Chapter 11

Building a Jupiter Radio Telescope

Here is one example of a radio telescope where you can buy a complete kit of parts to build yourself an instrument that will not only receive radio Jupiter but will also detect solar flares. It comes under the title of Radio Jove (more on this later). Referring to the Chapter 2 on the astrophysics of Jupiter it is clear the receiver needs to operate in the high HF radio spectrum. This means a conventional short wave receiver could be used as an alternative, but don't forget it's best to disable the automatic gain control (AGC).

As an introduction to the topic of receiving Jupiter let's look at what is required to turn a conventional radio with an audio output into a radio telescope with data logging functions.

First an antenna is required, whichever way you build the receiver. There are at least three variations used for this purpose. There is the good old wire dipole; you can refer to Chap. 5 for specific design parameters. Then there is the Radio Jove project, which recommends using a pair of dipoles, and lastly there is a loop antenna with a reflector. However there is some doubt about whether the loop version is very effective.

The best frequency to use for observing Jupiter lies in the range of from 18 to 22 MHz. This is sufficiently high to avoid the worst of the ionospheric cutoff problems (especially at night) and falls within a spectral band where Jupiter can get very noisy. The Radio Jove receiver is designed to work at 20.1 MHz. Of course this needs to be clear of other local noise or communications.

The Dipole

The first dipole recipe uses a trick to increase the bandwidth of a standard dipole antenna. By using three elements cut to three closely spaced wavelengths the antenna will be responsive to the three wavelengths simultaneously and reasonably good for the bits in between. A broader band dipole of this type would be suited to a telescope based on a tunable short wave receiver, where you could hunt for a frequency with the least interference. It is not worth building this for a fixed frequency instrument such as the Jove receiver. Note when combining more than one

J. Lashley, *The Radio Sky and How to Observe It*, Astronomers' Observing Guides,
DOI 10.1007/978-1-4419-0883-4_11,

Fig. 11.1. Dipole antenna. This one is based on a commercially made balun. There is an adapter fitted to the base to provide a BNC output. The wire used was a 2.5 mm^2 electrical mains cable. Additional elements can be fitted to increase the bandwidth so long as they are not mutually resonant. For an antenna to work between 18 and 24 MHz use three pairs of wires a total length of 7.94, 6.81, and 5.96 m wide. See Chap. 5 for more information.

dipole into the same aerial using a common feed point it is important that design wavelengths are not integer multiples of each other, so that only one set of dipoles can be in resonance at any time.

Fig. 11.1 shows a drawing of the antenna with a picture of the 4:1 balun that was purchased from an amateur radio equipment supplier. The wire lengths are given in the figure.

The aerial should be suspended in an east–west orientation, so that it is most sensitive in the north–south direction.

The Dipole Array

A single dipole antenna is most sensitive in a perpendicular direction to its orientation, but this sensitivity is theoretically distributed 360° around the antenna, although in practice the ground influences the beam pattern. At the time of writing Jupiter is low in the sky, about as low as it can get, in fact. This is worsened the further north you live. So the aim of the dipole array is to manipulate the beam of the antenna to increase its effectiveness in a given direction, to maximize our potential to observe Jupiter.

The Jove project sells a complete kit of parts to build a dipole array, but it is a simple thing to construct from locally sourced materials. The kit contains plastic tubing, the sort used for household plumbing, to construct masts to support the antenna. Two pairs of masts are needed. However the lower the antenna beam the higher above ground the dipole height must be increased. If Jupiter is relatively high in the sky, then a height of 3 m is OK, but when Jupiter is low as it was in 2009 a height of 6 m is better. Plastic tubing is a bit flexible in lengths a few meters long, but can be supported by attaching guy ropes at several points and tying these to ground stakes. Eye bolts can be inserted through the pipe to attach the guy ropes. To allow for a variable height adjustment, use a larger diameter pipe for the first 3 m, and a smaller sliding fit pipe for the upper 3 m. Guy ropes will be needed at least at the top of the

