FR. TOM McGAHEE'S PIC CONTROLLED DIGITAL CAPACITANCE METER

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SPECIFICATIONS

The Capacitance Meter has 4 ranges. In Manual Mode each range has an absolute minimum and maximum reading that corresponds to a count range from 0 to 16,777,215 counts. The extremes of each range are where the greatest error occurs, so in the Auto Mode we restrict the range to that portion where we will attain the greatest accuracy.

Furthermore, in the Auto Mode the count range can be seen as having five special points. These points correspond to the following:

ZERO: The absolute lowest value that can be measured. In Auto Mode this ZERO value is only shown on the lowest range. In Manual mode it is displayed on all ranges. When changing capacitors the unit will AutoRange to Range 1.

DOWNRANGE: This corresponds to any count lower than 4,096 in Ranges 1-3, and 32,768 in Range 4 . In Auto Mode if the count drops **below** this value then the meter will automatically shift to the next lowest range. If in the lowest range, then the count is displayed.

ENTRYRANGE: This corresponds to 5,242 counts on the current scale and 524,288 counts on the previous scale. This provides some hysteresis between the value where AutoRanging enters **from** a lower range and down-ranges back **to** a lower range. If this hysteresis was not present, then the circuitry might oscillate at the point where AutoRanging kicked in.

UPRANGE: This corresponds to a count of 524,288 on the current range. In Auto Mode the circuitry will initiate a move to the next higher range when this count is reached or exceeded. If the current range is the highest range, then counting will simply continue up to the MAXCOUNT value.

MAXCOUNT: This correspondd to the Maximum Count value of 16,777,215 which is the maximum count value that can be attained with the 24 bit binary counters maintained by the PIC.

RANGES

RANGE 1: This range employs a precision 250k resistor and a divide by 100 external pre-scaler that allows the meter to measure from 0.00 pf to .00524288 uf (5,242.88 pf) in the Auto Mode.

Note that the digits behind the decimal point will often be seen to change from reading to reading. This is *partially* due to the fact that the meter is responding to slight variations in the capacitor, and to stray capacitance in the leads. Coming close to the leads can cause the stray capacitance to vary by a picofarad or two. There is also the matter of a certain amount of digital error that creeps in and gets magnified due to the use of the divide by 100 prescaler. However, I have found it useful to have the extra two digits behind the decimal point.

In Manual Mode the range is from 0.00 pf to .16777216 uf (167,772.16 pf).

RANGE 2: This range employs only a precision 250k resistor, and has an Auto Mode range from 4,096 pf to .524288 microfarads (524,288 pf).

In Manual Mode the range is from 0.000000 uf to 16.777216 uf (16,777,216 pf).

RANGE 3: This range employs a trimmable resistance whose nominal value is 2.50k. I chose to use a trimmer pot to adjust the value so that the unit can be adjusted to compensate for a few sources of error that stem from the characteristics of the opamp I used. The Auto Mode range is from .4096 uf to 52.4288 uf.

In Manual Mode the range is from 0.0000 uf to 1,677.7216 uf.

RANGE 4: This range employs the same trimmable resistance of 2.50k that was used in Range 3, and a multiply by 10 circuit that allows us to expand this range to be exactly ten times that of Range 3. The times ten circuit is also trimmable so we can adjust where the circuit has maximum accuracy. In general it is useful to adjust for maximum accuracy at 100 uf. The Auto Mode range is from 32.768 uf to 16,777.216 uf. Always adjust Range 3 before adjusting Range 4.

In Manual Mode the range is from 0.000 uf to 16,777.216 uf.

ACCURACY

The accuracy of the PIC Capacitance Meter is influenced by several factors. The accuracy of certain resistors is critical to the accuracy of the circuit. **I chose to use .1% precision resistors for the two resistors that comprise the 250k resistance used on Range 1. I chose two .1% precision 10.0k resistors for the ratiometric comparator section, as these are crucial to the basic accuracy of the circuit on ALL ranges.** The other resistors were chosen to be 1% metal film resistors. Trimmer pots are used to adjust the accuracy on Range 3 and Range 4.

