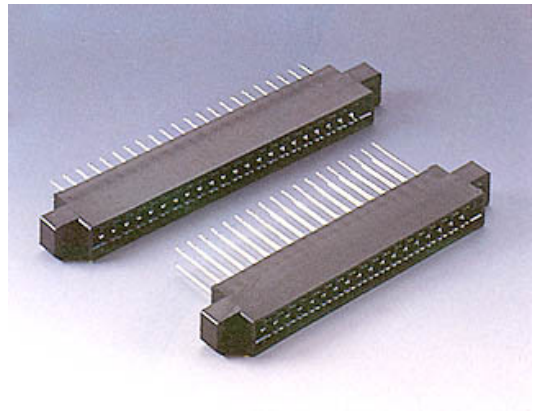
Contact materials

beryllium copper, phosphor bronze, spring brass, low-leaded brass.

High-quality contactors use gold or silver plating on specific contact areas.

Connectors

Flat cable connectors



PCB edge connectors: crimp or solder type.

D-Type connectors

BNC connector

Circular connectors

Connectors

- Coaxial connectors:

  Usually restricted to two wires: a signal and ground.
  Typically for radio frequency (RF) and audio applications.
  Most popular is the BNC connector.
  Audio types are called phonojacks, and mini- and micro-plugs.

- Circular connectors:

  high-quality, military type

- Zero Insertion Force (ZIF) connectors:

  used for high number of contacts, for superior contact.
  Contact force is applied separately after insertion.
  Most typical application is EPROM programmers.

Interfacing

Outline

- Logic Families
- TTL
- CMOS
- Interfacing between logic families
- Switches as input devices
- Driving digital logic from comparators and op-amps
- Driving LEDs
- Driving Relays
- Opto-couplers

Logic Families

- Characterstics
  - Logic threshold voltage
  - Required input current
  - Output current capability
  - Fan-out
  - Noise immunity
  - Speed

Logic Families

- RTL (Register transistor logic)
- DTL (Diode transistor logic)
- TTL (74x series) (Transistor transistor logic)
  - High speed (74H series)
  - Low power (74L series)
  - Low power Schottky (74LS series)
- CMOS
  - 4000B series
  - 74C and 74HC (compatible with TTL)

Design Reccommendation

- Use 74HC logic for all new designs
- 74HCT for compatibility with existing TTL
- 74AC(T) for speed
- 4000B/74C for extended power supply range like with unregulated battery

Electrical properties of logic

- As the typical fan-out is 10 loads, there is no need to bother much for single family design
- When using digital logic outputs for driving other devices, it is necessary to know what it takes to drive a logic input and what a logic output can drive
- When mixing logic families, it is essential to understand circuit properties of logic input and outputs

TTL

- Supply voltage +5V
- Typically pulls HIGH only to about +3.5V
- Good sinking almost to GND
- Can drive TTL, HCT, ACT, NMOS
- Pull-up resistor can swing TTL output to full +5V
- 4.7K is typical pull-up resistor
- TTL with a pull-up can drive HC, AC, 4000B/74C

TTL input and output Ch.

- Input
  - Sources a sizable (mA) current when held LOW
  - Draws only a small (20μA) current when HIGH
- Output
  - Its output is an *npn* transistor to ground and an *npn* follower with a current-limiting resistor in its collector
  - Can sink a large current to GND when LOW
  - Can source at least a few mA when HIGH at about +3.5V
- Threshold is around +1.3V (+0.8 V and +2.0V)
- Low noise immunity in low state is the intrinsic weakness

More caution on TTL

- An open TTL input is barely high so do not leave it open when require it to be high
- Unused inputs that affect the logic state of a chip (e.g. RESET input) must be tied to HIGH or LOW as appropriate

CMOS

- Wider supply voltage (3V to 18V)
- Better input protection
- Zero static current
- Draws dynamic current during logic switching for charging discharging of internal capacitors

CMOS input and output Ch.

- Input
  - Draws no current for input voltages between ground and supply voltage
  - Input protection diodes prevent damage from static electricity during handling
- Output
  - A push-pull pair of complementary MOSFETs
  - Output is like r_{on} to ground or V+
  - Swing is rail-to-rail

