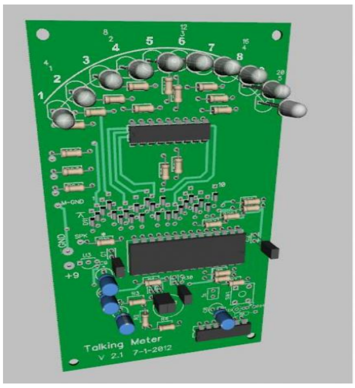
Talking Voltmeter

PART NO. 2169061



The Talking Voltmeter provides the builder a practical tool to measure voltages with both a visual display and voice output. Since the user records the audio, there are many possibilities for the audio output in addition to speech. In addition the user can opt to choose set points with appropriate recorded warnings, resulting in a device that only alerts on or above the set point value! As designed, the Talking meter has three selectable voltage ranges with design calculations. The builder can redesign these for user chosen voltage ranges or other meter applications. Modifications will require materials not included in the kit such as rectifiers, capacitors, resistors, and enameled wire.

Time Required: 5 hrs depending on experience

Experience Level: Intermediate

Required tools and parts:

Soldering iron and solder
Basic hand tools including precision diagonal cutting pliers
Adjustable power supply (0-20V) for calibration
Voltmeter for calibration and testing
Optional project box and power switch
Hot glue gun
Nuts and bolts (4-40x1 or 6-32x1 inch) or equivalent (4 each)
1' Red and 1' Black stranded hook up wire 22-24 gauge

Bill of Materials:

Qty	Jameco SKU	Component Name
10	25523	C1-C5, C10 - 0.1uF monolithic cap
1	31000	C6 - 4.7uF Electrolytic Cap
1	93739	C8 - 22uf Electrolytic Cap
2	198872	C7, C9 - 220uf Electrolytic Cap
1	2159082	R1 - 470K 1/4W resistor
2	2157159	R2, R29 - 1K 1/4W resistor
5	2157167	R3-R7 - 10K 1/4W resistor
2	2161078	R8, R21 - 47K 1/4W resistor
11	2159111	R9-R18, & R20 1.5K 1/4 W resistor
1	2159120	R22A - 150K 1/4 W resistor
1	691606	R22B - 1.2M 1/4W resistor
R22A & R22B are parallel combination for precision multiplier.		
1	691462	R23A - 330K 1/4W
1	691770	R23B - 6.8M 1/4 W resistor
1	2159091	R24 - 680K 1/4W resistor
4	691180	R25 - R28 22K 1/4 W resistor
1	2158864	R30 - 4.7K 1/4W resistor
10	333973	D1-D10 - LED T1-3/4
24	36038	D11 - D34 1N4148 diode
1	141671	U1 - ISD1110P
1	893283	U2 - CD4011Quad NAND
1	51182	U3 - 78L05 Voltage regulator

1	24230	U4 - LM3914 Dot display driver
1	40301	Socket U1 - 28pin DIP
1	37162	Socket U2 - 14pin
1	38113	Socket U4 - 18pin DIP
1	320179	MIC - Electret condenser Mic
1	1954826	Speaker 16ohm
1	153702	J1 & Input Terminal pins
1	112432	J1 Shorting Jumper
4		User supplied Nuts & Bolts 4-40 or 6-32 X 1" - 4ea
Available at hardware stores locally, 4-40 or 6-32 will work.		
1	153251	SW1 - tactile pushbutton
1	109154	9V Battery Snap
2	248921	Alligator Clip Pair - 2 pair required

Step 1 - Assembly overview

As an intermediate to advanced educational project, the instructions will focus on how the functional blocks of the meter can be understood and even modified by the builder to suit your individual goals. If you just want to build this kit without learning about function you can skip to the "Assembly" portion of the step. However important operational information is sometimes included in the technical descriptions.