I have used a set of precision capacitors of known value to test the accuracy of this meter, and here is what I found:

On Ranges 1 and 2 the accuracy is about .1% when run in the Auto Mode. When run in the Manual Mode at counts above 1 million, the accuracy degrades to about 1%.
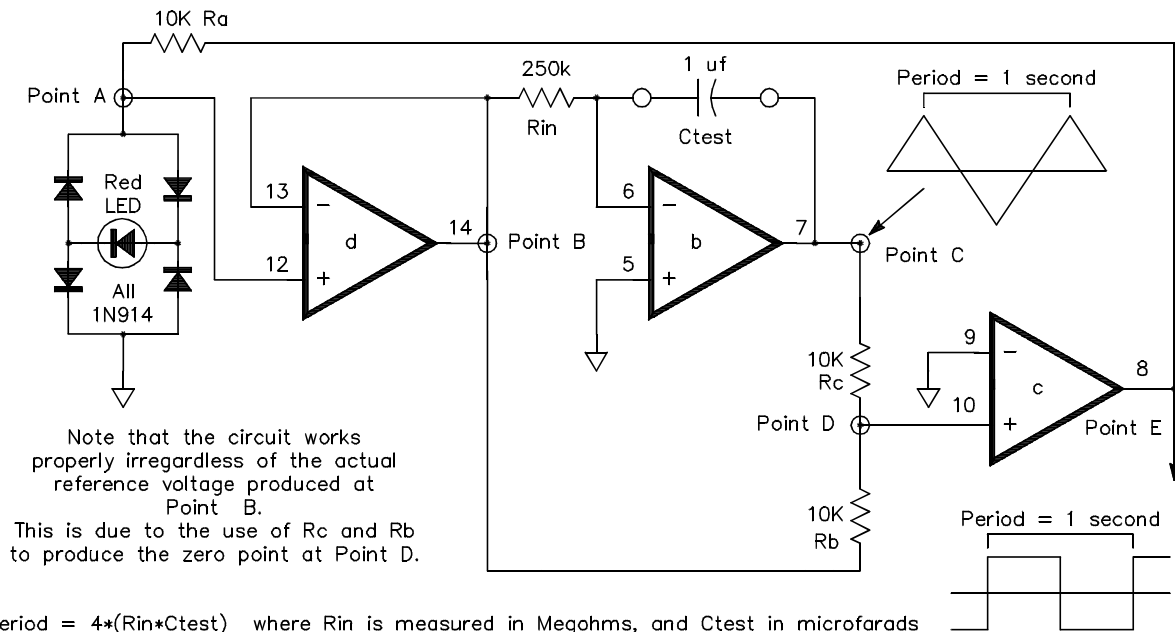
On Range 3 the accuracy is typically 1% when used in Auto Mode. In Manual Mode at counts above 1 million the accuracy degrades to about 3%. Careful adjustment of the trimmer pot can result in getting the accuracy of any desired point to be within .1%, but above and below that point the accuracy will decrease as the distance from that point increases.

On Range 4 the accuracy is limited by all the same factors discussed concerning Range 3. In addition, this range uses an opamp multiply by ten circuit. So the accuracy is also affected by the accuracy of this multiplier and the fact that the multiplier also multiplies any noise present in the triangle wave being fed to the comparator section. In general, don't expect this range to give you much more than 1% accuracy . This can degrade to as much as 10% accuracy at the extreme high ends of the range.

You might be able to increase the basic accuracy of the circuit by choosing a better operational amplifier. I chose the TL084 because it was fairly decent, readily available, and inexpensive. There are some pin-for-pin compatible opamps out there that have lower input bias current and higher slew rates, and plugging one of these in may get you a bit more accuracy.

Theory of Operation

SIMPLIFIED SCHEMATIC OF ANALOG CAPACITANCE TO PERIOD CONVERTER

Note that the circuit works properly irregardless of the actual reference voltage produced at Point B.
This is due to the use of Rc and Rb to produce the zero point at Point D.

Period = 4*(Rin*Ctest)   where Rin is measured in Megohms, and Ctest in microfarads

Later we will show you complete schematic diagrams for the circuitry. However, to make it easier to understand the basic principles of operation I have prepared a simplified diagram of the analog section. The analog section produces a period whose width is directly proportional to the capacitance being measured.

The four diodes form a full-wave bridge. Across this bridge is a regular RED LED. Whenever a voltage of either polarity is applied across the 10k resistor that feeds the bridge, the voltage developed at Point A will be either +3 V or -3 V. [Two diode drops plus LED diode drop]. In reality the voltage will be slightly above or below 3 volts, but 3 volts is the value we will use in this explanation. So, let's assume that the voltage at Point A is exactly +3 V. Point A connects to a simple voltage buffer (IC section D), so the output at Point B will also be +3 V. The purpose of the buffer is to prevent loading of our reference voltage, especially at the higher ranges.

