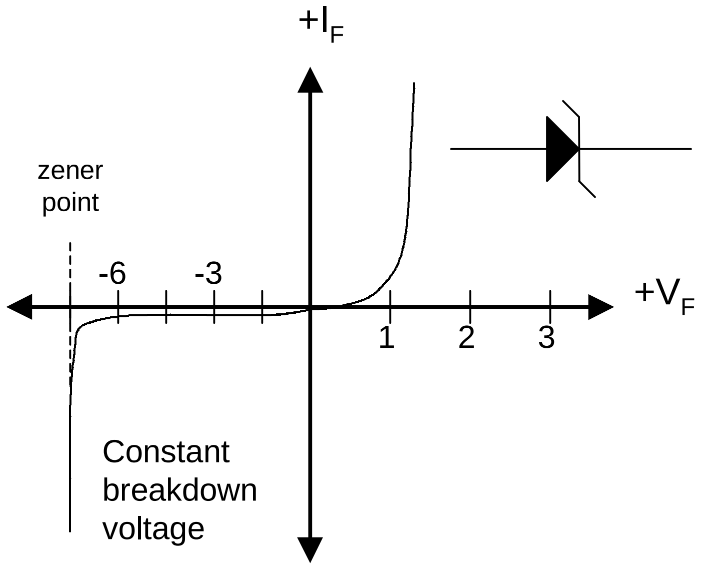
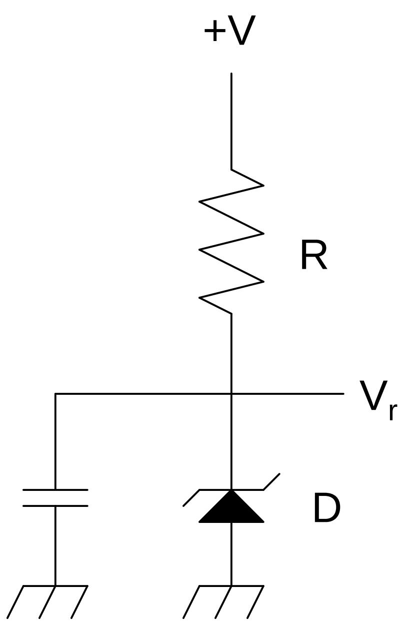
The Zener Diode

The zener diode exhibits a constant voltage drop when sufficiently reversed-biased. This property allows the use of the zener diode as a simple voltage regulator.



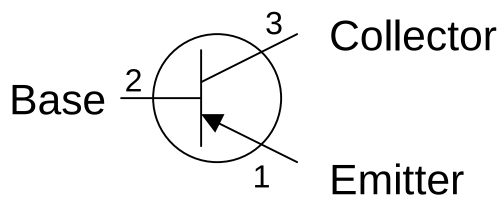


Here, V_r will be equal to the reverse breakdown voltage of the zener diode and should be constant. What is the purpose of the resistor in this circuit? Its job is to limit the current flowing through the zener diode:

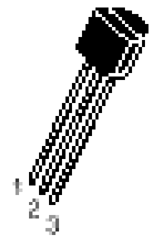
$$I = \frac{V - V_r}{R}$$

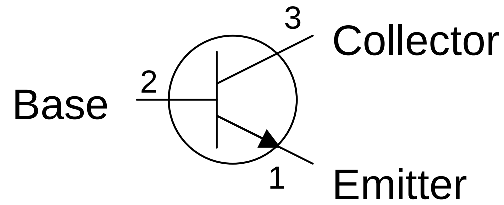
The Bipolar Junction Transistor

The transistor is a versatile device usually configured to perform as a switch or as an amplifier. The bipolar junction transistor (BJT) is the most common type and has three leads:



PNP Transistor

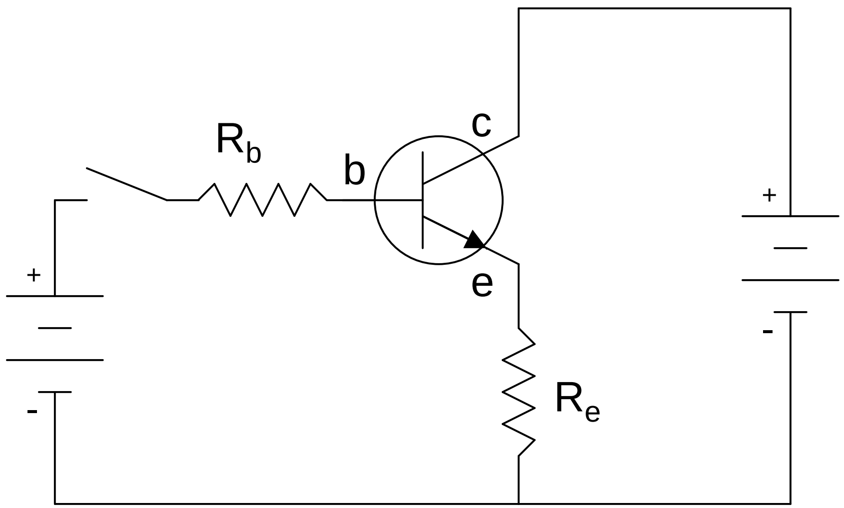




NPN Transistor

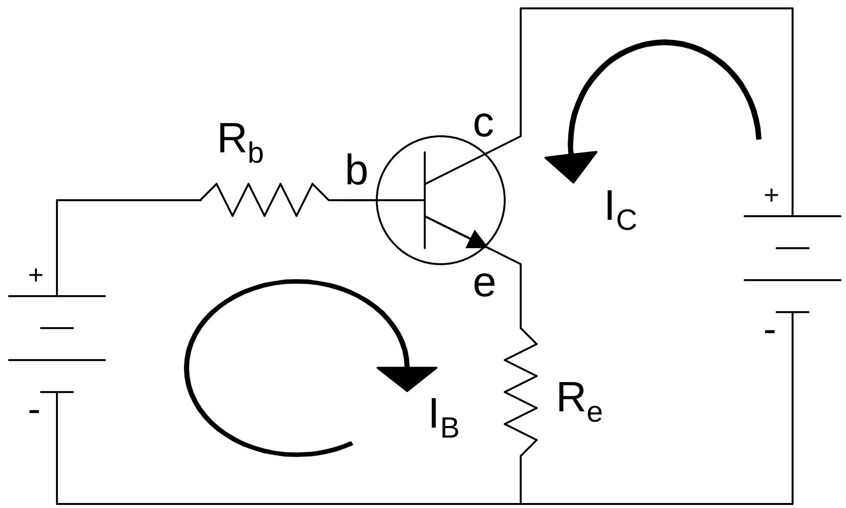
In a transistor, the flow of current from the collector to the emitter is controlled by the amount of current flowing into the base of the transistor. If no current flows into the base, no current will flow from the collector to the emitter (it acts like an open switch). If current flows into the base, then a proportional amount of current flows from the collector to the emitter (somewhat like a closed switch).

The NPN Transistor



No current flows from base to emitter, so the transistor acts like an open switch and no current flows from collector to emitter.

(Note: current never flows from base to collector or vice versa, regardless of the base current.)



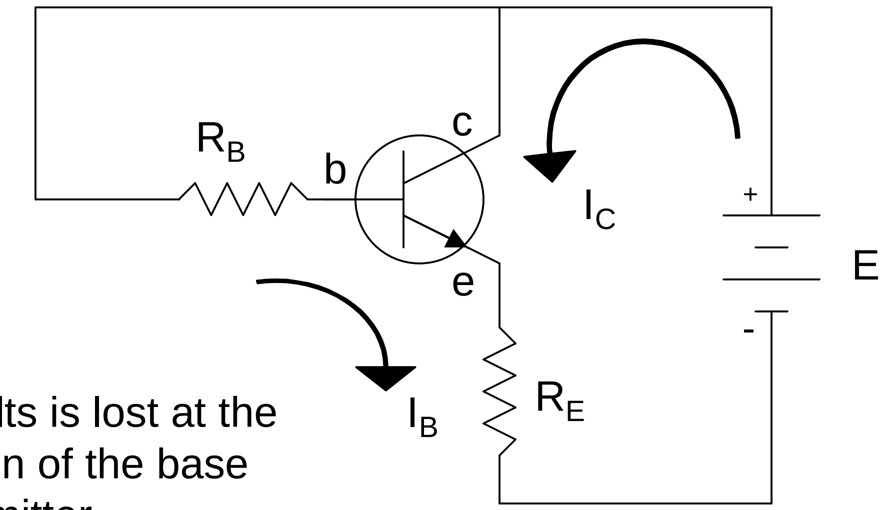
Current now flows through the transistor from base to emitter. This causes the transistor to allow current to flow from the collector to the emitter. The size of the collector current depends on the size of the base current and the beta β of the transistor:

$$\beta = I_C / I_B$$

A typical transistor has a beta of about 100.