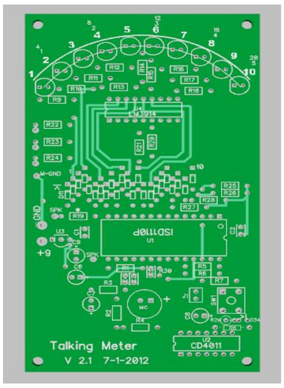
A practical method of building a complex system with interrelated functional blocks, is to build each functional block on its own, then to test that block before going on to the next system. The primary advantage of this from the builder / designer standpoint is that you can verify the function of each section by itself, and thus if a problem creeps in you will often find it early and with only one area of the larger system to concentrate on. This also can prevent destroying a particular part because of an error in a different system that feeds that part, such as the power supply.

The primary functional blocks and assembly sections of this kit are,
1 - The voltmeter - LM3914
2- The power supply - 78L05
3 - The Clock pulse generator - CD 4011
4 - The digital address encoder - Diodes 1N4148
5 - The audio recorder ISD1110P

Step 2 - Building and testing the voltmeter section

Theory:
The voltmeter section is based on the LM3914 Dot/Bar display driver wired in the dot mode. It accepts an analog voltage between 0 and 1.3V and creates a linear 1 of 10 output corresponding to the actual value of the input. It can drive LEDs directly but in our application requires resistors to each LED to provide the necessary voltage levels to the digital encoder circuit which will provide a digital address to the audio recorder chip.

Assembly:
Locate the LM3914, ten LEDs, eleven 1.5K resistors BRN /GRN / RED, the battery snap and R21 47K YEL / VIO / ORN resistor.
Install the 1.5K resistors in positions R9 through R18 near the LED locations and R20 below the chip. Install 47K at R21.
If the kit includes the 18pin IC socket, note the orientation on the PC board. Install the socket and the 9V snap. Note the large pads on the left of the PC card. The lower one should be marked +9 for the red lead and black goes to GND.
Install the ten LEDs. Note the orientation, the negative lead (short-flat side) matches the indication on the PC card.



Step 3 - Pre-test the Voltmeter section

Connect the battery and use a voltmeter to verify +9V on pin 3, and ground on pins 2, 4, and 8. If all is OK, disconnect battery and install U4 - the LM 3914 IC - Note polarity, notch goes to the Left with LEDs at the top of the board.

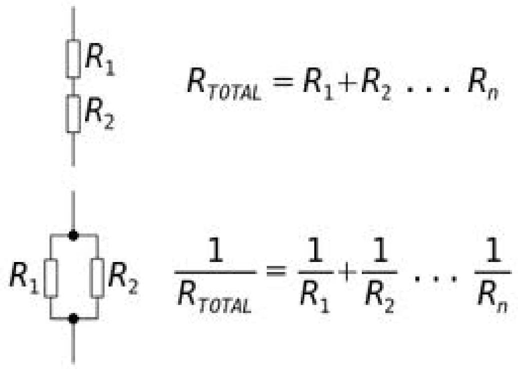
Step 4 - Calculate multiplier resistors

A multiplier resistor is a resistor that "multiplies" the base voltage of a meter. This is true for basic panel meters that you buy or even a commercial voltmeter with multiple ranges. For this kit the LM3914 chip in this configuration can accept 0 to 1.3V DC on its input pin 5. So with no multiplier resistor you could only measure voltages of 0 to 1.3V! If you put a resistor in series with that pin, you can then "multiply" the range of the meter to pretty much whatever you want. For practical reasons we will keep the ranges below 20V, but once you know how to do this you can design a range for anything you want, just be really careful if you decide to exceed about 50V!

Here is the calculation method.
1 Find the maximum voltage of the meter by itself -- in our case 1.3V
2 Find the current the meter requires at this Voltage -- in our case 27.7 uA (0.0000277A)
3 Decide the max voltage you want a given Range to have -- lets do 10V
4 Subtract the meter voltage from the desired range voltage -- 10 - 1.3 = 8.7V
5 Get multiplier resistance by dividing result by meter current -- 8.7 / 27.7uA = 314,079 ohms
6 Find the closest standard value above this value -- 330K ohms
7 This will give you a functional meter, but not too accurate. Next step will show you how to get accurate values without ordering precision resistors!

