On Clocks and Things

In his article on clock restoration, (May 92 SK), M. Fox suggests that electronic clocks are non-repairable. This may be the case on some electronic clocks, but not all. These clocks divide into 3 rather distinct types:

1. Fully electronic clocks with no moving parts (typically with an LED or LCD[1] display, but sometimes with a green vacuum fluorescent display), and push buttons for setting the time and date.

2. Fully electronic timer mechanism which drives a stepper motor. The stepper motor drives a set of gears which move the hands of an "analog" clock. The time is set by rotating a set knob.

3. Electronic quartz oscillator driving a small AC motor which drives a set of gears which move the hands of an "analog" clock, or the digits of a Vreeder-Roote type (digital) counter to display the time. The time is set by rotating a set knob.

There may also be some car clocks (I haven't seen any, but they may be out there) using an acoustic resonator like the acutron watch, or other mechanisms. Let's examine these three mechanisms in some detail - in general all are repairable to some extent by a careful hobbyist (I say this because I have repaired some, so presumably you can too).

Fully Electronic Clocks

The fully electronic clocks may well be the most fearsome to the typical car mechanic/restorer since there are no gears or anything to study, so lets examine those first. Electronic clocks have four main parts - a display assembly, a clock electronics assembly, a switch assembly, and a case. Typical failures I have seen include no display (clock dead), missing or partially formed numbers on the display, inoperative switches, and poor time-keeping accuracy. I will attempt here to explain how these clocks work, and in the process elucidate how they can fail. Don't be too afraid of attempting to work on these clocks, they are new enough that replacements are generally available (albeit at some expense), and if the clock is sick the worst that can happen if you damage it trying to fix it is that you have to buy a new one, which is what you would have done anyway.

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[1]LED stands for light emitting diode - LED displays are usually red, although other colors can be found. LCD stands for liquid crystal display, typically a silver display with black letters, often back lit.

The heart of an electronic clock is the clock electronics. This is really a rather simple circuit consisting of a quartz crystal oscillator, a counter, and some decoding logic. Quartz is a piezoelectric material - that means that if you squeeze it, the increasing strain causes it to build up a voltage differential, and that conversely if you apply a voltage to it, it will expand or contract. A good example of a piezoelectric device that you all have seen are the butane lighters which put out an electric spark to light the butane when you squeeze a trigger. A quartz crystal oscilator works by using this effect and the acoustic properties of quartz to establish an acoustic resonator (OK, that's a big word, think "tuning fork"). The quartz crystal is cut to a specific size (and shape) that resonates at the desired frequency. An oscillator tuned to near that frequency and hooked to the quartz crystal will oscillate at the crystal's resonant frequency because that is the easiest for it (in more technical terms because the impedance of the crystal rises rather sharply at resonance, so it "shorts out" energy at other frequencies).

If we count the oscillations of this quartz crystal, we can tell how much time has passed. Quartz oscillators are very stable with time (because the quartz doesn't wear out or degrade) and over temprature (because its expansion coefficient is small)[2]. A quartz oscillator for a clock may run anywhere from a few hundred kilohertz to a few megahertz[3]. A set of binary counters reduces this to 1 count per second (to increment a seconds display), and a pair of base 60 counters and a base 24 counter produce the seconds and hours values. These values are then used to produce the drive signals for the display. If the clock has a date function, there are some more counters and a lookup table so it knows how many days in a month.

If you look at a typical electronic clock you will see the quartz crystal and a capacitor which make up the oscillator, and an integrated circuit. The crystal (sometimes a cheaper ceramic resonator) usually looks like a small aluminum cylinder with two wires coming out of it, and may have a number representing the resonant frequency stamped on it. In some clocks, the capacitor is variable (you can tell this because it will have a small adjusting screw on it) and can be used to vary the oscillator frequency slightly. If the clock seems to gain or loose time at a constant rate, you can try turning this adjustment screw **SLIGHTLY** and see what happens. Note that while you can turn the screw round and round, the full effect occurs over 180 degrees so don't bother turning it more than 90 degrees in either direction from its initial location. On many clocks, the integrated circuit chip is bonded directly to the circuit board rather than being separately encapsulated in an epoxy package. In this case you will see a blob of black epoxy on the circuit board with traces going into it - the clock chip is under that epoxy - don't mess with it. You can test the clock chip partly by seeing if the oscillator is running - take an oscilloscope (if you don't have one, try a local college or TV repair shop) and look at the leads to the crystal - a working clock will have a clearly visible oscillation (at some integer multiple of the crystal frequency) on these leads. If there is no signal on the crystal, and the clock chip is powered, the clock chip is dead (or the crystal is shorted). If the clock chip is under an epoxy blob, forget it and look for a new board (or a new clock) if it is dead. Otherwise, the clock chip can be unsoldered and replaced (as can the crystal).

