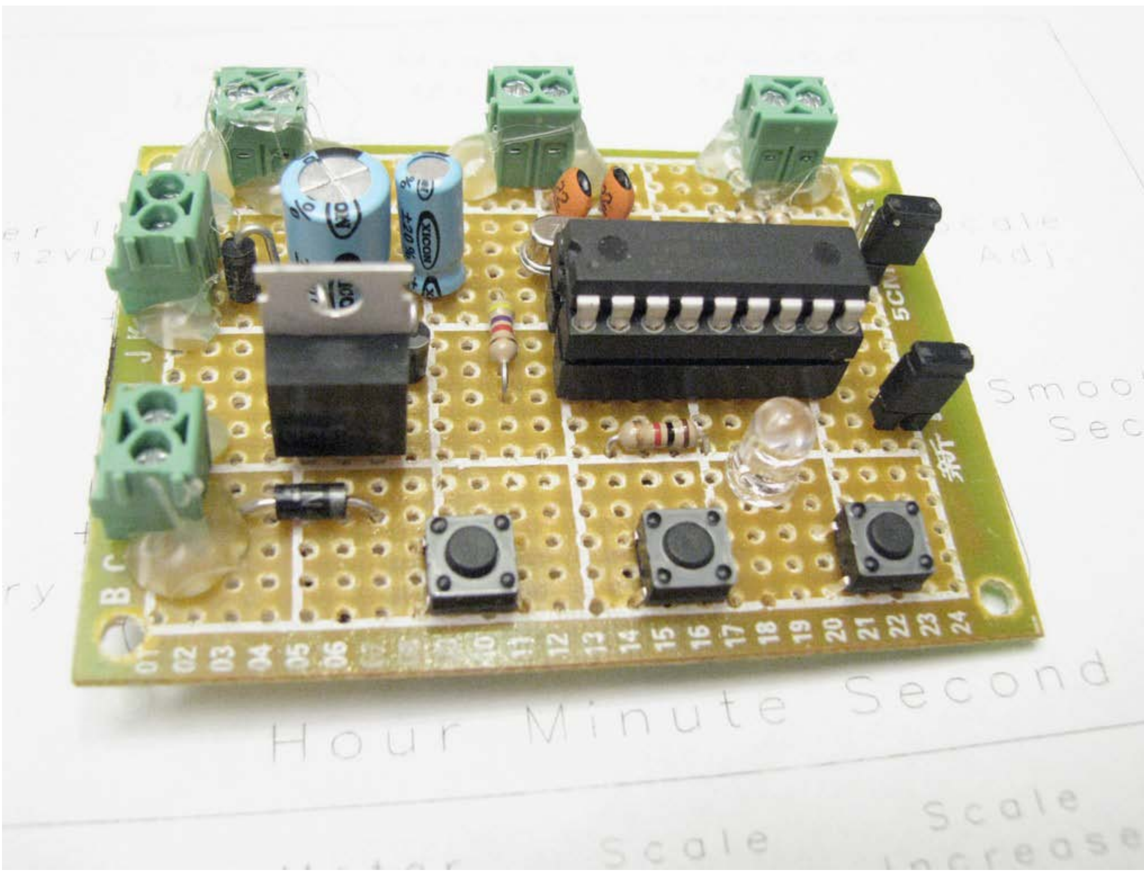
THE GADGET FREAK FILES CASE #165

Analog Clock Measures Time in Meters

Alan Parekh took a different approach to time keeping with his electronic clock that registers hours, minutes, and seconds on individual multimeters. A microcontroller keeps track of time and calculates the current each meter needs to move its needle at the proper rate. A separate MCU output drives each meter. Instead of simply lining up the meters, Alan also created a unique way to display them. Build the circuit now: Time waits for no one!

This Gadget Freak project requires some knowledge of PIC microcontrollers and how to program them. Alan provides both hexadecimal code ready for use as well as source code written in PICBASIC PRO. Download these two files and a larger version of the schematic diagram at: www.gfreak.com/GF165/GF165.zip.

View Alan's video at: http://alan-parekh.com/multimeter_clock.wmv.



How It Works

Three outputs on a Microchip Technology PIC 16F628A microcontroller drive three multimeters that individually display Hours, Minutes, or Seconds. Alan set his meters to measure 0.5 mA DC full scale and connected the three negative leads to ground and each positive leads to its own MCU PWM-output pin through a 4.7-kohm current-limiting resistor. Builders can adjust this resistor value depending on the current scale of their meters. The information in Table 1 suggests resistor values for four meter scales.