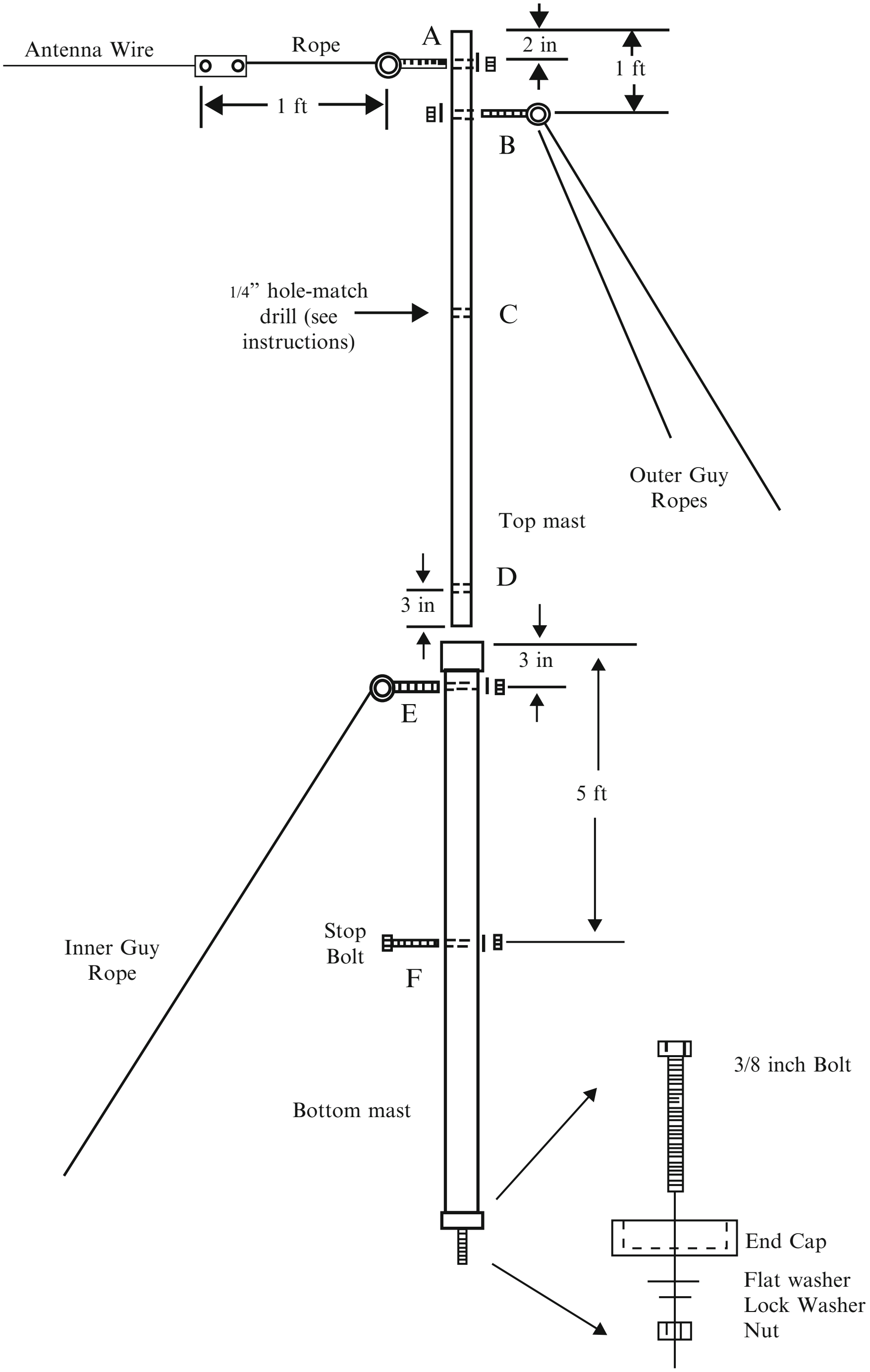

Fig. 11.2. A typical mast.