The +3 V is then applied across Rin. IC section B forms a simple integrator. The +3 V across the 250k resistor will cause a current of 12 microamps to flow into Ctest, which for this example is chosen to be 1 microfarad. This causes the voltage at Point C to ramp **downwards** at 12 volts per second when the reference voltage is +3 volts.

The +3 V from Point B is **also** connected to resistor Rb. The negative-going voltage from Point C is connected to Ra. Since Ra and Rb are precision resistors of equal value, when Point C ramps down to -3 V, the voltage at Point D will go to zero volts. IC section C is a simple voltage comparator

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which compares at the zero point. As soon as the voltage at Point C goes below -3 volts the output of IC section C will switch to a large negative voltage.

This large negative voltage is applied across the 10k resistor that feeds the LED bridge, causing the reference voltage to rapidly switch to -3 volts. The voltage at Point C will now start to ramp **up** from -3 volts. It will continue to ramp up until it reaches +3 volts. At that moment the comparator section will switch again, causing the reference to go back to being +3 volts again.
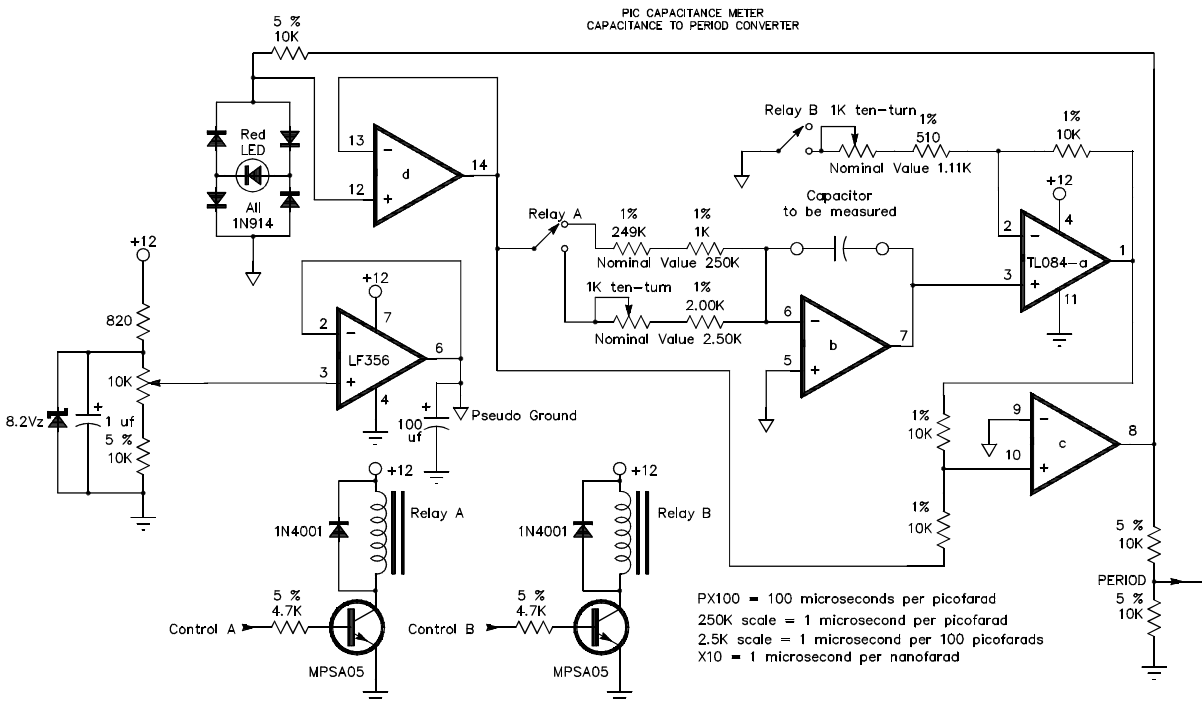
This produces a very linear +/- 3 volt triangle wave at Point C, and a clean square wave at Point E. The period of both waveforms is the same. We use the square wave output (after proper conditioning) to provide the period waveform that the PIC will measure to determine capacitance.

Since during each period the triangle wave goes up a total of 6 volts and down a total of 6 volts, it experiences a total travel of 12 volts. Since (for the present example) we know that the voltage ramps at a rate of 12 volts per second, the period for the given example will be exactly one second.