Keep in mind the PIC MCU can deliver a maximum of 25 mA to each meter, so a meter with a lowest current setting of greater than 25mA would not work without additional circuitry. Builders also should ensure they can drive the meter to full scale. If a meter lacks accuracy it could take 10 or 20 percent more current than expected to move the meter needle to full scale.

Table 1. Resistor-Current Suggestions for Meter Scales.

Meter Scale	Resistor to Use
0.5mA	4.7K ohm
1mA	2.4K ohm
5mA	510 ohm
10mA	240 ohm

The MCU uses pulse-width modulation (PWM) to pulse the current to each meter, which allows for precise needle positioning. If the minute meter must move its needle to display 30 seconds, for example, the PWM output would provide pulses half the width needed to move the needle to full scale, or 60 seconds. (For the moment, ignore the meter's printed scale. You'll learn how to create custom scales later.)

When the clock MCU starts, the code creates a 50-percent duty cycle for the three PWM outputs so an accidental overdrive doesn't damage the meters. ("Pinning" a meter with too high a current can actually bend the needle and ruin a meter.)

In a prototype design, the current limiting resistances included a calibration potentiometer that would properly adjust each meter's full-scale current. The final design, however, includes a scale-adjustment mode that lets you set the PWM value needed to move each meter needle to its full-scale position. The MCU saves this value in non-volatile memory so you never need to adjust it again.

Because the Seconds meter experiences a current change every second, the meter needle tends to "bounce" from one value to the next. Wrist watches have a second hand that moves either smoothly or that "jumps" from second to second, so Alan wanted his clock to emulate either mode. If you place a jumper across the Smooth Seconds pins (S5), the MCU changes the current output for the seconds meter every 0.1 second to cause the Second meter needle to move smoothly.

Alan designed the clock to run from a 9-to-12V DC mains-powered wall cube or "wall wart" power supply, but he wanted to maintain the time during a power outage. So the circuit includes a 4.5V battery that will supply backup power. The circuit must know when the clock runs on backup power so it can reduce its power consumption. When the Main Power Monitor signal on MCU pin 1 changes to ground, the MCU will reduce power to the three meters and to the heart-beat LED, D6.

The circuit uses four diodes, (D2, D3, D4, and D5) and a resistor (R5) to implement the battery backup and provide the Main Power Monitor signal. Diode D2 causes the LM7805 voltage regulator (U2) to raise the regulated power output to about 5.7V. Diode D4 produces a 5V Main Power Monitor signal when the clock operates from mains power. If the circuit loses mains power, resistor R5 pulls the Main Power Monitor signal line to ground.

Diode D3 passes 5V power to the clock circuit. The optional 4.5 volt battery-backup power connects to the 5V power via diode D5. You can use three AA-size batteries in a plastic battery holder and connect its two leads to terminal block TB2 as shown in the schematic diagram.

How to Use the Multimeter Clock

When the clock first receives power, the three PWM outputs default to about 50-percent of the each meter's full-scale current reading, as noted previously. So, you must adjust the scale of all three meters. To start, place a jumper across the Scale Adj pins at S4. In this mode the MCU will power only the meter you choose to adjust. As you perform the following steps, you aim to move the needle on each meter to its full-scale, or maximum reading, position.

1. Use the Hour pushbutton (S1) to select the meter to adjust. Each button press selects the next meter in a repeating sequence.

2. Use the Minute pushbutton (S2) to decrease current to the selected meter; that is, to move the needle away from full scale, or its maximum reading.

3. Use the Second pushbutton (S3) to increase current to the selected meter; that is, to move the needle toward the full scale, or its maximum reading.

