Capacitors

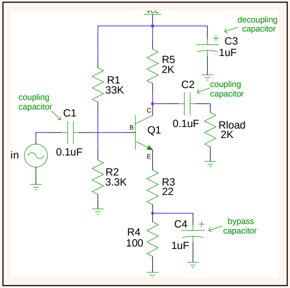
- Selecting the correct capacitor is essential to making a circuit perform as expected.
- They differ mostly in what type of dielectric they use and their physical configuration.
- The dielectric determines the capacitor's voltage rating, its size, equivalent series resistance (ESR) and inductance (ESL).
- The dielectric also determines if the capacitor is polar or non-polar.
  - Polar: electrolytic, tantalum
  - Non-Polar: ceramic, film, polypropylene, polyester, polystyrene, air
- Capacitors are found in three basic physical configurations: axial, radial and SMD.
  - Axial, lead come out both sides, "like an axle"
  - Radial, leads come out one side
  - SMD, surface mounted, no leads

Capacitors

- The key properties to consider when selecting a capacitor for an application:
  - capacitance value
  - voltage rating
  - frequency response
  - cost
  - size
- Once these are known, the dielectric type and physical configuration make themselves clear.

Capacitors

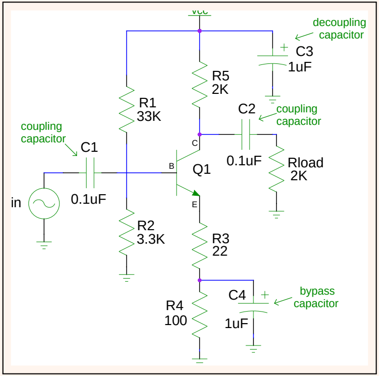
- There are several terms used when talking about a capacitor's function in a circuit.
- The next few schematics shown below illustrates some of those names.



- C1 and C2 are *coupling* capacitors. They block DC and pass AC signals. They are usually seen in series with the signal path.
- Obey polarities for C1 and C2 if electrolytic. If ceramic, and thus piezoelectric, they may induce noise.

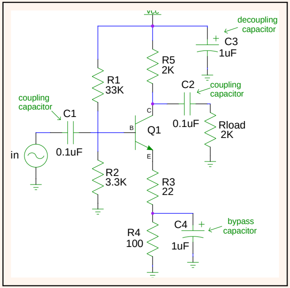
Capacitors

- C4 is commonly called a *bypass* capacitor. It provides an alternative path for AC signals around R4.
- The combination of R3 and C4 help determine the AC gain of the amplifier.



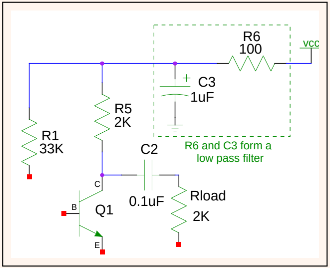
Capacitors

- C3 is a *decoupling* capacitor. It decouples the circuit from the inductance and noise present on the Vcc line.
- The capacitor type at C3 is determined by the frequencies present in the circuit which would also dictate the size of the capacitor. Its value should be effective at frequencies of interest.



Capacitors

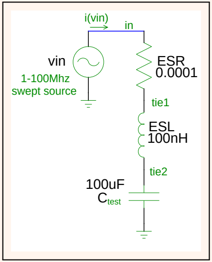
- Consider the partial schematic below.