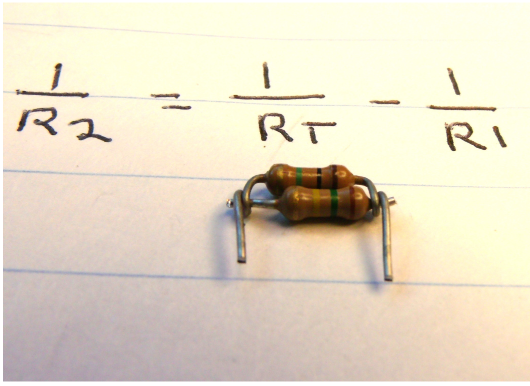
Step 5 - Create precision resistors

To get a more precise value from the result in the previous step, you can combine standard values of individual resistors together in series or parallel. (See diagram) The picture and formula for series looks the easiest, and some times will be. You could add a 300K and a 15K to get 315K which will be about 3% over, and will work. However parallel resistors will fit in the space better and you can piggy back them to ones already installed if need be. Also you can often get more precision with two resistors in parallel than with two series values. When doing so you must start with a value ABOVE the RT that you need! The closest standard value above our target value of 314079 ohms is 330K. So plug 330K (330000) into the formula as R1, (one of the two parallel needed) and 314079, our target value, as the total, RT. Solve for R2.
Hint:
The formula can be rewritten --- 1/R2 = 1/RT - 1/R1 or R2 = 1 / (1/RT - 1/R1)
Your solution should come out to 6.51M approx. (6,510,000)
You might note that the result is not a standard value either, no worries, just pick the standard value closest to it either above or below, which in this case is 6.8M. Wire the 6.8M in parallel to the 330K to get the new precision resistor for RT. You may notice that since we didn't use the exact value calculated for R2, that we will not get exactly the RT we need. No problem! If you were to solve the original formula for 6.8M parallel 330K you will find the result within about 2% of the needed RT! This will be a typical kind of result that can usually be achieved with just two parallel resistors. That's why it is the recommended method for this project, but any method you use to get a reasonably accurate RT is OK.



Step 6 - Install 10V range resistor

Locate the 330K (ORN / ORN / YEL) and the 6.8M (BLU / GRY / GRN). Wrap the wires from one resistor around the other one right at the resistor body. (See picture). Solder both ends and clip the excess leads. Then install and solder to the PC in the 10V position (R23).
At this time install a test pin at the M-GND location. The kit includes an 8 pin header which you will cut into 4 individual pins an one pair of pins for J1 (2 extras). Cut apart with diagonal cutters while holding the pin to be cut against a soft cloth on the bench to avoid losing it. The pins make a connecting point at which to clip a small alligator clip to select the voltage input to be used. Do the same for the larger pads at the 5V, 10V and 20V locations (R22, R23 & R24). Solder these in place and also Solder in J1 at this time. Locate two pair of alligator clips and solder one pair to about 1' (or longer) of black stranded wire as a ground lead, and solder the other pair to about 1' of Red stranded wire. (22 - 24 AWG) These will be the Meter Leads for + and ground (or common).



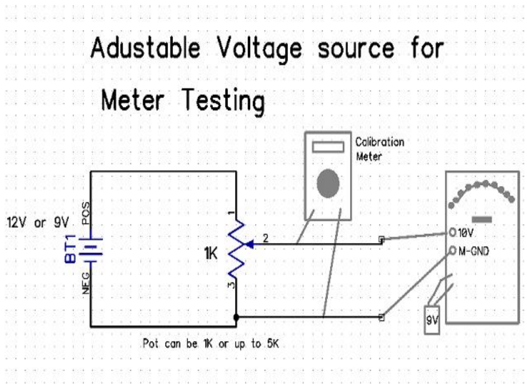
Step 7 - Voltmeter section test

Now is time to make sure your voltmeter works correctly and is accurate. You will need to power the voltmeter with a 9V battery, and use a variable power supply to note if the LED display matches the voltage under test. If you do not have a power supply and meter to monitor the input voltage as a "calibration standard", you can easily create one by connecting the two outer leads of a 1K (or up to 5K) potentiometer across a 9V or 12 V power source such as a battery or fixed supply. The center lead and the negative battery lead will then provide the "adjustable calibration source" for you. Again, you will need a "test meter" so you can verify if the voltmeter section of your project is reading correctly.