The interesting thing about the circuit is that the actual voltage level that appears at Points A and B has literally no effect on the period that results! If the voltage was, say, 6 volts instead of the 3 we used in our example, then the voltage at Point C would be ramping up twice as fast, but it would have to go twice as high or low before the comparator would trip. Thus it would take the same **time** as before. The only requirement that is made on the voltage reference is that it be a stable voltage over the time the period being measured. **The actual exact value of the reference doesn't matter.** Obviously, if the reference is too low or too high, that may create other problems for the opamps. The best value happens to be about +/- 3 volts. Too low, and noise in the circuit begins to dominate. Too high, and the opamps have trouble supplying enough output current near the rails.

If the use of the RED LED offends your sense of propriety, then by all means use a low voltage zener in its place. Just remember that there are two diode drops due to the use of the bridge, so you want to choose a low voltage zener such as 2.5 volts.

THE FULL ANALOG CIRCUIT

When you look at the full schematic of the analog section above, you will see that I have added an LF356 opamp to produce a decent pseudo ground for the quad opamp. This allows us to run the quad opamp with a single 12 volt supply. As far as the quad opamp is concerned, it sees +/- 6 volts as its supply voltages. Keep this in mind if you decide to go snooping around with an oscilloscope or voltmeter. Expect to see an offset of about +6 volts with respect to the digital ground.

A trimmer pot is used to fine adjust the actual offset voltage. This allows us to adjust the offset such that the symmetry of the +/- 3 volt reference is preserved. This helps us to get a bit more resolution out of the circuit. The 100 uf capacitor shown connected between the pseudo ground and the system digital ground is there to improve the response of the analog ground and reduce systems noise.

Relay A is used to control the value of Rin. This allows us to switch between Ranges 1-2 and Ranges 3-4. Relay B is used to switch Section A of the quad opamp between a gain of 1 and a gain of 10. The gain of 10 makes it possible to reduce by a factor of ten the time it takes to obtain a given count. Without this feature the upper limit would have been about 1,000 ufd. With this addition we can go out to over 16,000 ufd, though we do lose some accuracy in the process. I used relays here because any additional circuit resistance would have affected overall accuracy. CMOS switches create too much error in this particular application.

The 74HC390 is arranged so that it provides a symmetrical divide by 100 function. The 4011 IC is wired up as a simple Data Selector. The PIC can control whether it is selecting the Period or the

Period multiplied by a factor of 100. This is used to increase the accuracy of the lowest range so that we can accurately measure down to the picofarad level.

A 555 timer circuit is connected up as a negative voltage generator in case the LCD you are using requires a negative bias. If your LCD works with the bias line grounded, then you can leave out all the parts associated with the negative voltage generator. In that case, connect the bias line of the LCD to a ground point on the pc board.

THE PIC PART

The PIC 16F84 provides the control functions that determine the Range, and it also provides the logic for implementing AutoRanging. The PIC internally counts the number of 1 microsecond instruction cycles that occur during a given Period. The PIC then subtracts an offset value from the binary count and uses this to help eliminate many of the sources of error that would otherwise reduce the accuracy of the circuit.

The offset that is subtracted can be either the intitial stray capacitance for each of the four scales that is determined when the unit is first turned on, or it can be a value that was in effect when the Manual Mode is entered.

THE LCD PART

The PIC takes the binary information and uses that and the Range information to format the numbers displayed on the LCD.

The LCD display that I used is one that displays two rows with 16 characters per row. The top row displays the numerical part of the measurement. The number displayed will include a comma if the value exceeds 1,000 units. Leading zeros are suppressed up to the decimal point.

Digits after the decimal point may include trailing underscores to indicate non-implemented digit locations.

Various markers are displayed to show the state of the machine, and error messages are displayed when appropriate.

A + or - in the first position of the first line is used to indicate whether the currently displayed value is larger or smaller than the reference value. The reference value is initially set to zero, but the user may choose to lock in any current value as a reference value. For example, if you have a reading of 1.2345 uf and you press the ZERO button, then the display goes to zero and the Manual Mode is entered. If you now remove the capacitor, then you will see a reading of -1.2345 uf displayed. Put a 1.0000 uf capacitor on, and the reading goes to -.2345. Put a 2.0000 uf capacitor on, and the reading will change to +.7655 uf. This is a feature not found on other capacitance meters.

Sometimes you will see the letter "M" displayed in the second position of the first line. It will usually appear to be blinking. It's purpose is to warn the user that the currently displayed value is

outside the usual limits used on that Range in the Auto Mode. We flag this condition because the accuracy of the meter falls off when you get outside the suggested range limits.

In the first position of the second line there will be a number from 1 to 4 displayed. This number corresponds to the currently selected Range.