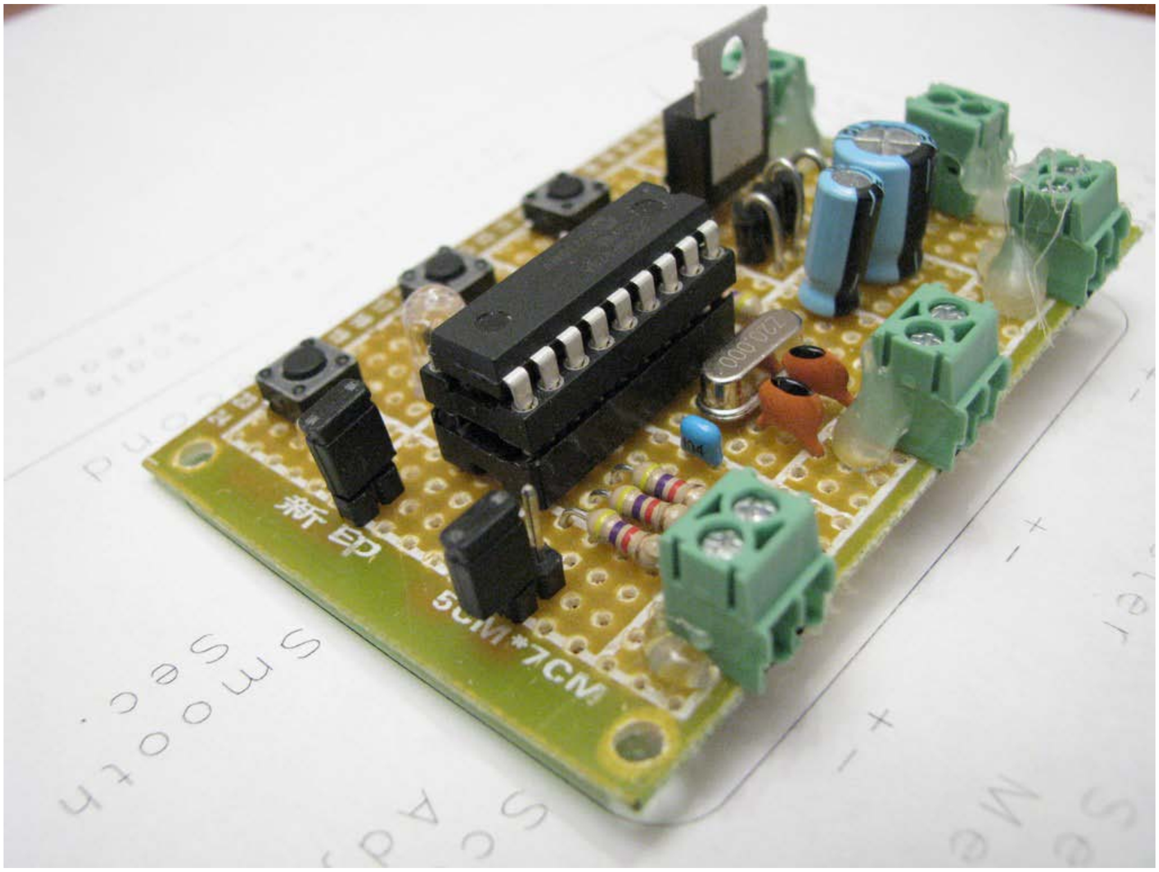
After you have the three meters properly set for the full-scale position of their needle, remove the Scale Adj jumper (S4) to return to normal clock mode. The MCU stores the calibration information for each meter and you can move on to set the current time.

Use the Hour, Minute, and Second pushbuttons. The Hour button increments the current time by one hour. The Minute button increments the current time by one minute. The Second button resets the seconds to 0.

After you enter the proper time, the MCU will keep track of time. An interrupt "fires" every 0.1 second and the interrupt service routine increments a 10^{th}-second counter by one. Another routine checks to see if the counter has reached one second, at which time the current time increments by one second. If you choose the Smooth Seconds setting, the "Second" meter receives a new current every 0.1 second instead.

Building the Clock

You can use a piece of perforated board with a 0.1-by-0.1-inch spacing of holes to hold the MCU and discrete components. This type of "perf board" gives you a lot of flexibility in how you lay out the circuit. Construct the circuit according to the schematic diagram. When you power the circuit--with the programmed PIC MCU installed--the blue LED (D6) will give you a visual indication that things are working, during the power up phase the LED will light steady-on and as soon as the clock starts to run it will flash on for one second and off for one second.



Alan used the PICBASIC PRO compiler from microEngineering Labs (www.melabs.com) to created the clock software. So you will need that software if you plan to change the clock's functions or operation. The present code leaves about 20 percent MCU's code memory available for your "hacking."

If you want to duplicate Alan's Multimeter Clock, you can download the hexadecimal code and use a PIC programmer to load it into the MCU. A Microchip Technology PICkit 3 pod (part no. PG164130) provides a means for in-circuit programming of a PIC MCU and the free Microchip MPLAB Integrated Development Environment (IDE) tools.