Slowly adjust the calibration standard upward and stop when an LED lights up. Note if the LED lit corresponds with the applied voltage as measured by your test meter. On the 10 Volt range, each LED corresponds to a 1 Volt change as indicated by the larger scale markings on the board. Depending on test voltage available to you, try to test each LED up to 10V. If all is working correctly then congratulations, you have successfully built the Voltmeter section. If you are having troubles, consider the following.

Trouble shooting voltmeter:
Remove all power, check all solder joints, Chip and LED orientation. Make sure the resistors for this section are installed in correct

locations and are correct value.
If your readings are "off calibration" check R23 parallel combination for accuracy, and measure with an ohmmeter. It is not unusual for the first LED position (1V on 10V range) to be off a bit.



Step 8 - Adding more ranges

Using methods described in steps 4 & 5, calculate Range resistors for any two ranges you would like to add to your meter. The smaller numbers above the 1-10V scale are for a 5V range and a 20V range, but you could change these numbers or have them represent what you would like. For example if you need a 50V range you can use the 1-5 markings to indicate the LED's for 10 - 50V readings. Each LED would indicate a 5V increment with the highest LED indicating 50V.
Assembly:
Assuming you want the 5V and 20V ranges proceed as follows. For the 5V range resistor (R22) locate the 150K (BRN / GRN / YEL) and the 1.2M (BRN / RED / GRN) resistors and assemble in a parallel combination. Install this combination in R22.
For the 20V range locate the 680K (BLU / GRY / YEL) resistor, this one is close enough without a parallel value. Install in location R24.
Test in a similar fashion as in the previous step. Note that for the 5V range each LED will indicate a 0.5V increment and for the 20 V range each LED will indicate a 2V increment.

This completes the Voltmeter section construction and testing.

Step 9 - 5V power supply

The 5V power supply uses a 78L05 regulator and filter caps to convert the 9V from the battery to 5V for the ISD1110 and the CD4011 circuits.
Assembly:
Locate C1 & C2 0.1uF monolithic caps. Likely will be marked 104. Locate C9 220uF Radial Electrolytic. Locate U3 78L05 Voltage regulator. Solder these components as indicated by the board silkscreen layout. Observe polarity for Electrolytic Cap and U3!
Testing:
Connect 9V battery and test for 5V at U1 pin 28, U2 pin 14. Yes you can use the voltmeter section of this project to test these points! Or use a separate voltmeter if preferred.

Step 10 - Clock circuit

Theory:
The clock circuit provides a pulse to the voice recorder chip to tell it when to speak. As designed the clock will trigger the speech at about once per second. This can be slowed down by increasing R8 or C8. U2 is a 4011 quad NAND gate with two of the gates wired in a common oscillator configuration which will normally produce a roughly 50% duty cycle square wave. In this circuit R29 and D34 have been added to shorten the OFF pulse length to increase the duty cycle to about 90%. This results in frequency of approximately $f = 1/(R*C)$ The narrow negative (OFF) pulse is important to trigger the ISD1110 in a manner that the trigger pulse ends well before the end of the recorded speech.
Assembly:
Locate 14 pin Chip socket and U2 CD4011, C8 22uF Electrolytic, R8 47K (YEL / VIO / ORN), R29 1K (BRN / BLK / RED) D34 1N4148, and J1 2 pin header. Note polarities for socket, chip, C8 and diode. Also note that D34 and R29 are vertically mounted (Standing on end). Solder and install chip.

