



Cloud Charge Monitor

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Did you ever wonder how the charges were changing in the clouds directly overhead during a thunderstorm? Does an early-warning voltage exist right before a strike or do the charges jump from cloud-to-cloud too quickly? Is the polarity of the charge always the same? Build the Cloud Charge Monitor and watch the charges ebb and flow for yourself!

The Cloud Charge Monitor is an extremely sensitive device capable of detecting subtle (and not-so-subtle) changes in the accumulated charge overhead. The device consists of a charge-sensing antenna, a 60 Hz notch filter, a self-zeroing integrator, a signal limiter, and a leakage zero adjustment. The monitor is a fairly sophisticated device with a few special construction requirements and beginners may wish to solicit some help with construction and testing. For the more advanced experimenter each circuit function is described along with possible variations and performance enhancement ideas.

ANTENNA

The overhead charge is sensed by an antenna fashioned from a large aluminum-foil pizza pan or similarly large metal sheet. An insulated wire is connected to the pan in any convenient way including the following technique:

- 1) Strip back several inches of the wire's insulation.
- 2) Unroll a few inches of the pan's rim.
- 3) Roll the rim back wrapping the bare wire inside.
- 4) Crimp the rim in a few places with pliers to insure a good connection.
- 5) Cut a hole in the center of the pan just large enough for 1/2" PVC.



The pan is mounted at the end of a short piece of 1/2" electrical conduit PVC pipe. It may be secured by cutting small washers about 1/4" tall from a 1/2" PVC coupling. Glue one washer about 1/3" from the end of the pipe, slip on the pan (with a hole punched in the center just large enough for the pipe), then glue on another washer on top. Press the two washers together as the glue sets to firmly secure the pan. The insulated wire is now threaded down through the pipe. The pan may now be insulated by gluing two round pieces of trash bag plastic cut to be slightly larger in diameter than the pan. The bottom piece will need a hole for the conduit. (Satisfactory operation is possible without insulation.)



The other end of the pipe may be secured to a metal box in a similar manner. An ordinary electrical outlet box is a good choice since there is a center punch-out just the correct size for the conduit, there are mounting ears that may be used to nail or fasten the box to a board, and there is plenty of room for the amplifier. A bottom cover is not necessary.



CIRCUIT CONSTRUCTION

The circuit is built on a piece of copper-clad circuit board using the "dead bug" technique. The amplifier IC is mounted upside-down (leads pointing up) and will look a bit like a dead cockroach. Bend the ground pin (pin 4) back to the board and solder it directly to the foil. The other leads may be air-wired or little "islands" may be made by cutting small pieces of copper-clad board. The "bites" that come out of a typical nibbling tool are about the correct size! They may be

soldered in place if the board has copper on both sides or they may be glued. Make sure to inspect the edges to insure that no metal sliver is shorting the island to the ground plane. Other construction techniques are also fine but there are a couple of points in the circuit that should be wired in a special way. R6, R7 and pin 2 should be air wired and should not be allowed to touch anything. The base of the IC must be clean and free of solder flux. Use alcohol or lacquer thinner to clean the package if necessary. (The “dead bug” technique makes inspection easy!) The input filter is built on a separate piece of board which may be mounted on the main board but the foil is biased to 6 volts instead of ground. R4 and R5 connect directly to the foil which is indicated by a dotted-line in the schematic. This bias helps to reduce leakage current from the input circuit to ground. If the builder has access to Teflon-insulated terminals then the input circuit may be air wired between terminals without concern for leakage. The insulated wire from the antenna should not rest against the metal box so cut it short enough that it is stretched from the conduit to the circuit board. It is a good idea to solder a ground wire from the circuit ground foil to the metal box and to strain-relieve the power and signal cable.

OPTIONS

The output of the circuit may be connected to a variety of readouts including a simple 1 mA current meter with a 5.6k series resistor or a multimeter. The output voltage will read about 6 volts when no charge is present. R14 is adjusted to zero any offset due to leakage and it may be remotely located with the meter and power supply, if desired. Leave R13 in the metal box, however. Remember, this circuit has a VERY long time constant on the autozero circuit so the effect of any adjustment will take several minutes.

R7 may be a single resistor or several lower value resistors connected in series. The purpose of R7 is to automatically drive the output toward zero charge indication (6 volts out) so that the user isn't required to constantly adjust an offset control. The rate of autozero is determined by the value of R7, the integrating capacitor, C5, and the antenna capacity. The effective value of R7 is much higher than 220 megohms thanks to the bootstrapping circuit formed by R8 and R10. If R10 is decreased, the amount of bootstrapping will increase and the feedback resistor will seem even larger. A lower limit of 10k is recommended unless the experimenter is quite experienced! The effect of a larger feedback resistor is to increase the autozero time constant. A similar effect is realized by increasing C5 but there will be a proportional loss in sensitivity. Lowering C5 will increase the sensitivity, if desired, but the sensitivity is sufficiently high for storm monitoring as shown.

The bootstrapping technique also amplifies the op-amp's offset voltage and drift but the chopper-stabilized ICL7650 has virtually no offset. Other CMOS op-amps may be used and might be more desirable since they have better overload recovery behavior. If the experimenter has extremely high value resistors in the junk box, R10 could be increased or even removed and the diodes eliminated giving a circuit with less sensitivity to op-amp drift and excellent overload recovery properties. Try a CA3160 op-amp or one of the numerous new CMOS amplifiers.