The seconds, minutes, and hours counters are initialized to the proper time by pressing push buttons. These bypass part of the countdown oscillator (and sometimes activate other logic) so that the selected counter advances more rapidly (for example one count per second rather than one count per hour). Often the push buttons are elastometric and contact conductive pads on the clock assembly circuit board. Sometimes there are standard mechanical switches. If a switch doesn't work and it is of the mechanical type,

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[2]Super high accuracy quartz oscillators actually put the crystal and certain other critical parts in a tempeture controlled oven so that these tempeture effects are eliminated. You will not find this in a car clock, of course.

[3]The prefixes Kilo and Mega mean thousand and million respectively. Hertz used to be abbreviated CPS, or cycles per second, but because most people dropped the "per second" when speaking, things got pretty confusing so this new name memorializing an electical pioneer was adopted.

try cleaning it, replacing it, or spraying contact cleaner into it. If the switches are elastometric (small domes of a rubber substance which is conductive - when you press on the switch the dome collapses and shorts out a pair of contacts on the underlying circuit board), you can remove the rubber domes from the circuit board and carefully clean the contact area (use a pink pearl eraser, then rinse with alcohol). If the rubber dome is damaged or torn, get a similar sized dome from something else (many calculators and other electronics use this technology) - it will work if it fits. Note however that switch problems on clocks are quite rare because the switches are used very infrequently.

Typically the display consists of 7 segment numerals. There may be a separate driver chip, or the clock chip may directly drive the display. I have seen three display technologies used in car clocks: LED, LCD, and vacuum fluorescent. I have only seen LED displays in after market clocks, but maybe some manufacturer used them in OEM equipment. LEDs require fairly high drive current (typically 20 to 100 milliamps, depending on color and brightness), and require current regulation since their forward voltage drop is .7 to 2.4 volts. If a few segments of an LED display are inoperative, check for bad wires and solder connections. If that is all OK, you can measure the drop across the affected LED segments and see if it is the same as the drop across working LEDs - a failed LED will measure either near 0 volts (much less than 0.7 VDC), or a much higher voltage than the working LEDs. The driver for the affected segment(s) could also have failed. Sometimes this is a discrete transistor, but more usually it is another chip - just change it if in doubt. Since some LED clocks use a multiplexed driver technique to reduce parts count, troubleshooting can be interesting (to say the least). Since these parts are inexpensive, brute force changing of anything that might be involved is often easier than trying to understand how the circuit really works. And, if it is an after market clock, I would throw it away if re soldering the relevant connections doesn't fix the problem.

Vacuum fluorescent displays are typically green or blue. A thin heated wire (which you can see glowing dull red if it is really dark) emits electrons which strike phosphor coated plates causing the phosphor to emit photons (particles of light) which is what you see. These displays operate with plate voltages between 30 and 300 volts (usually on the lower end of the range). When the plate is positive with respect to the filament, electrons (having a negative charge) will be attracted to the plate and it will glow (remember, opposites attract). As with the LED display, the usual cause of failures is either bad connections or a damaged driver. In addition, the filament can fail, but that will cause all segments to be inoperative. If you have a vacuum fluorescent display that is completely inoperative (note that this applies to radios too, which until recently were the place where you were most likely to find this technology), then check for the proper high voltage, and for an operative filament. If some segments work and others don't, then it is a driver or a wire that is bad. Note that since the display module is glass, it can be broken and like the picture tube in your TV, it won't work if it doesn't have a vacuum inside it.

Finally, we have liquid crystal displays. These work by using organic chemicals which form long thin molecules. These molecules are stacked side by side and form little pipes for light to travel through. When voltage is applied, they either twist, changing the polarization of the light, or they block the passage of light. The display assembly consists of two plates of glass with receptacles in between to hold a thin layer of the liquid crystal material. The front layer of glass includes a polarizing filter and transparent electrodes (made from an atom thick layer of gold or other metal) to activate the crystal, and the back layer includes more electrodes and (typically) a mirror. If you work this all out, you can see that if the crystals rotate the light 45 degrees when energized, and 0 degrees otherwise, the energized areas will appear dark because the light has been rotated 90 degrees by passing twice through the crystals. (And yes, liquid crystal is an oxymoron, but that's what the stuff is called). When not energized, the display looks like a small piece of a mirror, and the active areas can barely be seen. Along the edge or back there will be a row of contacts on a fine pitch (close together) to connect to the driver circuits. If the display is cracked, replace it, of course. If it is not cracked, and a segment or two are inoperative, it is usually a bad connection between the driver and the display. Because LCD's require extremely low drive currents, it is very rare for anything else to fail. The display may be connected to the driver through a normal looking connector, but usually a different technique is used. A silicon rubber strip consisting of alternating bands of conductive and non-conductive rubber is sandwiched between the display and the driver board. The conductive pads on the driver board contact a few of the conductive layers of the rubber, and the rubber contacts the contacts on the back (or edge) of the display.