Following the range number will be the value designators, such as uf nf pf. These are arranged so that they line up immediately below the corresponding numerical digits on line one. I chose to display more than one value designator at a time, because sometimes I want to know the value in microfarads, and at other times I may want to know it in nanofarads or picofarads. This arrangement also allowed me to get by with just 4 ranges. Ranges 1 and 2 share a common display arrangement, as do Ranges 3 and 4.

The last three positions on the second line are used for special markers. Position 13 will be displaying an "A" if the unit is in Auto Mode, or an "M" if the unit is in Manual Mode. Positions 14 and 15 are used to display the current "state" of the meter. When the unit has achieved synchronization and is waiting for the count to be accumulated, a black box will move back and forth. When a new count has been displayed "**" will be displayed as well.

Whenever you begin to measure a new capacitor, wait until you have seen the unit go through this cycle of moving black box and ** at least two times to insure that you are getting a valid reading.

Whenever the unit AutoRanges it will display a message to that effect. This is to warn you to wait a second or two so you get a stable reading. If a count exceeds the 24 bit binary limit of 16,777,216 then an OVER-RANGE message will be displayed.

In the Manual Mode if you go out of range then the error message becomes MANUAL OVER-RANGE to remind you that you are in Manual Mode.

THE PUSHBUTTONS

Several pushbuttons are available to allow Reset, UpRange, DownRange, and Zero. Because the presence of a pushbutton closure is only tested for at certain points in the program, it is best if you hold the button depressed until you see that the activity marker stops. The button will be responded to when you **release** the button. If you just take a quick stab at the pushbutton it may not be detected.

RESET performs the same function as turning the power on. A new set of auto-zero values are accumulated for each range, and Auto Mode is entered. It is important that you remove any capacitor before doing a reset. Otherwise the unit will valiantly attempt to use the current capacitor value as the auto-zero value. If the capacitor value is large then you may start to get over-range error messages on the lower ranges, and the unit may get "hung up".

UPRANGE causes the meter to enter the Manual Mode and move to the next higher range. Once the highest range is reached, the meter stays at that range.

DOWNRANGE causes the meter to enter the Manual Mode and move to the next lower range. Once the lowest range is reached, the meter stays at that range.

ZERO causes the meter to enter the Manual Mode and sets the meter to read zero at the current range. This is useful not only for zeroing out stray capacitance, but also for subtracting the entire current capacitance value from displayed reading.

A + is displayed whenever the current capacitor value is greater than the zero value, and a - is displayed whenever the current capacitor value is lower than the zero value. This is extremely useful for comparing two capacitors, or for watching the changes that are occuring in a given capacitor

SOME ENLIGHTENING EXPERIMENTS.

Try this interesting experiment:

Turn the unit on with no capacitor OR leads attached. The unit will come up in Range 1. Wait a few seconds and write down the displayed value, which is typically less than .2 pf. Now add a set of clip leads to the terminals. Twist the leads slowly together while you watch the display. You will find that the lead capacitance will amount to several picofarads, perhaps going as high is 30 pf. If you touch one of the leads directly, or even if you just handle the insulation, you will see that your body has a capacitance that amounts to several pf.

Another enlightening experiment:

Connect an electrolytic capacitor having a value of about 1,000 uf and wait about a minute so the capacitor value has a chance to stabilize. Then push the ZERO pushbutton for a second or two. When you release it the display should go to zero within a few seconds. (You may have disturbed the unit in the middle of a count sequence, and it will begin a new full conversion sequence to insure it gets the proper "zero" value).

Once you get the zero reference reading, note that the count varies a bit from reading to reading. This is NOT due to error, as you will soon see! Grab the electrolytic capacitor tightly so that your body heat begins to heat the capacitor up. As you warm it up with your body heat you will see that it will vary its capacitance by several microfarads. I can usually get a change of about 20 uf just using body heat! Hopefully this will explain to you why the unit will measure 1,000 uf today and 1,100 uf tomorrow when it has been sitting in the sun. This experiment also shows you why electrolytic capacitor values are usually given tolerances like +80 -20 %.

You now know that you have to exercise care when measuring very small AND very large values of capacitance.Guess what? You have to be careful when measuring ANY size capacitor! Capacitors DO change their values based on temperature and other factors.

The unit is very useful in comparing different TYPES of capacitors so that you will know how they respond to environmental factors.