For more information:

"PICkitTM 3 Programmer/Debugger User’s Guide." ww1.microchip.com/downloads/en/DeviceDoc/PICkit_3_User_Guide_51795A.pdf.

"In-Circuit Serial Programming." ww1.microchip.com/downloads/en/DeviceDoc/31028a.pdf.

To program the MCU you will need a way to program the device. Alan uses a stand-alone programmer and WinPIC 800 software (www.winpic800.com) to "burn" the HEX file into the MCU's flash memory.

You can find other PIC programmer modules and kits via a Google search. Look at, for example, the VEK8048 - PIC Programmer & Experiment Board ($US 49.95) from Carl's Electronics at www.electronickits.com/kit/complete/prog/ck1700.htm. The company sells other types of PIC programmers, too.

Quasar Electronics in the UK sells the 3149E - USB or Serial-Port PIC Programmer (approx. $US 75). Visit www.quasarelectronics.com.

Canakits in Canada sells the UK1301 - Mini USB PIC Programmer (assembled, $US 49.95; kit, $US 34.95). Visit: www.canakit.com.

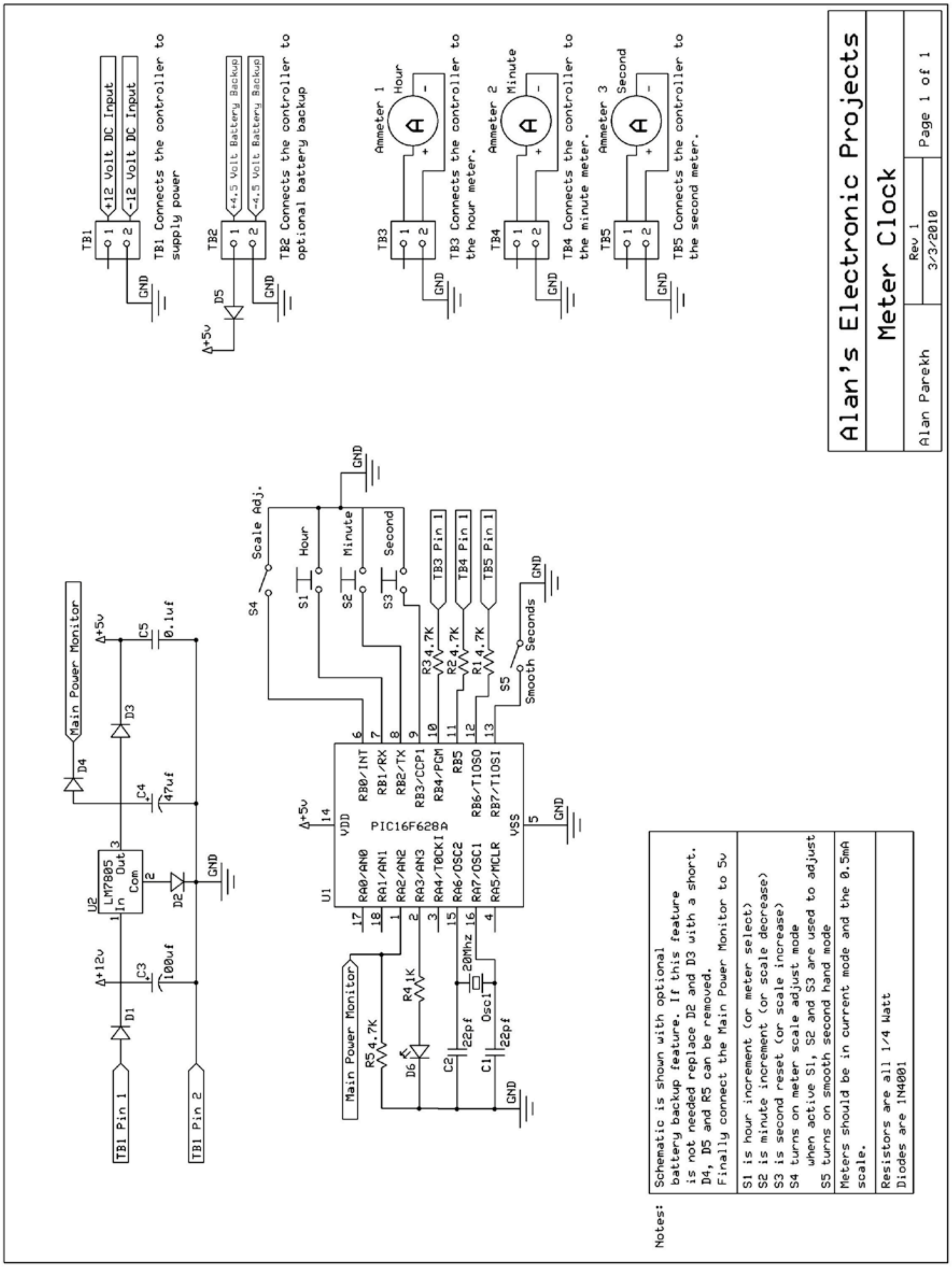
Adapt the Meter Faces

The multimeter faces, or scales, require modification to provide scales that someone can use to directly read hours, minutes, and seconds.
Alan used a program called MeterBasic by Tonne Software (www.tonnesoftware.com/meter2.html). To make a new meter face you enter the measurements of the meter face, the name for the meter and scale information. In the end you have a perfect matching scale for your meter. Just ensure you can remove the multimeter face to attach the new scale.

Clock Housing

You can create a housing for the Multimeter Clock to match your office furniture, shelves, lab bench, and so on. Alan created a CAD version of a Simpson 260 multimeter and cut it out on a CNC machine. Why the Simpson 260? That was the first analog meter he used in college.


Multimeter Clock
Hours
Minutes
Seconds
SUNWA YX-1000A
SUNWA YX-1000A
SUNWA YX-1000A
-10A
Output
Simpson
50u Amps
+10A
-DC
+DC
AC
25V
10V
50V
250V
1000V
100MA
10MA
Rx1
Rx100
Rx10,000
Zero Ohms
Common
260
AC
DC


Alan's Electronic Projects
Meter Clock
Alan Parekh
Rev 1
3/3/2010
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TB1 Connects the controller to supply power