Base and Collector Currents

What's the base current I_B? Use Kirchhoff's voltage law:



$$E = I_B R_B + I_B R_E + 0.7\text{V}$$

$$E = I_B (R_B + R_E) + 0.7\text{V}$$

$$I_B = \frac{E - 0.7\text{V}}{R_B + R_E}$$

0.7 volts is lost at the junction of the base and emitter

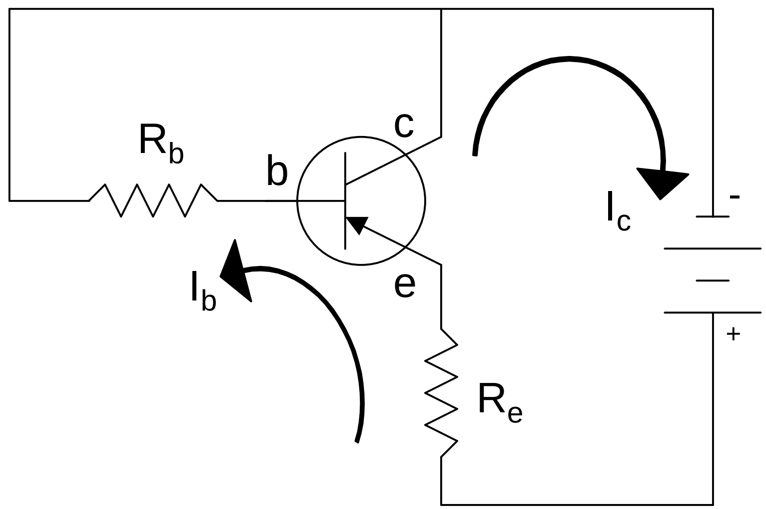
Now find the collector current I_C:

$$I_C = \beta \cdot I_B$$

What's the maximum value for the collector current?