Testing: Connect battery and test for a pulse at pin closest to C8. You can use the meter section for the test. It should remain high for about a second, then drop low for about a tenth of a second and do this repeatedly. If it does not, remove power check all component values, locations, soldering, polarities, and make sure no chip pins got bent plugging into the socket.

Step 11 - Digital address encoder

Theory:
The voice chip will have its memory divided into ten locations, each of which stores the recorded audio then plays back when the corresponding voltage is reached. The voltmeter that you built produces an output known as " active low - one of ten" meaning that at any given voltage within its range, one of ten possible outputs will be pulled low. The voice chip on the other hand will need an active high binary address using four input lines weighted (or value of) 1,2,4, & 8. For example to say "One" or the word in the first locations, line 1 needs to be high while 2,4,8 are pulled low. Or to say "Five" or the word in the fifth location line 1 and 4 (1+4=5) need to be high while the 2 and 8 are pulled low.
A diode encoder is used to do this and is made up of diodes D11 - D33. For each of the ten outputs from the voltmeter section, a group of diodes is activated when that output occurs. So when LED 1 (1 volt) lights, the corresponding 3914 line is LOW, and D11, 12, 13 "see" this low and pull the 2,4,8 lines low so the chip is being addressed at location 1. If you study the PC card and diodes you should be able to discern how each of the addresses are achieved. When a diode is not actively pulling a line low, there needs to be some way to make sure the line is high, and that is the job of the 22K resistors R25 - R28.

Assembly:
Locate R25 - 28 22K resistors (RED / RED / ORN), locate 23 1N4148 diodes D11 - D33. Note polarity of diodes (all bands toward top of board) solder diodes ad resistors inspect.

Testing:
You will need a separate meter, (or logic probe), and adjustable power source for this test. Connect power to your meter, attach test voltage to 10V range. For each LED output you will test the value at the LEFT end of R25, 26, 27 & 28, where R25 is the "1" line, R26 the "2" line, R27 the "4" line and R28 the "8" line. The locations that indicate high should be added together by their "values" and the result should match the LED lit. For example when testing 7 (LED 7 Lit), the 1, 2, & 4 lines should be high and the R28 "8" line should be low. (7= 1+2+4) A table has been provided to help.
If you have a problem check the lines with no LEDs lit, all should be high, if not check the 5V supply and connections to R25 - 28. If an individual value is not correct, check the soldering and orientation of the diodes in its group.

Digital Encoder Output Table

The listed values are the expected outputs as read by a meter or logic probe on the left end of R25, 26, 27, & 28. A High should be about 5V and a Low should be less than 2V.

LED ON	R25 (1)	R26 (2)	R27 (4)	R28 (8)
1	High	Low	Low	Low
2	Low	High	Low	Low
3	High	High	Low	Low
4	Low	Low	High	Low
5	High	Low	High	Low
6	Low	High	High	Low
7	High	High	High	Low
8	Low	Low	Low	High
9	High	Low	Low	High
10	Low	High	Low	High

Step 12 - Voice recorder IC theory and operation

Theory:
The ISD1110P is a voice recorder that can record up to 10 seconds of audio. I know, doesn't sound like much but it is perfect for this application. Since we have a one of ten voltmeter output, each output through the address encoder can select one of ten internal locations in the voice chip. Each of these locations can therefore hold 1 second of sound. Enough to record a digit such as "Seven", or alternately other information such as "Warning". If you are quick, you can even record a very short phrase such as "Voltage High". Once recorded, the chip will store the recording for up to 100 years, so it might even be useful for your grandchildren. You can also change the recording as you choose, so no need to feel locked into one application.
Recording is initiated by removing the shorting jumper on J1, and then pressing SW1. This pulls the REC input low.
To fill the ten locations you will adjust an input voltage to the meter to get the LED lit, then record that value, adjust the input voltage until the next LED that you want recorded is lit, then record that value and so on. It is not necessary to record every location, depending on your application. It is important that you release SW1 before one second, otherwise you will automatically go into the next recording position. It takes a bit of practice to get it right, so if you accidentally erase another number just do it over.
When recording is completed, the jumper at J1 is reconnected to put the chip in playback mode and it is then ready for use. The clock circuit will initiate the playback, not the LED lighting up, keep this in mind when the input voltage changes quickly. Values continuously changing more quickly than once per second are not appropriate for this type of meter. The clock can be slowed down