+12 Volt DC Input
-12 Volt DC Input
TB2 Connects the controller to optional battery backup
+4.5 Volt Battery Backup
-4.5 Volt Battery Backup
TB3 Connects the controller to the hour meter.
TB4 Connects the controller to the minute meter.
TB5 Connects the controller to the second meter.
Ammeter 1
Hour
Ammeter 2
Minute
Ammeter 3
Second
PIC16F628A
LM7805
Main Power Monitor
TB1 Pin 1
TB1 Pin 2
TB3 Pin 1
TB4 Pin 1
TB5 Pin 1
Scale Adj.
Smooth Seconds
Notes:
Schematic is shown with optional battery backup feature. If this feature is not needed replace D2 and D3 with a short. D4, D5 and R5 can be removed. Finally connect the Main Power Monitor to 5v
S1 is hour increment (or meter select)
S2 is minute increment (or scale decrease)
S3 is second reset (or scale increase)
S4 turns on meter scale adjust mode when active S1, S2 and S3 are used to adjust
S5 turns on smooth second hand mode
Meters should be in current mode and the 0.5mA scale.
Resistors are all 1/4 Watt
Diodes are 1N4001

Parts List

Amt	Part Description	Allied Part #
1	Perforated Prototype Board (about 2 X 3 in.)	237-0112
5	Two-Position Terminal Block	409-0730
1	100µF Capacitor, 35V	852-7050
1	47µF Capacitor, 16V	852-7002
1	0.1µF Capacitor, 50V	648-0303
2	22pF Capacitor, 50V	507-0201
5	1N4001 Diode	411-0001
1	L7805 Voltage Regulator	248-0415
4	4700Ω Resistor, 1/4W*	296-4769
4	2400Ω Resistor, 1/4W*	296-6509
4	510Ω Resistor, 1/4W*	296-6513
4	240Ω Resistor, 1/4W*	296-6495
1	1000Ω Resistor, 1/4W*	296-4741
1	Blue LED	265-9058
1	20-MHz Crystal	614-0055
1	18-Pin DIP IC Socket	374-5536
1	16F628A PIC Microcontroller	383-0400
3	Tactile Button, Normally Open	676-0217
2	Two-Position Pin Header	863-0308
2	Pin Header Jumper	863-0339
1	AA Battery Holder (4.5V)	839-3059
1	9V DC Plug-In Power Supply	653-0250
1	Plug-In Supply US Adapter	653-0260
3	Analog Multimeter	See below

* You will need one of these resistor values will be needed based on the chosen meter. See Table 1 for resistor suggestions.

Typical Inexpensive Multimeters:

Sears Craftsman Analog Multimeter, No. 03482362000

Actron CP7849 Analog Multimeter Tester

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