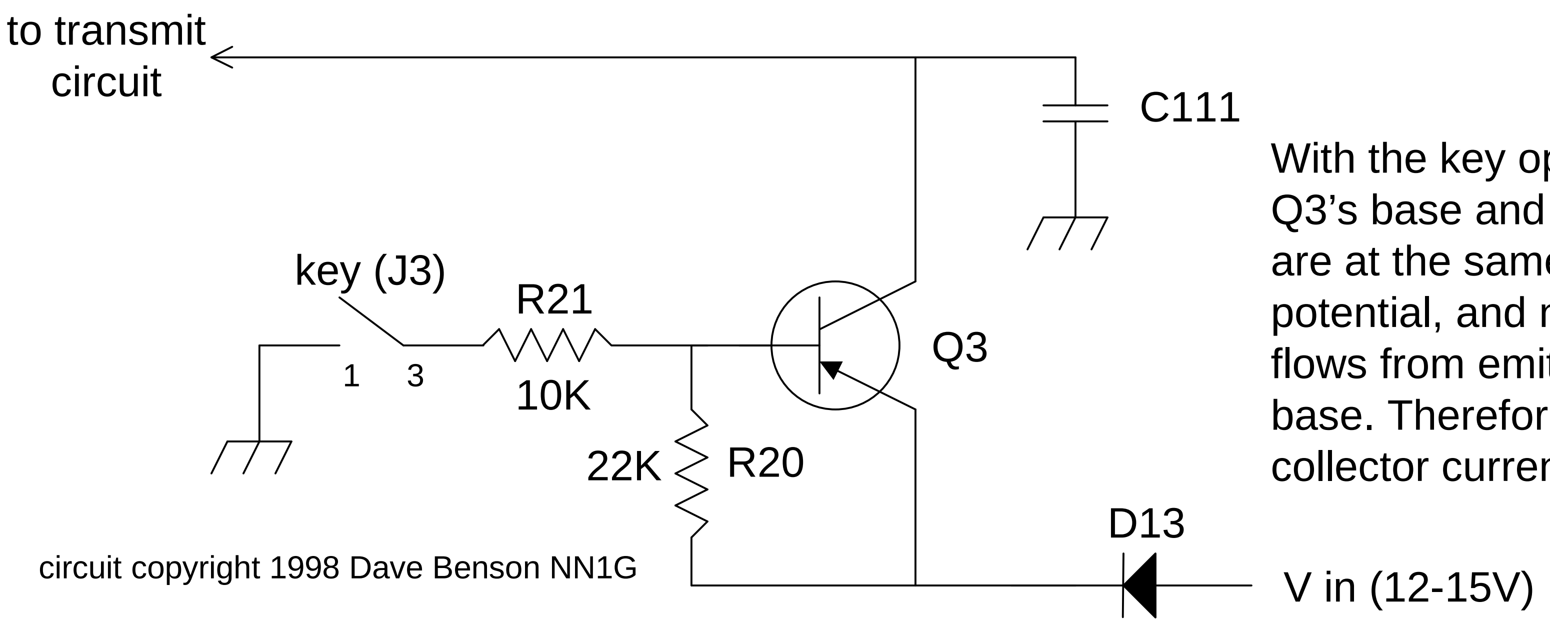
$$I_C = \frac{E}{R_E}$$

The PNP Transistor



The PNP transistor behaves identically to the NPN transistor, except that all polarities are reversed. The voltages are applied with opposite polarity, and the currents run opposite to those in the NPN transistor, but all other behaviors are the same.

The SW+ Transmit Switch

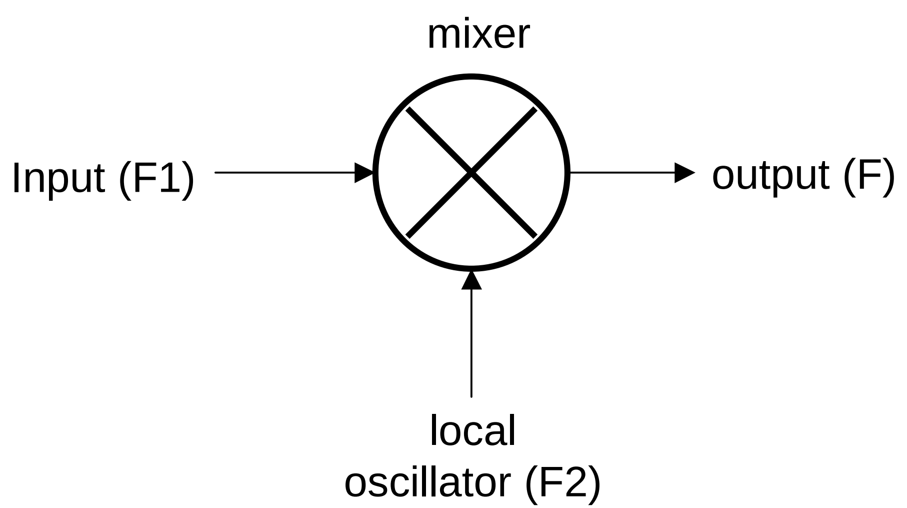


With the key open, Q3's base and emitter are at the same potential, and no current flows from emitter to base. Therefore, no collector current flows.

Closing the key allows current to flow through R20 and R21. The voltage drop across R20 lowers the potential at the base of Q3 and current flows from emitter to base. This also turns on the transistor and allows a collector current to flow. The collector current is fed to the transmit circuit, turning it on. R20 and R21 form a voltage divider to provide the correct bias voltage to the base. With the switch closed, what is the voltage at the base of Q3?

Mixers

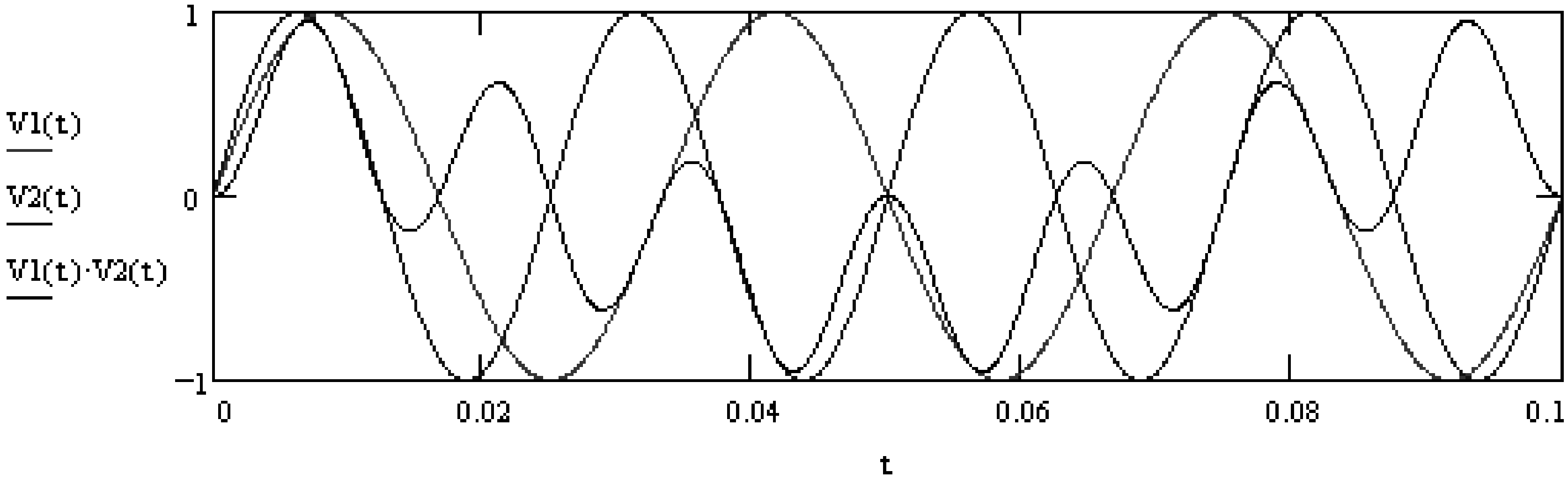
In radios, a mixer is a device which is used to shift the frequency of a signal. It does so by multiplying the signal with another carefully-chosen frequency:



The output of a mixer is a signal which is a combination of two frequencies: F1+F2, and F1-F2. In reality, other frequencies are also present at the output, due to distortion. All the unwanted frequencies need to be filtered out.

The SW+ has three mixers: two in the receiver and one in the transmitter. In the receiver, the received 7 MHz signal is mixed with 3 MHz from the VFO to get the 4 MHz intermediate frequency (IF). The IF is further mixed with the beat frequency oscillator (BFO) to get audio frequencies out. In the transmitter, the VFO is mixed with a 4 MHz signal to get the 7 MHz output.

Mixing Two Signals

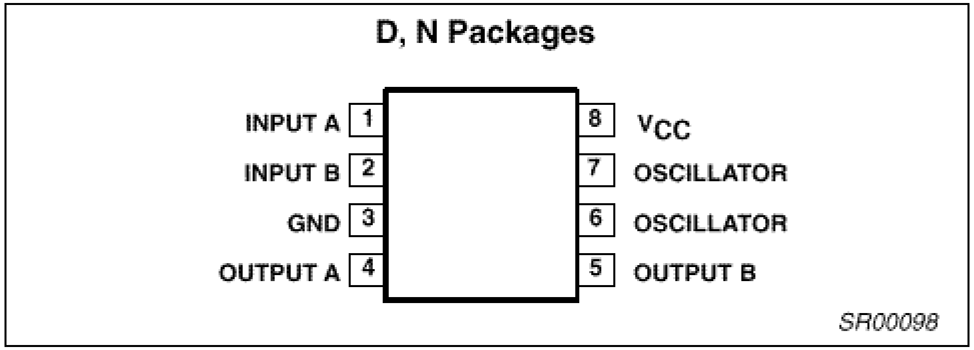


Here, V1 and V2 are the voltages of two signals (sine waves), and they are plotted versus time t. V1’s frequency is 30 Hz and V2’s frequency is 40 Hz. The third line on the graph is V1 times V2, and it has a frequency which is higher than both V1 and V2. Can you see from the graph what the frequency is? It’s easy to see the ***sum*** frequency, but can you see the ***difference*** frequency in the signal?

The NE602 Mixer Chip

The NE602 mixer chip (or the SA602, NE612, or SA612, which are all essentially identical) is a low-cost solution for mixing needs and is often used in kits.

PIN CONFIGURATION

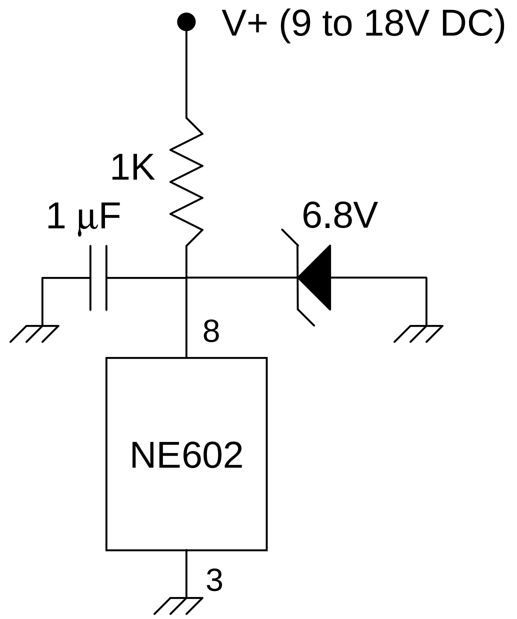


In order to produce an output at pins 4 and 5, three things are required:

1) A supply voltage Vcc which is well-regulated, between 4.5 and 8 volts
2) An input (this is the signal whose frequency is to be shifted)
3) An oscillator to provide a signal to mix with the input.