If the driver board shifts relative to the display, or if the pressure between the display and the driver board is lost, then the strip will not make proper contact and the display won't work. Since the pitch on the conductive strips is usually between 5 and 20 thousandths, and the line pitch on the circuit board and display is usually less than 50 thousandths, a pretty accurate alignment must be maintained here. Pushing the display to one side or the other (with a wooden or plastic object so as to not crack the glass) will often fix alignment induced problems. Sometimes distorting the case or shimming with a piece of paper is needed to increase contact pressure or uniformity.

LCD's are often back lit with either electroluminescent panels or a light bulb. If the bulb burns out, replacement is usually a long and involved process and the bulb is some obscure part that only the dealer has, but you can handle that, right?. If a bulb is used, the clock will almost always have a Plexiglas assembly to conduct the light from the bulb to the back of the display and to distribute it uniformly across the display. This needs to be clean. And, if it cracks, the crack will block the light.

Finally, there is the case, which is generally not meant to come apart, and which is a marvel of tabs and latches which holds everything in its proper place within a few thousandths. Take your time taking the thing apart, figure out how the tabs hold it together, and don't distort it or you'll never get everything lined up again. If you take your time, these cases almost always will come apart without breaking, and will go back together again. If you do break something, try using one of the EDB adhesives (like Weld-On number 3) - these are solvent adhesives which dissolve a bit of the case material (usually acrylic plastic) and thus make an excellent bond. Super glue (a cyanoacrilate adhesive) is not too effective for this application). If the case is not acrylic, try Devcon plastic epoxy.

Stepper Motor Driven Clocks

Stepper motor driven clocks have an electronic assembly consisting of a quartz oscillator and a counter as described above. The electronics produces one pulse per second (or one pulse per minute) into a stepper motor which moves a set of gears which drive the hands of the clock. The hands on these clocks move in jumps, typically once per second on car clocks because they have second hands. If one of these clocks doesn't work, there is a pretty good chance that the problem is mechanical, and that cleaning and oiling the gear assembly as described in Mr. Fox's article will cure the problem. You can test the electronics by looking at the stepper motor drive signals for appropriately timed pulses.

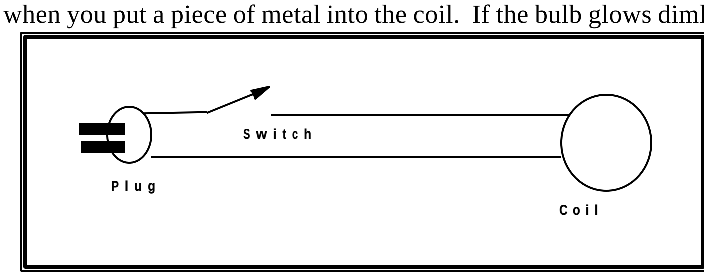
Stepper motors consist of a permanent magnet armature, a magnetized stator, and at least two separate coils. The armature aligns itself with the stator due to magnetic attraction. To mode the armature, current is applied to the coils in sequence to override the magnetism of the stator and shift the armature to a new position. To make this simple, imagine a stepper motor with 4 poles 90 degrees apart. Coils would be located at 30 and 60 degrees. To move the motor clockwise, starting with the armature aligned with the 0 degree pole, the electronics energizes the 30 degree coil. This creates a strong magnetic field at 30 degrees, so the armature rotates to align with the new field. Then the 60 degree coil is energized (so the resultant field moves to 45 degrees) and the armature rotates a bit farther. Then the 30 degree coil is de-energized, and the armature aligns with 60 degrees. Finally, the 60 degree coil is de-energized and the armature rotates to the nearest pole, which is the 90 degree pole. Actual clock stepper motors have many more than 4 poles, but the principle is the same, and the operation can be readily observed with an oscilloscope or sometimes even a voltmeter. The most sensitive part is the stepper motor bearings, which can wear or become sticky. If the stepper turns freely with power off, but does not with power on, then there is something wrong in the electronics.