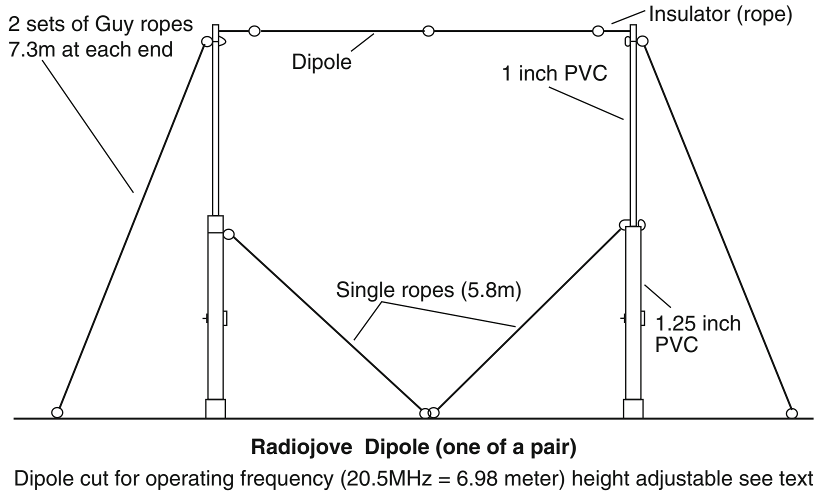

Fig. 11.3. Side view of the dipole and mast construction.

base section and the top of the moving section; more may be needed to improve rigidity. Alternatively steel or aluminum pipe could be used, such as scaffold poles or large conduit, but guy ropes are still recommended (Figs. 11.2–11.5).

The Jove antenna uses a combination of a phasing cable and height above ground to control the beam pattern altitude. The layout of both dipoles is in an east–west direction separated by 6 m (20 ft). The extra 0.375λ phasing cable is adding into the path of the southern dipole before the two dipoles are combined. Don't forget the velocity factor of the coaxial cable. RG59/U has a velocity factor of 0.66 so the length of the phasing cable is $0.375 \times 14.93 \times 0.66$ m, which is 3.69 m (assuming a Jove frequency of 20.1 MHz). This layout schematic is for middle to high Northern hemisphere observers.

Table 11.1 lists the height above ground to mount the aerials for a given altitude of Jupiter.

The power combiner could be easily made, but in fact it is so cheap to buy it would cost you more in RF connectors and boxes than it is to buy one. Power combiners are marketed for television installations, allowing two televisions to use a common aerial. They take care of impedance matching. Note that the ones you want are splitter combiners. They work both ways to combine signals together or to split a single signal into two. They usually come with F connector sockets and operate over a band of 5–2,400 MHz. F connectors can easily be fitted to RG59/U cables. Seal all cable connections and joints with self amalgamating tape to keep water from getting into the cable insulation.

The Loop Aerial

This type of antenna was written about in a few journals some time ago. It consists of a broken loop 1.37 m in diameter made from small-diameter copper tubing. Something like car brake pipe material would work. This is supported on insulating