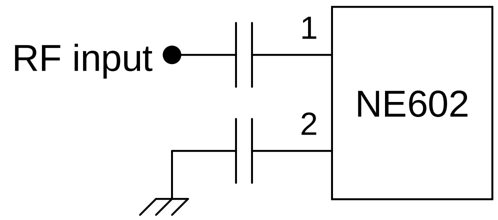
The NE602 has built-in circuitry for providing the oscillator input, requiring only the addition of a few parts which determine its frequency.

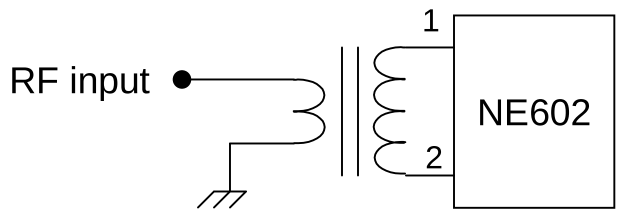
Inputs to the NE602



Pin 8 powers the NE602. It requires from 4.5 to 8V DC. The above configuration provides a regulated 6.8V input. The 1K resistor serves to limit current, while the capacitor provides a path to ground for any AC. Pin 3 is the chip's ground.

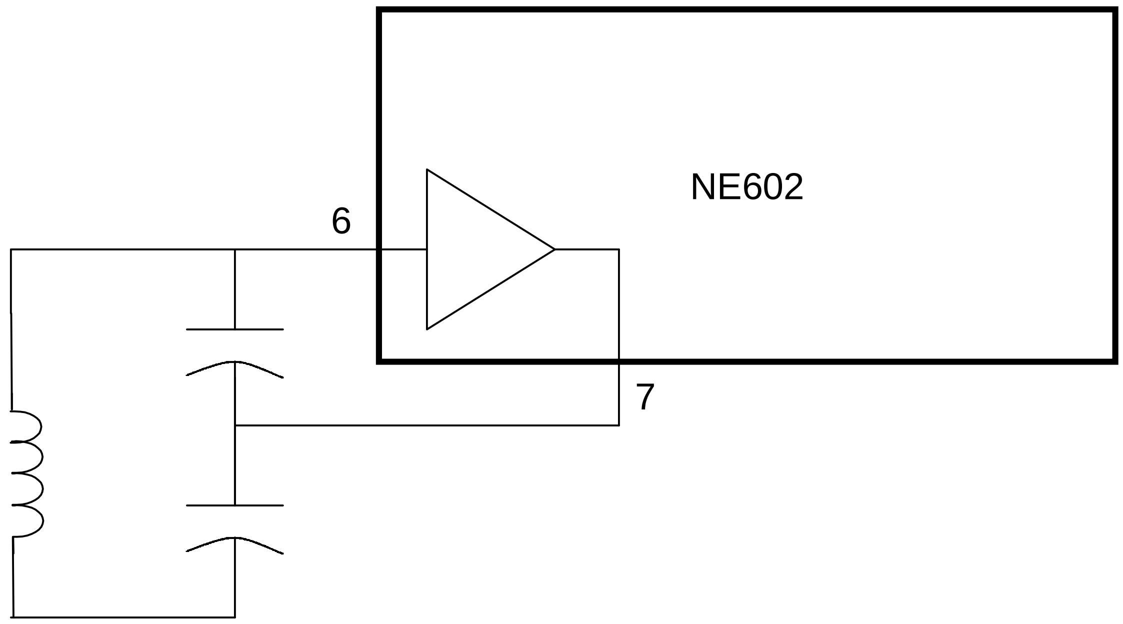
The input signal can be unbalanced, as shown here (either pin 1 or 2 can be used). The input signal should be small (less than 180 mV peak-to-peak).