Interfacing different logic families

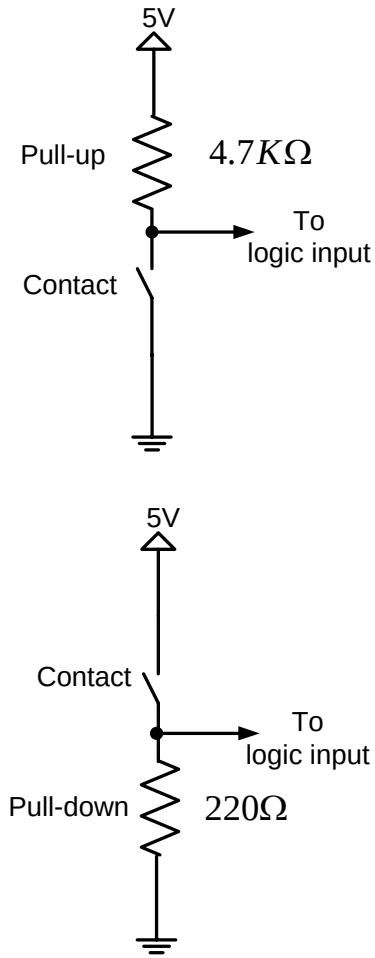
- Three things to look for
  - Logic-level compatibility
  - Output drive capability
  - Supply voltages

Interfacing TTL-CMOS

- To drive high-voltage CMOS, use level translator like 40109, 14504, or LTC 1045
- 4000B/74C CMOS have feeble drive when running from 5V and hence can not drive TTL. A level up-translator is required for this purpose.
- Or run CMOS at 3.3V which puts the input threshold near TTL value of 1.4V so that it can drive TTL and vice versa
- Cannot connect 3.3V CMOS to other 5.0V CMOS signal from other devices

Switches as input devices

- When driving TTL:
  - use a simple pull-up resistor with switch closure to GND
    - Switch easily sinks the LOW state input current
    - Pull-up brings HIGH to +5V giving good noise immunity
  - Pull down to GND with switch to +5V is undesirable because
    - Pull down has to be small at 220ohm drawing large current
    - Noise immunity is only 0.6V with switch open
- For CMOS, use any method



Mechanical switch bouncing

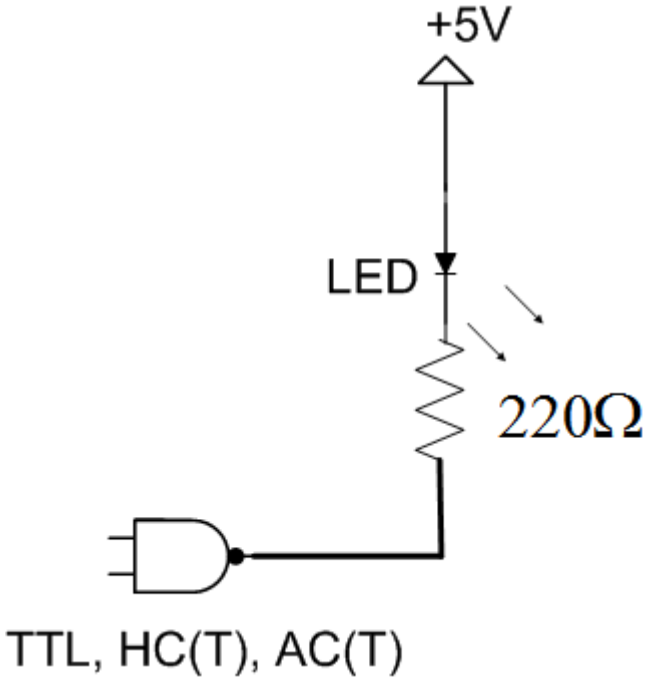
- Use SR flip-flop for mechanical switch debouncing
- ‘279, 4043, 4044 are quad SR latches
- Use RC(20ms to 25ms) slowdown network to drive CMOS Schmitt trigger
  - Not suitable for TTL as it requires low driving impedance
- Use Hall-effect switch instead

Driving digital logic from comparators and op-amps

- Most comparators (311, 339, 393, 372) have an npn output transistor with open collector and grounded emitter.
- Connect a pull-up to drive the TTL.
- For CMOS, connect the pull-up to the +Vdd
- No need for split supply as many are designed for single-supply
- Comparators are faster compared to op-amps
- Use threshold detector with hysteresis to avoid unwanted glitches