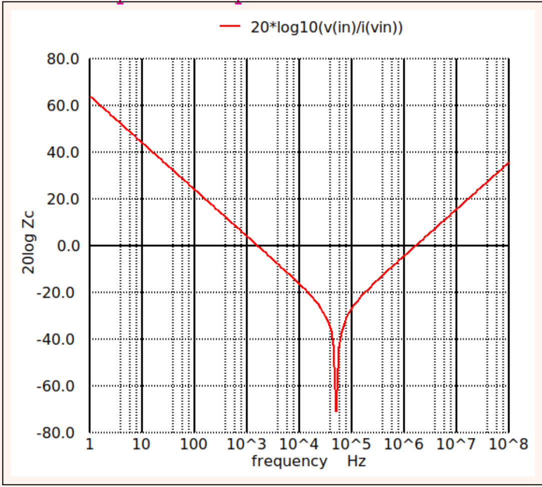


- C3 is made more effective if a small value resistor is placed in series to V_{cc}.
- The combination of C3 and R6 from a low-pass filter with a much lower cut-off frequency than with C3 alone.

Capacitors

- The value of the capacitor and its parasitics strongly effect its frequency response. Plot is from: cap_eval.sp

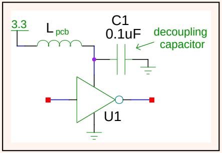




- For lots of great information on capacitor behavior see: Kemet Component Simulator

Capacitors

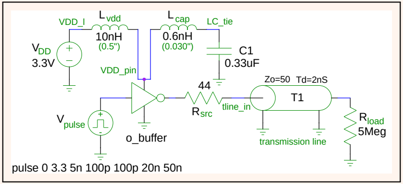
- C1 is a *decoupling* capacitor. It decouples the circuit from the inductance present in the PCB power distribution plane.

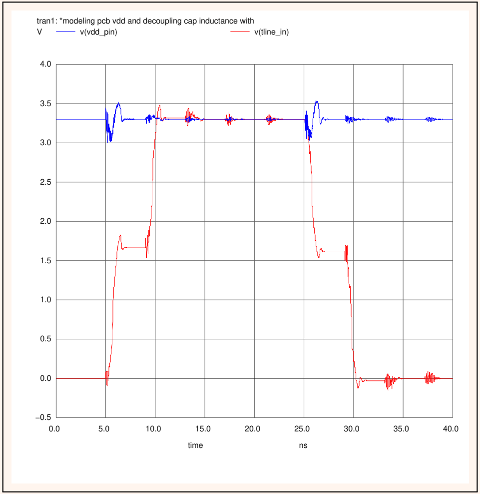


- Decoupling capacitors for digital ICs are usually very low ESL ceramic types. The capacitors act as a current source supplying the current needed to launch a signal edge.
- The physical placement for digital decoupling capacitors is critical. The capacitor should be placed as close as possible to the supply pin of the IC.
- Vias in series with digital decoupling capacitors should be avoided if possible when using fast ICs ($t_r, t_f < 1ns$).

Capacitors

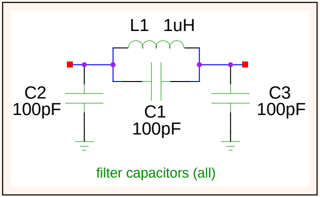
- Digital decoupling capacitors should be placed as close as possible to the supply pin of the IC. Plot is from: `equal_np.sp`





Capacitors

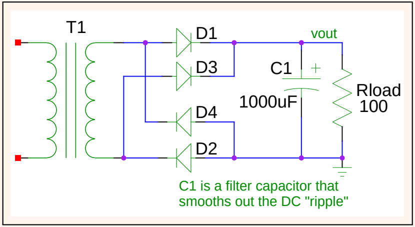
- Some capacitors are called *filtering* capacitors. Here are two cases where you might read this.



- This is a low pass filter with a stop-band notch added. All the caps could be called filter capacitors since they are in a filter.

Capacitors

- C1 is a *filter* capacitor. Its job is to remove (or filter) out the pulsating component (commonly called *ripple*) of the DC signal after the full-wave bridge rectifier.



- Another way to think about C1 is that it supplies the current that V_{out} requires between the positive pulses coming from the rectifier.

Capacitors

- Plot shows v_{out} as the filter capacitor stepped through 5 values; 1uf, 10uf, 50uf, 1000uf and 10,000uf. Plot is from: `full_wave_caps.sp`