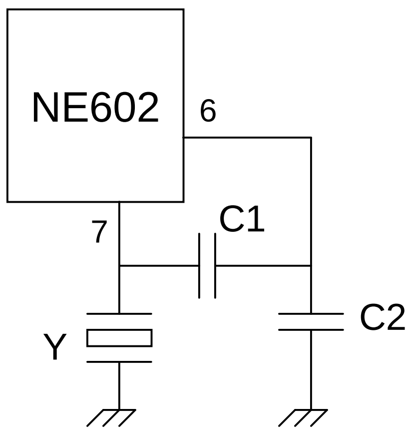
The input signal can also be applied in a balanced configuration. Here a transformer is used, and it is chosen such that it provides a match to the 1500-ohm input impedance of the NE602. Other configurations might add a capacitor across pins 1 and 2 in order to form a tuned circuit, passing only the frequencies of interest.

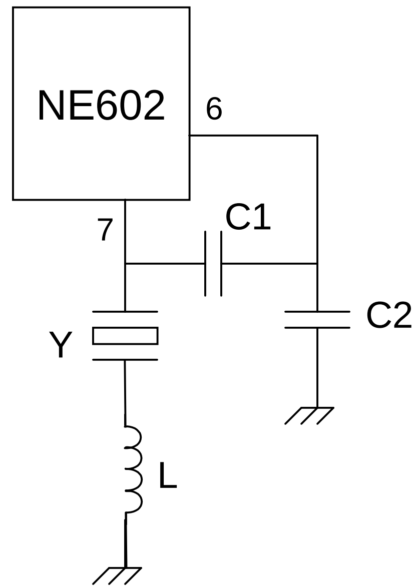
The NE602 Oscillator



Remember our simple oscillator circuit from Lesson 2? Here it is again--a tank circuit with an amplifier to amplify and reinject a part of the signal to keep the oscillator going. The NE602 provides the amplifier internally. To use its internal oscillator, all that’s required is to connect a suitable tuned circuit across pins 6 and 7. Alternatively, if we want to use our own oscillator, its output should be connect to pin 6, with pin 7 unconnected, and the input level should be between 200 and 300 mV.

NE602 Oscillator Circuits



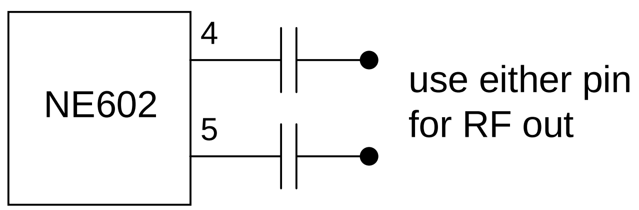


Here, a crystal is used to set the oscillator frequency. Crystals can be thought of has having both internal inductance and capacitance, and these set the frequency of the crystal. C1 and C2 form the feedback network for the oscillator.

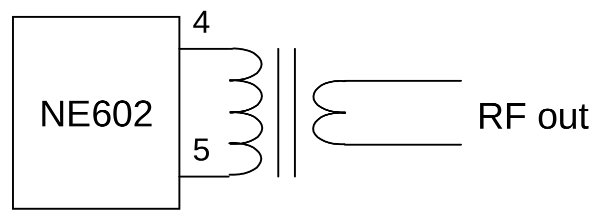
Here, an inductor has been added in series with the crystal. This has the effect of increasing the inductance of the circuit, which causes the resonant frequency to decrease. This is known as *pulling* the crystal--getting it to chance its oscillation frequency a bit. What would happen if we replaced the inductor with another capacitor?

The NE602 Outputs

Pins 4 and 5 of the NE602 are the outputs. The signals from each pin are identical but of opposite phase (pin 4 is negative when pin 5 is positive, and vice versa). Either or both pins can be used for output.



This is an example of an unbalanced output. Only one of the two pins is used--the other is left unconnected.