CALIBRATION OF THE PIC CAP METER

ADJUST LCD BIAS

Turn the unit on and adjust the negative bias 10k trimpot for the best looking display on the LCD. This is the trimpot shown on the left, nearest to the 555 timer. *If using an LCD that does not require a negative bias voltage, ensure that the bias input line (pin 3) from the LCD is connected to ground. There is a ground point connection pad available for this purpose at the extreme left of the analog pc board, just below and to the left of the 10 uf capacitor.*

SAFETY PRECAUTIONS

Before attaching any capacitor, always short the leads out first! It is normal for a capacitor to have a residual charge, so ALWAYS be safe and short out the capacitor before attaching it to the binding posts.

The TL084 Quad OpAmp may be damaged if you accidentally apply more than ten volts. The unit itself will normally not apply a voltage in excess of +/- 3 volts, so it may be safely used to measure electrolytic and other polarized capacitors. Binding posts are not polarized, and capacitors may be connected up either way.

ADJUST PSEUDO GROUND SYMMETRY

Place the unit into Manual Mode and switch to Range 3 by using the UPRANGE pushbutton. The current Range is displayed as a number from 1-4 at the beginning of the second line. Attach a 10 uf capacitor to the binding posts. Adjust the pseudo ground symmetry 10k trimpot located at the right side of the board, just above the LF356 IC. Look at the RED LED at the upper right hand side of the analog pc board. Adjust the trimpot so that the brightness of the RED LED is constant. This adjustment ensures that the voltage of the reference source is equal for both polarities. This adjustment will normally leave the trimpot near its midpoint. The reason for using a 10 ufd on Range 3 is that with this value and range combination the output of the comparator will have a frequency of about 10 Hz. The human eye can easily discern any current mismatch as a visual flickering. The flicker is hard to discern when the period is too short, and difficult to compare when the period is too long.

CALIBRATE RANGE 1

Range 1 requires no calibration, as it uses .1% precision resistors to ensure an accuracy of better than 1%. The 74HC390 divider section introduces no appreciable error.

CALIBRATE RANGE 2

Range 2 requires no calibration, as it also uses the same .1% precision resistors to ensure an accuracy of better than 1%.

CALIBRATE RANGE 3

Range 3 requires that the leftmost 1k ten turn trimpot be adjusted near the center of its range. You can make use of the fact that Range 2 and Range 3 overlap. Use the UPRANGE and DOWNRANGE pushbuttons to get into Manual mode and on Range 2, which is already calibrated. ZERO the display. Attach a capacitor having a value between .4 uf and 3 uf. Write down the capacitor value displayed. Use the UPRANGE pushbutton to move to Range 3. Adjust the Leftmost 1k ten turn trimpot such that the reading coincides with the value you wrote down. You may want to go back and forth between Range 2 and Range 3 a couple of times to verify that the displayed values coincide within 1%.

CALIBRATE RANGE 4

Range 4 relies heavily on the calibration of Range 3. Anytime you calibrate Range 3, you should then re-calibrate Range 4. In addition to relying on the calibration of Range 3, Range 4 uses a precision multiply by ten circuit. You can adjust the exact multiplication value by adjusting the rightmost 1k ten turn trimpot. Calibrate by using a capacitor with a value of about 100 uf. Place the unit on Range 3 and write down the displayed value. Switch to Range 4 and adjust the rightmost 1k ten turn trimpot until the displayed value is as close to the value you wrote down as you can get. You may want to go back and forth between Range 3 and Range 4 a couple of times to verify that the displayed values coincide within 1%.

System is now calibrated.

BITS AND PIECES

The remaining pages contain the parts list, schematics, parts placement diagrams, and pc board layouts. Note that I have built my unit using two separate pc boards. I piggy-backed these two boards so that I could fit the whole unit into a reasonable sized case. I piggy-backed them in such a way that the foil sides faced one another with a separation of about 1/2 of an inch. This allowed me to easily get at the components on both boards. I recommend that you have the analog board facing away from the front panel. This allows you to easily get at the calibration adjustment controls, especially the pseudo ground symmetry control.

The diagrams are given at 100% scale so that you can use them to directly produce the pc boards. The parts placement diagram shows all parts, jumpers, and interconnecting wires. I have shown the parts from the top view, and you will notice that a light gray is used to indicate the underlying printed circuit board traces.

The two 1k ten turn pc board pots that adjust the ranges can be either the long skinny type, or the little square types. The pc board pattern has been designed so that it will accomodate either style.