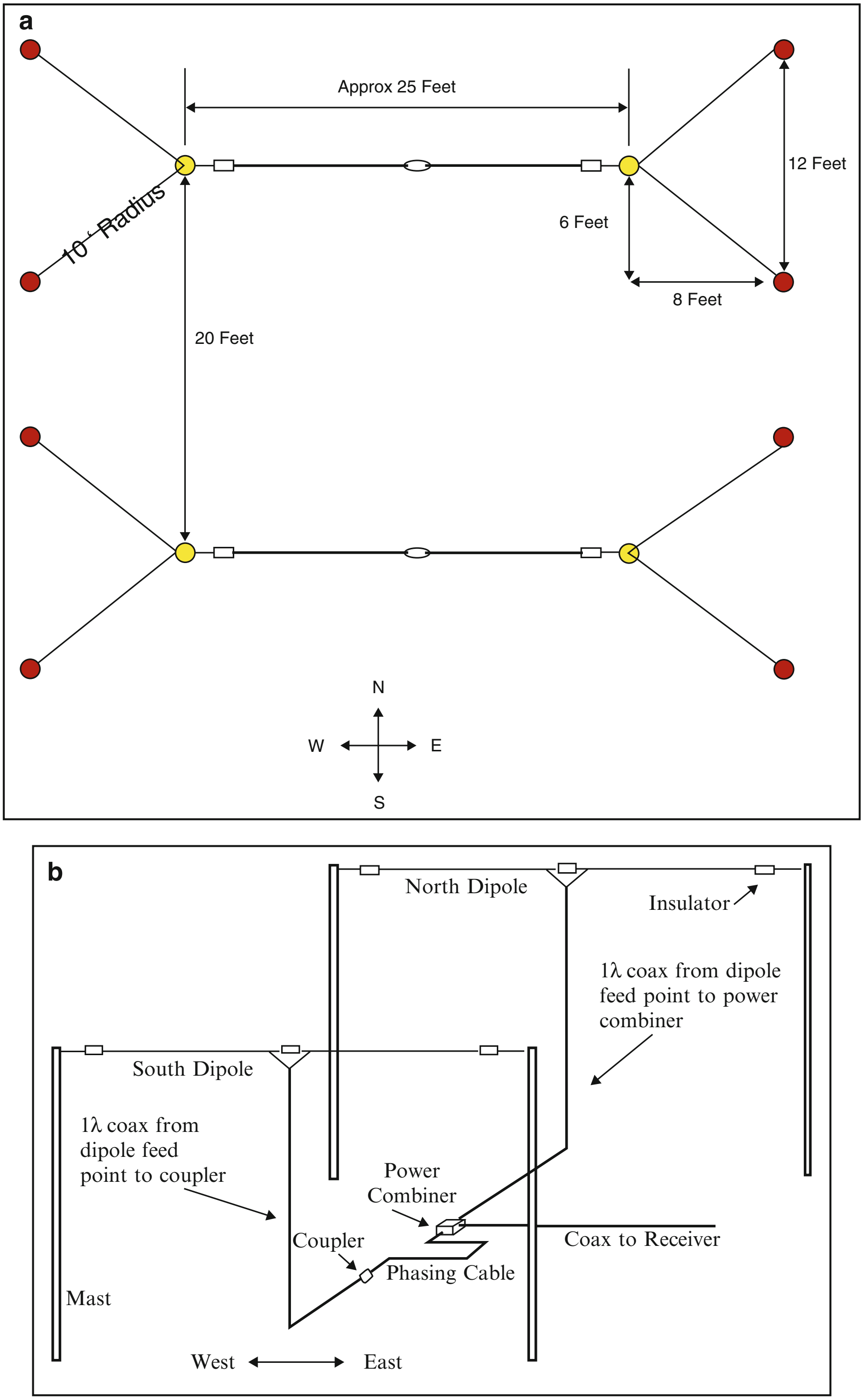

Fig. 11.4. (**a**) The birds eye view of the dipole array layout. (**b**) Another view of the dipole array showing the feeder and phasing harness.

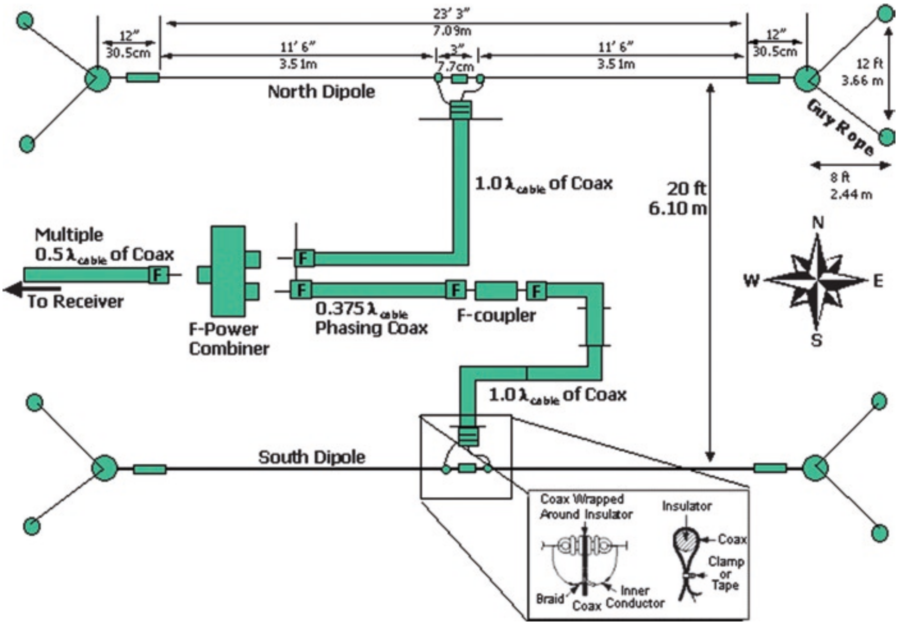

Fig. 11.5. A more detailed view of the dimensions of the dipole array, and feeder connections. Note the main feeder to receiver section should be in half wavelength multiples.