AC Motor Clocks

Finally, there are clocks which use a form of synchronous AC motor (like your house clocks do). My 76 Cadillac has such a clock. These clocks have a quartz oscillator and a counter, but the counter produces an wave form that drives a small alternating current motor. This motor rotates fairly rapidly (5 to 50 RPM) and drives a gear assembly which in turn drives the clock hands (or the counter wheels if it is a digital clock). The electronics are extremely simple and quite reliable. The wave forms at the motor can be observed with a scope. The most common failure here is either contamination and old oil, or worn motor bearings. So, clean the clock and re-oil, and then adjust the motor bearings. On the Cadillac, these bearings are nylon. One bearing is threaded and can be adjusted to set the end clearance for the motor. Over time the bearings wear, the clearance increases, and the clock starts to make noise. Eventually it stops. If this happens to you, readjusting the bearings and oiling with clock oil is almost guaranteed to fix things. Moreover, these clocks are mechanically much simpler than escapment driven clocks, and so are easier to work on. Since there are many plastic parts, I would be very careful in cleaning to avoid anything that dissolves plastic - I use a spray designed for cleaning flux off of circuit boards for cleaning this kind of mechanism. Be sure not to over tighten the bearing or the motor will stall. Fixing a noisy clock is actually much faster than buying a replacement, so it is clearly worth a try.

Other Items

There has been some discussion about how to magnetize tools. The simplest way to magnetize (or demagnetize) any tool is to make a 115 VAC coil for the purpose. You can use a growler if you have one lying around (a growler is a tool for testing armatures), or you can make one by winding thin insulated wire (say number 24 enamel insulated wire) around an adhesive tape spool, or you can take an old clock motor or BBQ rotisserie motor, and use that. If you make your own coil, wind a lot of turns (several hundred), and then put a 40 watt bulb in series with the coil and plug it in. The bulb should glow dimly, and get dimmer when you put a piece of metal into the coil. If the bulb glows dimly it is save to remove the bulb and plug the thing in directly, if not, wind more turns around it and try again. If you use a coil from an old motor, you can start with the series bulb to be safe, and then proceed to a direct connection. Wire a momentary contact switch in series with the coil, so that the coil is only energized when you press the switch. The figure below shows how to wire the magnetizer/demagnetizer.



To magnetize a tool, put the tool into the coil, press and hold the switch for a couple of seconds and then release. The tool will end up magnetized unless you are unlucky enough to release the switch when the 60 Hz AC current is going through 0. If that happens, just try again.

To demagnetize a tool, put the tool in the coil, press and hold the switch, and then slowly withdraw the tool from the coil until it is about 2 feet away, then release the switch. The tool will be demagnetized because the AC current produces an oscillating magnetic field which 60 times a second magnetizes the tool with the opposite polarity. As you move the tool away, the field (and hence the residual magnetism) gets weaker and weaker, until it is insignificant.

There has also been some discussion about operating 12 volt gauges, etc. on 6 volt vehicles. Sometimes connecting up a 12 volt gauge and sensor works fine because the gauge relies on a current balance, and the voltage is irrelevant. More often, the gauge relies on current through a coil to either magnetically move a pointer against a spring, or (in the case of the Smiths gauges in my Morgan and some other British cars), to heat a bimetallic strip that moves a needle through a gear and lever assembly. In these cases you have a couple of choices:

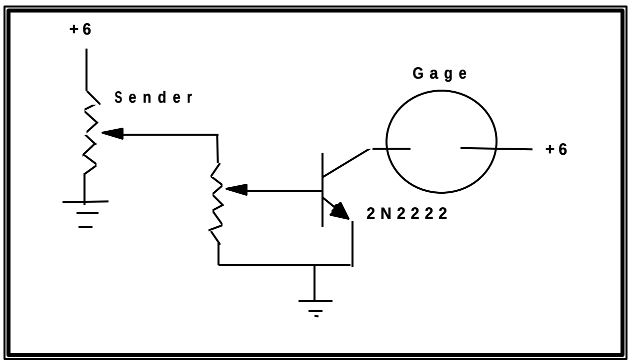
1. Use a new sensor and the old gauge. The gauge will probably not read correctly, but it will move and you can learn what the various indications mean.

2. Use the new sensor and the old gauge, but add a trimmer resistor across the new sender to adjust the normal indication on the gauge so it appears in the normal range. On a fuel sender, I would adjust it so that empty reads empty.

3. Use a new sensor and gauge - maybe it will be OK on 6 volts.

4. Use a new sensor and gauge and add a 6 to 12 volt converter to drive the gauge. If there is enough interest I can provide a schematic for a small converter suitable for running a gauge or two.

5. Use a one transistor amplifier to boost the current to the original gauge so that it reads properly, as shown in the schematic below:



For a positive ground vehicle, use a PNP transistor (like 2N2907) instead. Further adjustment can be gained by adding an adjustable resistor between the collector and ground (from the gauge low side to ground). All adjustable resistors should be around 1K ohm. Just play with the adjustments and the sender until the minimum reading on the sender causes a minimum reading on the gage, and a maximum reading on the sensor causes a maximum reading on the gauge.