I purchased all my parts from:

MOUSER Electronics
1-(800)346-6873
http://www.mouser.com

The only parts not purchased from MOUSER were the PIC 16F84, which I got from:

DIGI-KEY
1-(800)344-4539
http://www.digikey.com

and the 16x2 LCD, which I liberated from a piece of industrial equipment. These are available from many sources, including DIGI-KEY.

PARTS LIST

RESISTORS

1   10 ohm 5% or 1% metal film [non-critical 10-33 ohms ok]
1   510 ohm 1% metal film
1   820 ohm 5% or 1% metal film [non-critical 750-1k ok]
1   1k 5% or 1% metal film [non-critical 750-2.2k]
1   1k 1% or preferably .1% metal film [marked with a dot on the placement diagram]
1   2.00k 1% metal film [marked with a dot on the placement diagram]
2   4.7k 5% or 1% metal film [non-critical 2.2k-6.8k ok]
9   10k 5% or 1% metal film
3   10k 1% or preferably .1% metal film [marked with a dot on the placement diagram]
1   249.0k 1% or preferably .1% metal film [marked with a dot on the placement diagram]

POTENTIOMETERS

2   10k round style single turn pc mount [negative bias adjust may be as large as 25k]
2   1k ten turn pc mount trimpots. [May be long & skinny or square style.]

CAPACITORS

2   20 pf at least 10 v [Not critical. For 4.000 Mhz crystal]
1   .01 uf at least 16 v [Not critical. Used for negative bias generator]
3   1 uf at least 16v tantulum or electrolytic. [Not crititcal. 1-6.8 uf ok.]
1   10 uf at least 16v tantulum or electrolytic. [Not critical. 10-47 uf ok.]
3   100 uf at least 16 v electrolytic. [Not critical. 100-470 uf ok]
1   220 uf at least 10 v electrolytic. [Not critical. 220-470 uf ok]

SEMICONDUCTORS

1   **RED** LED used for reference voltage. [May use a LOW voltage 2.5v Zener instead]
1   8.2 v Zener used to set range & stability of pseudo ground. 250 mw ok.
6   1N914 or equivalent silicon signal diode such as 1N4148
6   1N4001/1N4002/1N4003/1N4004 or equivalent 1 amp diode greater than 50 v
2   MPSA05 or equivalent NPN transistor for use as relay driver. 25v Gain>100
1   7805 positive 5 v regulator. [No heat sink. Cool to the touch. Low current version ok]
      *It is a good idea to bend this over with **plastic side flush** with pc board before soldering.*
1   7812 positive 12 v regulator. [No heat sink. Only very slightly warm.]
      *It is a good idea to bend this over with **metal side flush** with pc board before soldering.*
1   555 timer IC
1   LF356 Single OpAmp IC [Used for pseudo ground, supplies 30 ma to quad opamp]

1   TL084 Quad OpAmp IC [substitute only with BETTER slew rate and input current]
             MOUSER # 511-TL084ACN $1.10 or 511-TL084IN $0.74 14 pin DIP
1   4011 Quad 2 Input NAND CMOS IC MOUSER # 511-4011 $0.39
1   74HC390 Dual Decade Counter CMOS IC MOUSER # 511-M74HC390 $0.67
1   PIC 16F84 Microchip Microcontroller (Must be programmed with CMETERA.ASM)

OTHER

1   Set of Single Sided Printed Circuit Boards. Homemade. Press N Peel works well.
2   12v @ 30 ma SPDT with 1 amp contactsubminiature relays MOUSER part # 431-1612
1   16x2 LCD Display such as those by OPTRONIX (Hitachi Controller)
             Mine used a 14 pin header organized as 2x7. Some models have a 1x14 organization.
             If you use the 1x14 style LCD, then you can just solder the wires directly to the digital
             pc board. Odd numbers are towards the PIC. Pins 1 and 14 are marked on the Parts
             Placement Diagram. Ignore the triangle symbol. That is just there to indicate the proper
             header orientation. Since the headers at the LCD are mirrored instead of normal, we had
             to mirror our pc header also. Before soldering wires direct to the pc board, just insure
             that pin 1 goes to pin 1, etc. See further discussion below...
1   4.000 Mhz Crystal
1   14 pin header to connect to LCD cable. Mounts on component side. Stripe of cable
             goes on side marked with number 1.
1   14 pin cable to connect LCD to PIC board (5" or more, Female connectors on both ends)
             If using 2x7 header, just plug in with stripe oriented on same side as pin 1. If using
             1x14 style LCD, you can leave off the header and solder direct if desired. But be careful
             if you decide to mix the pcb 2x7 and an LCD that is 1x14. The IDC cable pins are usually
             *numbered *1 2 3 4 etc., but due to the mirrored wiring used on 2x7 LCD displays,*
             *the cable coming from the pcb will actually be *2 1 4 3 6 5 8 7 10 9 12 11 14 13, where*
             *the * indicates the striped wire. Yeah, it can be confusing, so be very careful!*
X   Sockets for each IC (Optional)
4   SPST Normally Open Pushbutton Switches (el cheapo variety ok)
1   On/Off Switch (I used a push on / push off style)
1   Power Indicator LED and current limiting resistor (Optional. Steal power from +12v)
2   Binding Posts. (I used two white ones, as the terminals are NOT polarized)
1   Case. I used the MOUSER # 546-1595E-BU Sloped Case
             Measurements were 8.5" x 5.1" x 1.85" with rise to 2.9" at the back. $12.45
1   12 VAC Wall Power Cube rated for at least 100 ma. [May be DC style also. 18 V max]