as desired, but cannot be sped up beyond the output time of the recorded message.
The ISD1110P is designed to drive a 16 ohm speaker directly. If you use a lower impedance speaker, you should use resistance at R19 to compensate. The most common would be to use a 10 ohm resistor to allow use of an 8 ohm speaker. For most uses this will be loud enough, but remember, nothing prevents you from using an external amplifier if the measurement needs to be heard in noisy locations.
This circuit uses an on board electret condenser microphone. R4 supplies the voltage that these mics need to function.

Step 13 - Assembly: Voice recorder circuitry

Locate the chip socket. Note polarity and install.
Locate R1 470K (YEL / VIO / YEL), R2 1K (BRN / BLK / RED) R3- R7 10K (BRN / BLK / ORN) and R30 4.7K (YEL / VIO / RED). Install as shown on PC card. With 16 ohm speaker is supplied, install jumper at location R19, otherwise for an 8 ohm speaker install a resistor - 10ohm (BRN / BLK / BLK) - not included.
Locate 0.1uf Caps C3, C4, C5 and install. Locate C6 4.7uF Electrolytic and C7 220uF Electrolytic, note polarity and install. Locate the Mic - the leads should be offset from the center so there is only one correct, obvious way to install it. If you are not sure, use an ohmmeter to see which lead is shorted to the mic case - this will be the negative lead and goes into the hole nearest R2.
Locate the ISD1110P - note polarity and install in chip socket. Install SW1, it will require you to press firmly to snap into board, note that the lead spacing is wider in one direction as are the holes in the PC board!
Locate the speaker and install at the locations labled SPK. It is a good idea to put a dab of hot glue over the leads as a strain relief.

Testing:
Remove J1 shorting jumper - attach battery, and use adjustable power supply on 10V range. Adjust supply to light up an LED, then press the record button while speaking the number for that LED. Its best to try a couple, then put the jumper back on and adjust the voltage to see if each voice output corresponds to the LED lit as you intended. When satisfied, complete the process.

If not working, check all components in the audio section for value, location, polarity, and soldering. Make sure the chip is correct and there are no bent pins. If solder bridges have been made, remove them with a bit of flux and solder wick.

Step 14 - Extras

Extended applications:

There are many uses of the Talking Voltmeter beyond just measuring voltages on three ranges. The first thing to note is that any physical quantity that can be converted to a varying voltage can be displayed with audio on this meter. To do this all you really need to know is what is the range of voltage from minimum to maximum that you need to measure, and what do the voltages represent. For example lets say you want a talking anemometer for measuring wind speed. Find a little DC motor, attach a toy propeller, and hook it up to the meter. Using a known wind speed, note the voltage produced until you have decided the maximum and minimum values. Now using step 4 methods you can make a "wind speed" range by calculating an appropriate multiplier resistor. You will then decide what the ten LEDs will represent, such as 2 mph per LED, or whatever works out. (The voltage may not be linear with wind speed, so the first LED might represent 1, the second 3, the third 6 and so on with no linear pattern. That is fine, just use known wind speeds to determine the value each LED will represent). Once this is done and working to your satisfaction, you can record the audio, and then you have a talking anemometer!
Other things you could measure could be temperature, air pressure, altitude, light intensity, weight and so on. Any variable resistance transducer can have a voltage applied to it so that the output becomes a variable voltage. Although this meter would not be considered a precision instrument, you can have a lot of fun and get some accurate results if you understand the meters capabilities and limitations.

Warning System:
Perhaps you have some parameter that you do not need to constantly monitor, but would like an audible warning when it occurs. First, do not record audio for any of the LED positions below the alert value. Then at and above the alert value you record appropriate warning statements. In this manner, you will be alerted when the danger condition occurs. Remember, you can redo any Range resistor to a value of your choice, and each LED can indicate values appropriate for your choice of range multiplier resistor. So if you need the range to be 0 - 37.5 volts, just do the math!