Table 11.1. Antenna height above ground for different Jupiter altitudes

Jupiter elevation (°)	Aerial height (m)
20–40	6.1
40–55	4.5
55–70	3.0

stand offs from a square frame 1.8 m across at a height of 17.8 cm. The frame is covered with chicken wire mesh to act as a reflector. Coaxial cable is connected between the open ends of the loop and fed to the receiver or preamplifier. There is doubt about how effective this is, so here is a challenge for you. As an observational experiment test the loop antenna alongside the dipole one to determine how suitable it is. It would be best to build two receivers, though, so side by side comparisons could be made under the same observational conditions.

The Receiver

Many radio astronomy observers use the Icom IC-R75 receiver. This is certainly a capable receiver, with the distinct advantage of being able to turn off the AGC control. While at the time of writing this radio is listed on Icom America website, it does not appear to be officially available in the UK, for some reason. Other Icom products that are suitable are the computer-controlled receivers such as the PCR1000. The PCR1000 is no longer available new, but it had the AGC off func-

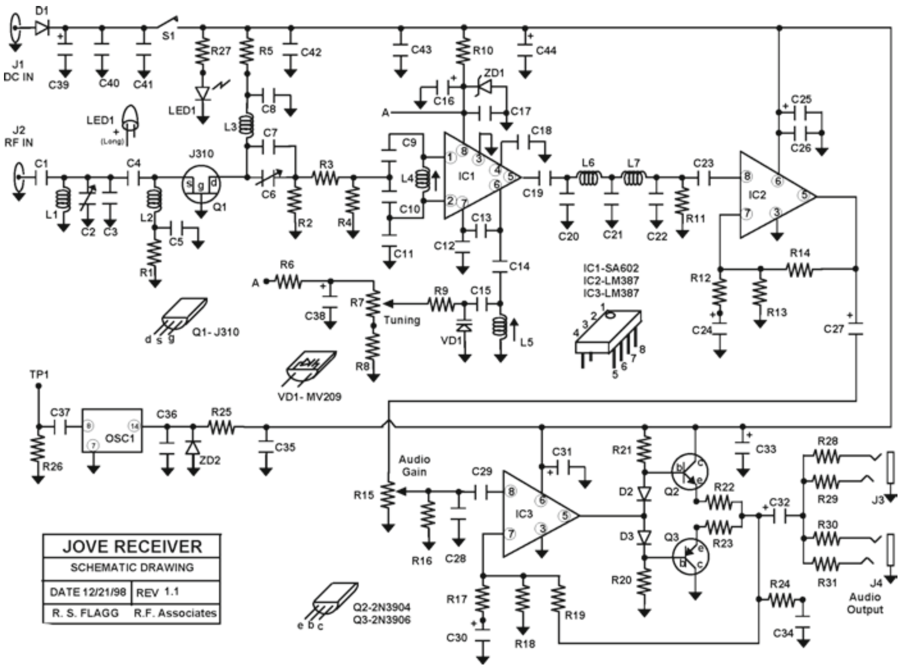

Fig. 11.6. Schematic drawing of the Jove receiver. (Diagram courtesy of the NASA Radio Jove team).

tion that is desired. The manuals for the PCR1500 and PCR2500 models do not list this feature. They indicate only AGC slow and fast – this is not the same as off. Unfortunately the AGC off control is not required much by amateur radio enthusiasts, so even the hardware dealers are not always familiar enough with their products to advise on it. It is always advisable to consult the manufacturers manual before you buy.

If you have not already got a suitable communications receiver, it would be cheaper to buy the Radio Jove kit, purposely designed for the job and a lot more fun knowing you built another radio telescope yourself. The manual for the receiver and antenna kits can be downloaded from the home page http://radiojove.gsfc.nasa.gov/, although you may have to trawl through a few of the pages to find it. The circuit diagram and PCB layouts are included in the book, so theoretically you could construct it from locally sourced parts, but this would only save a few dollars on shipping costs (Figs. 11.6 and 11.7).

The output of the Jove receiver is audio, which you could listen to by attaching a speaker. Sometimes Jupiter sounds like waves rolling up a pebble beach. More practically, however, it is designed to be logged using the Radio Skypipe software available from http://www.radiosky.com. See Chap. 13 for more information on this software.

One thing we have not covered yet. If you are going to use an existing radio with audio output, or even the Jove receiver, but you don't want to run a PC all day every day, you can easily build an integrator circuit to convert the audio output to a DC voltage, which can be logged to flash memory with a data logger. The circuit diagram is shown in Fig. 11.8.