Miscellaneous nuts, bolts, screws, wire, etc.

Make sure you install all jumpers shown on the Parts Placement Diagram!

I used a thin sheet of plexiglass (perspex) between the cutout for the LCD and the actual display
screen, so that the LCD display is protected.

Some Comments by the Author

The original diagrams were prepared using AutoCad version 12, and are based on custom schematic symbols that I prepared myself. These diagrams were then converted to PDF format using Adobe Acrobat version 4.0. Diagrams that would need to be re-sized and included on the same pages as regular text were then exported from Adobe Acrobat in Postscript format. These Postscript files were found to be the highest quality way to import the original AutoCad files into the desktop publishing program that I used.

The typesetting and layout work was done using Corel Ventura Desktop Publisher version 8. When all this was done, the final document sections were converted to PDF format. The assembly listing was done using Courier monospaced font in simple text format so that it can be directly used within MPLAB.

Adobe Acrobat was chosen as the final medium for presentation because of the widespread availability of the free Adobe Acrobat Reader software on many different platforms. Adobe Acrobat allows the user to print high quality copies. All artwork was prepared and saved at 600 dpi.

CMETER.PDF is this document, which contains the main text and two drawings.
PCB.PDF is the printed circuit board layouts for both boards.
PARTS.PDF is the parts placement diagram for both pc boards.
SCHANA.PDF is the large schematic for the Analog section.
SCHDIG.PDF is the large schematic for the Digital section.
CMETERA.ASM is the assembler file.

[CMETER.DWG is the Autocad file containing all the original drawings.]

The assembler file may be directly used under Microchip's MPLAB software to prepare the necessary HEX file required to program a PIC 16F84. The user should change the two message lines that appear when the unit is powered-up or reset. These lines currently say "PIC CAP METER", and "Fr Tom McGahee". Maximum line length is 16 characters.

I hope that even if you don't build one of these Capacitance Meters you will still have learned something from looking over these documents.

Feel free to share the plans with others. If you would like to post the plans on your web site, you have my permission to do so.

While I am making these plans freely available for hobbiests and professionals, I do want to maintain control and ownership of the designs. So, if you do distribute these documents, distribute them in their entirety. If you want to make changes, feel free to do so. In that case you might want to make a set of addendums to the original documentation.

Let me know if you found the plans useful. My e-mail address is on the first page.

TABLE SHOWING DISPLAY FORMAT AND RANGE INFORMATION

0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
+/-	(M)														
		u	f			n	f			p	f		MA	*	*

RANGE 1

[pselect = 1]   .00_ pf   to   .005 242 88_ uf   (.5 second)

Never Shifts Down.   Shifts Up at 524,288 (2^19)

RANGE 2

[All Off]   4,096 pf   to   .524 288 uf   (.5 second)

Shifts Down at 4,096 (2^12)   Shifts in Low at 5,242

Shifts in High at 409,600   Shifts Up at 524,288 (2^19)

0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
+/-	(M)														
						u	f			n	f		MA	*	*

RANGE 3

[Controla = 1] .409 6__uf   to   52.428 8__ uf   (.5 second)

Shift Down at 4,096 (2^12)   Shifts in Low at 5,242

Shifts in High at 409,600   Shifts Up at 524,288 (2^19)

RANGE 4

[Controla+controlb = 1] 32.768 uf   to 16,777.216 uf   (17 seconds)

Shift Down at 32,768 (2^15)   NEVER Shift Up: OVERFLOW past 16,777.216 ufd