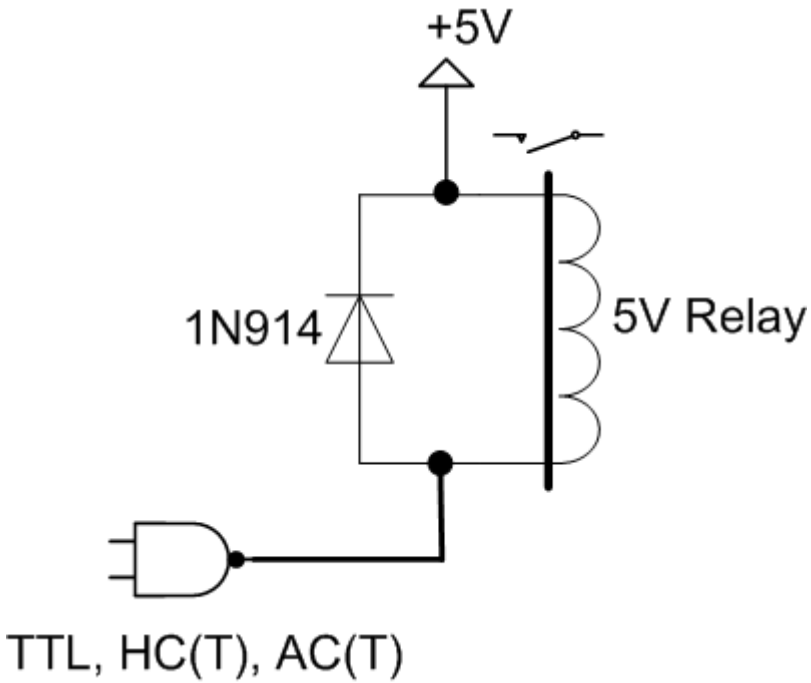
Driving LEDs from logic

- As TTL is better at sinking, return the LED to +5V
- LEDs have a forward drop of about 1.5V to 2V and need 5mA to 20mA
- Put a current-limiting resistor if there is no internal resistor



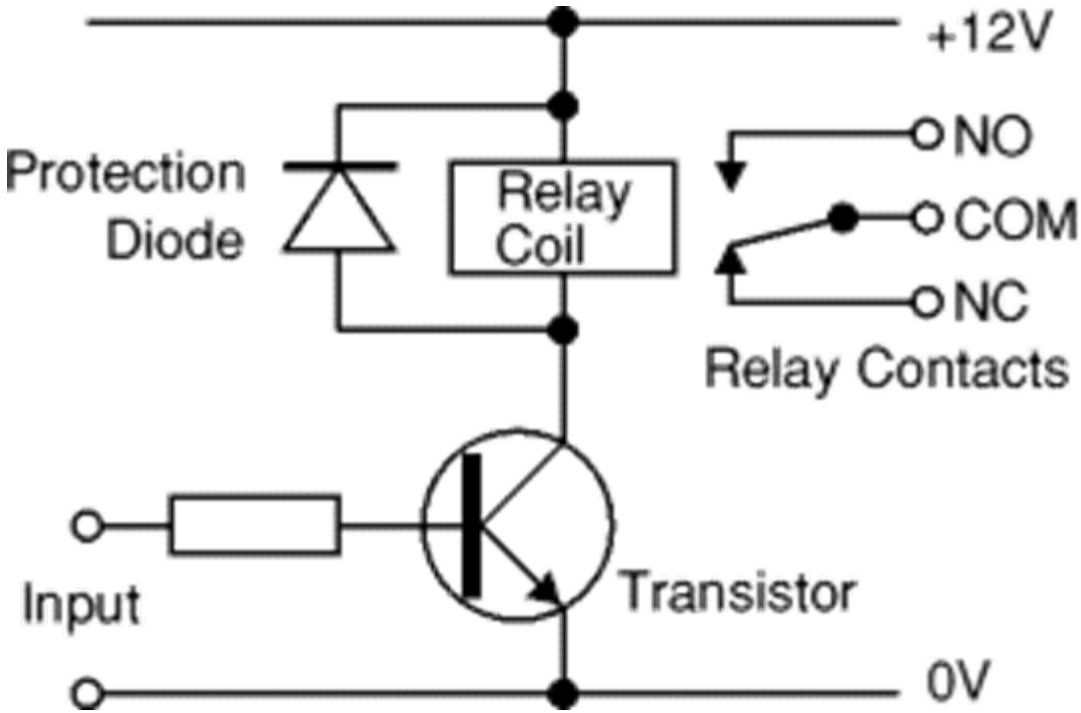
Driving Relays from logic

- Connect low-current 5V relays(500ohm coil resistance with 10mA current), put a diode across the coil to clamp the inductive spike