TIPS

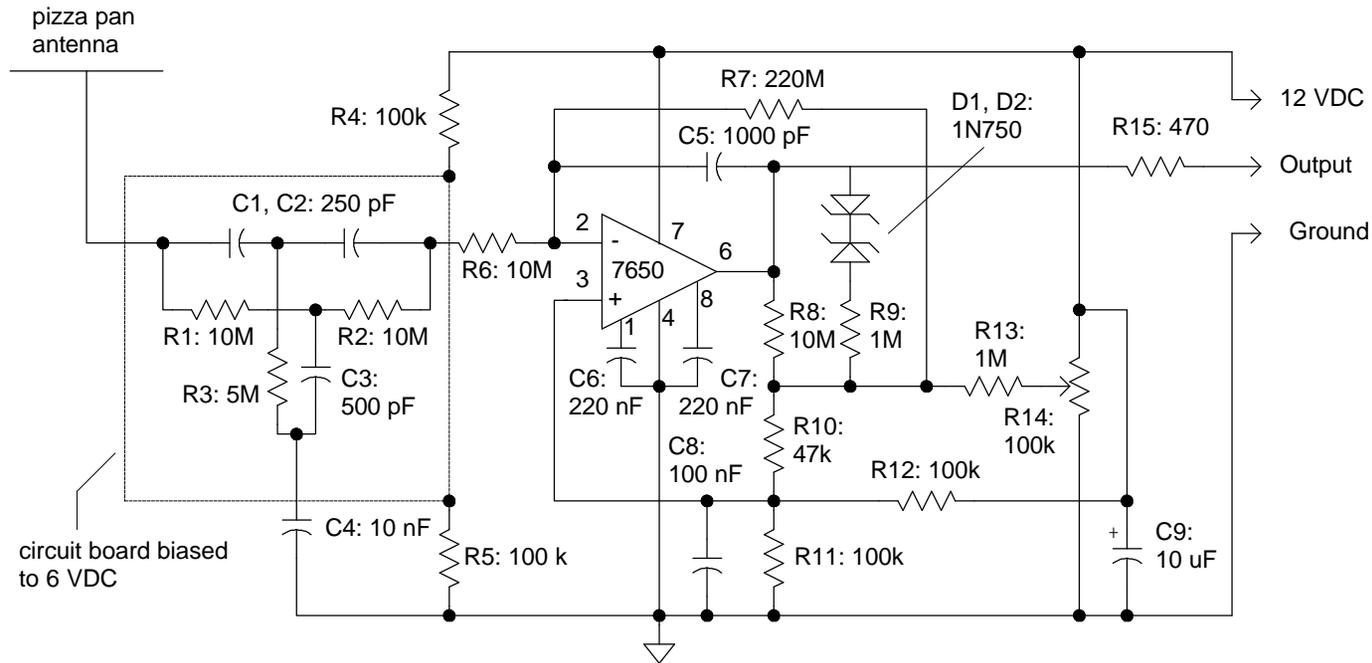
It can be maddening for the beginner to work with circuits that have several minute time constants and extremely high impedance but the experience can be quite educational. To slew the circuit back to the center point after an overload, simply touch the ground or the +12 volts with one finger (depending on which way the circuit must slew) and touch Pin 2 with the end of a 10 megohm resistor held in the other hand. To verify that the circuit is working, rub a CD or other piece of plastic on your hair and bring it close to the antenna. The meter should move up or down and then slowly drift back toward center.

Use a voltage regulator for the 12 volt supply. An LM7812 or similar regulator is adequate.

Each homeowner will have different antenna possibilities. Don't mount the antenna outside! It isn't necessary and it could invite disaster if lightning strikes! Place the device near a large window or hang it from the ceiling of a porch away from the rain. A different antenna could be made by taping

aluminum foil to a clean window and covering it with plastic wrap. The edge of the foil should be several inches away from the window frame at all points to avoid leakage. Ordinary roofs are usually too conductive for an attic installation but a plastic or glass greenhouse roof or large skylight might work well. Those experimenters who are experts at handling the threat of lightning strikes might wish to build a Plexiglas “umbrella” for an outside antenna but make sure that there is not a discharge path to ground when the Plexiglas becomes wet. The outdoor antenna should be mounted at ground level.

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| R1, R2, R6, R8: 10 megohm, carbon film or equiv. resistors | C5: 1000 pF low leakage film, mica, or ceramic capacitor |
| R3: 5 megohm, may be two 10 megohm resistors in parallel. | C6, C7: 220 nF (0.22 uF) ceramic capacitor |
| R4, R5, R11, R12: 100,000 ohms, carbon film or equiv. resistors | C8: 100 nF or larger ceramic capacitor |
| R7: 220 megohm, may be 10, 22 megohm resistors in series | C9: 10 uF or larger electrolytic capacitor |
| R9, R13: 1 megohm, carbon film or equiv. resistors | D1, D2: 1N750, 5 volt zener diodes |
| R10: 47,000 ohm, carbon film or equiv. resistor | IC1: ICL7650 chopper-stabilized op-amp. Other CMOS op-amps may be used with some loss in temperature stability. Simply leave out C6 and C7 to use a CA3160 or a similar amplifier. |
| R14: 100,000 ohm potentiometer - any value above 5k is fine | |
| R15: 470 ohm, carbon film or equiv. resistor | Antenna: a large pizza pan insulated with trash bag plastic or any well-insulated sheet of metal of similar size. A larger size will give increased sensitivity. |
| C1, C2: 250 pF made from 220 pF in parallel with 33 pF. Use low leakage types such as mica, glass, or ceramic capacitors. | |
| C3: 500 pF made from 470 pF in parallel with 33 pF. (low leakage) | |
| C4: 10nF (0.01uF) low leakage film or ceramic capacitor | Power: Well-regulated 12VDC power supply |