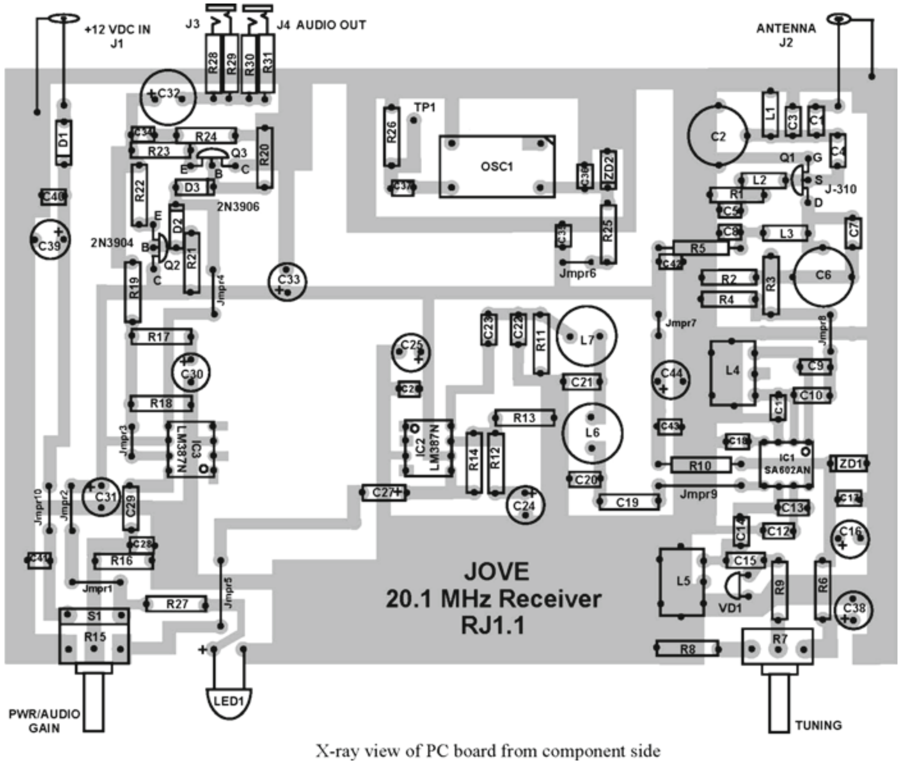

Fig. 11.7. X-ray view. (Diagram courtesy of the NASA Radio Jove team).

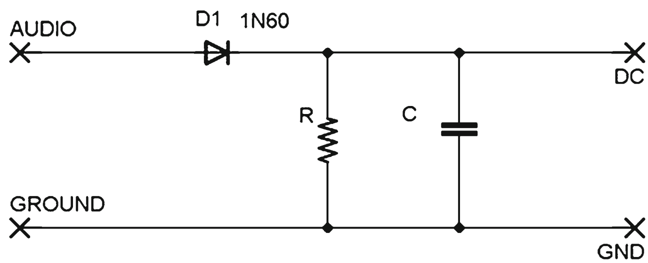

Fig. 11.8. Audio signal integrator.

The diode rectifies the audio signal from the output of the radio, and R and C together form the integrator. The choice of R and C defines the time constant of the circuit. The function of the integrator not only smoothes but provides a DC output that can be logged. The choice of time constant will vary, depending on the type of observing you wish to do. The down side of the integrator is it will mask very fast changes. Time constants of between 0.1 and 5 s would be a reasonable range. With modification and the use of a rotary switch the integrator could be fitted with several sets of RC values. The formula for calculating time constant t is

$$t = RC$$

where R is in ohms and C is in farads.

To calculate a given time constant, start by assigning a resistance value, and calculate the value of C. If C is, for example, unusually high in value, increase the resistance and try again. For example if you chose R = 100 Ω and a time constant of 1 s, C would have to be 0.01 farads, rather a large capacitor. By choosing a value for R of 100 K then C is a more reasonable 10 μF. A value like this will be an electrolytic type that is polarized. So it needs to be placed in circuit the correct way around with the negative pin to ground. The diode shown is a germanium type, chosen because it has a small forward voltage drop of about 0.2 V. Silicon diodes drop about 0.7 V and should be avoided.