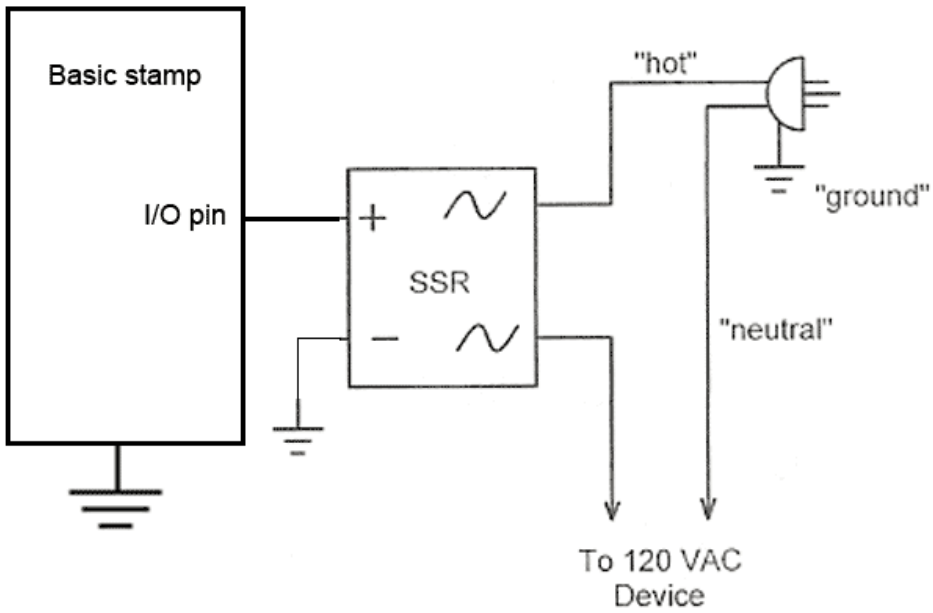
Higher current and voltage relays

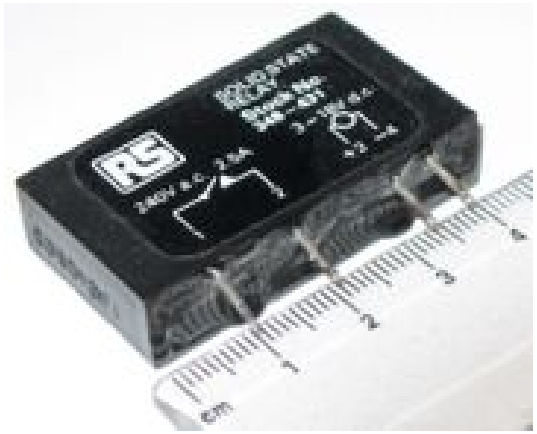
- For high current relays, an npn transistor where the base is connected to the 5V logic can act as a switch for the load



Driving high-power loads from logic

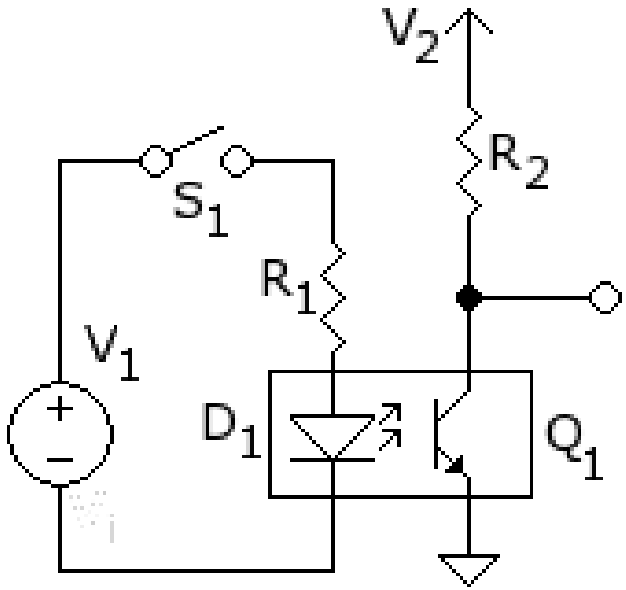
- Use these solid-state relays to drive higher-current and voltage loads. These come in different voltage and current ratings for the load contacts.





Opto-couplers

- Used for remote loads or loads with a separate GND
- Can be of low speed



Electronic Equipment

Lab Power Supply

- Most bench-top DC power supplies have two or three isolated power sources, eg.
  - one 5V DC fixed
  - two 0-30V variable
- Either power supply can be connected to the GND at one end i.e either the +ve or the –ve to the GND.
- To generate a +/- supply as needed for an OpAmp, connect the +ve of one together with the –ve of the other to GND. Put them in series mode and use the voltage control knob of the master to adjust the voltage.

Function Generator

- Note different types of outputs namely:
  - 50 Ohm
  - TTL, CMOS
- For logic inputs, use the TTL/CMOS type output

References

- The Art of Electronics – Horowitz & Hill, 2nd Ed., Cambridge. *http://www.artofelectronics.com/*

- Electronics Project Management & Design – D. Joseph Stadtmiller, 2nd Ed., Pearson Prentice Hall.