AC Voltage Ranges:
If you would like the meter to measure AC voltages you first need to convert them to DC with a rectifier. A single diode can be used, but to be DC you must use a small capacitor to ground to smooth out the pulses. This will be somewhat frequency dependent, but for 60Hz measurements you could try about 0.5 to 1uf. If the cap is too large, the meter will not react quickly to changing voltages. If too small, the value read may be incorrect due to meter loading of the capacitor.

Measuring Amperage:
In the original classroom application for this meter project Amp ranges were included, and the goal was to have students create Amp Range resistors from enameled wire. This method can produce precise results, but is harder to fathom without the advantage of either some previous experience or the classroom setting. But for those who wish to try it, here is a brief explanation.
First, an amp range resistor is called a "shunt" and is in parallel with the raw input of the meter. The raw meter input is the circuit trace that connects the right side of R22, 23,& 24. The shunt resistor that you design would connect from this location to ground, and

the current under test would be applied through this resistor. Another thing you must understand before undertaking this effort is that the meter itself must be IN SERIES with the circuit under test, which normally means that the item to be tested needs to have one end CUT from the circuit, and the ammeter connected to the two open "wires" produced by this cut. If this does not make sense, do not proceed until you can get it figured out, otherwise any further effort will likely destroy your meter, or the circuit you are trying to test or both!
Calculating Shunt Resistors.
From step 4 we know that our meter needs 1.3V and 27.7uA to read full scale. Lets say you want to make a 1A current range. That means the parallel shunt resistor Rs must carry the rest of the 1A and will also be at 1.3V when doing so.
Rs = 1.3V/ (1A-27.7uA) = 1.3 ohms (approx)
Calculate power for shunt Ps.
Ps = (1A-27.7uA) *1.3V = 1.3W

So you need a 1.3 ohm 1.3W power resistor for this job. You can create one from individual resistors, buy a precision resistor, or find an AWG enameled wire chart and look up the feet/ohm and find out how many feet of a given wire guage you would need to get this resistance. Usually try to shoot for 2 to 6 feet, because the result will be reasonably accurate, and the wire length easy to work with. You can coil wrap the wire around a large value 1/2 or 1 Watt resistor, that is 1K or larger, as a coil form soldering the enameled wire to its leads. Be sure to strip the ends of the enamel off before soldering. The parallel combination will have little effect on the total, and is easier to install than a glob of wire.

This meter was designed as a learning project with practical applications, so I hope you try lots of ideas, and have fun while you learn some new things.

Step 15 - Packaging

The PC board is made with a hole at each corner for a 4-40 X 1" screw and nut. These will provide a "stand" to keep the bare circuitry up and away from conductive surfaces. If you cut a piece of cardboard the same size as the PC board with holes in the corners it can be sandwiched against the bottom of the board with the screws and nuts. This also makes an ideal place to mount the speaker and battery. It is probably easiest to mount the speaker by putting it flat against the cardboard and dabbing some hot glue around the rim. Don't worry, the sound will still come out, and this method allows the wires to be easily accessed for future work. The battery can be attached using a couple of small holes in the cardboard with a rubber band through them to hold the battery.

If you want a more finished project Jameco also sells some plastic boxes that would be fine for mounting the whole project such as Jameco Part # 18893.

Talking Voltmeter Errata

1. **Microphone** The 320179 microphone has the positive and negative leads reversed.

   Bend leads as shown in photo, **OR** replace with Jameco Part no. 136574

2. **Cap C8** C8 board marking for polarity is reversed on PC Board Version 2.1

   Install C8 opposite board marking on board Version 2.1

3. **LED 1 Audio** Audio for LED 1 is not stable on PC Board Version 2.1

   Add cap C10 – 0.1uF monolithic across pins 1 & 2 of U4 – see photo.