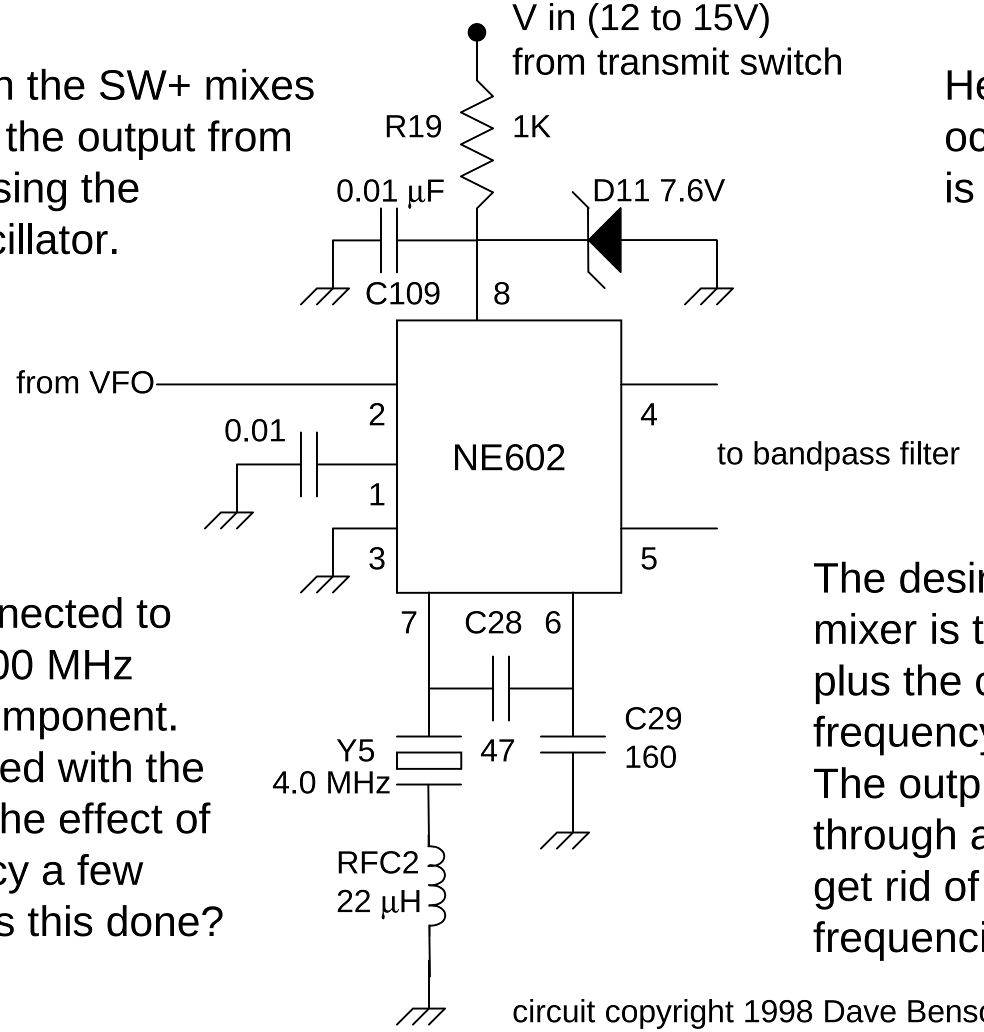


Here, both pins are used for output. Since they are of opposite phase, the voltage between them is twice the voltage of either with respect to ground. The transformer is used to transform the impedance for the next stage of the circuit. Capacitors could be placed in parallel with either side of the transformer to form tuned circuits to act as a bandpass filter.

The SW+ Transmit Mixer

The transmit mixer in the SW+ mixes the VFO output with the output from a crystal oscillator using the NE602's internal oscillator.

Here, mixing only occurs when the key is closed.



The tuned circuit connected to the NE602 uses a 4.00 MHz crystal for its main component. The inductor connected with the crystal in series has the effect of lowering the frequency a few hundred hertz. Why is this done?

The desired output from the mixer is the VFO frequency plus the crystal oscillator frequency (about 7 MHz). The outputs are passed through a bandpass filter to get rid of unwanted frequencies.

Troubleshooting Tips

- Reasons for problems:
  - poor soldering
  - wrong part installed
  - part installed backward
  - part installed in wrong holes
  - solder bridges (connecting parts which shouldn't be)
  - bad board traces
  - bad parts
- Tracking down problems:
  - double check parts placements and values
  - look for missed or bad solder joints and bridges
  - ensure all parts are installed
  - is power applied? Key down? etc.
  - follow voltages from source
  - make sure test equipment is connected correctly and working
  - if you can narrow the problem to one place, suspect the part or the traces on the board

Construction

- Install the following parts (all are in Group 5). Be sure to observe correct orientation for U5, Q3, D11, and C110.
  - U5 & its socket
  - Q3
  - D11
  - C28, C29, C108-C111
  - R19-R21 (note: R21 lays down on the board)
  - RFC2
  - Y5
  - J3
  - J3 wiring harness and jacks (see enclosure instructions)
- Testing:
  - connect key and tuning pot
  - apply power
  - measure voltage at pin 8 of U5 with key down. What should it be?
  - measure same voltage with key up. What should it be?
  - with key down, use oscilloscope to examine signal on pin 4 or 5 of U5. Do you see RF? What does the signal look like? Why?
  - any signal on pin 4 or 5 with the key up?