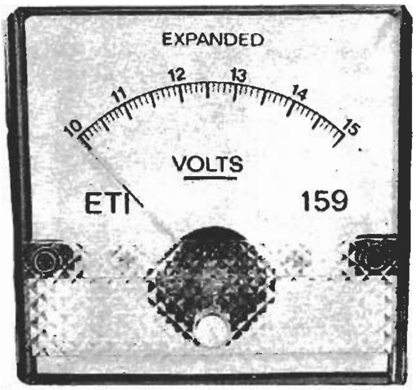
Expanded Scale Voltmeter Covering The 10-15 V Range

PROJECT

A simple, low-cost instrument that can be built into power supplies or used as a portable or fixed 'battery condition' monitoring meter.



COMMON STORAGE batteries to power nominal 12 V DC electrical systems have a terminal voltage that ranges from a little over 10 volts when discharged to around 15 volts when fully charged, the operating voltage being somewhere in the range 11.5 V to 13.8 V. Lead-acid batteries, for example, may have a terminal voltage under rated discharge that commences at around 14.2 V and drops to about 11.8 V. A 12 V (nominal) nickel-cadmium battery may typically have a terminal voltage under rated discharge that starts at 13 volts, dropping to 11 volts when discharged.

Equipment designed to operate from a nominal 12 V DC supply may only deliver its specified performance at a supply voltage of 13.8 V — mobile CB and amateur transceivers being a case in point. Other DC operated equipment may perform properly at 12.5 V but 'complain' when the supply reaches 14.5 V.

To monitor the state of charge/discharge of a battery, a battery-operated system or the output of power supplies, chargers, etc., a voltmeter which can be easily read to 100 mV over the range of interest, i.e., 10 to 15 volts, is an invaluable asset. This project does just that.

This instrument, being of the true analogue type, is intended for exacting measurement and is better characterized as a test instrument.

The Circuit

An LM723 variable voltage regulator IC is employed to set an accurate 'offset' voltage of 5 V, and the meter (M1) plus the trimpot RV2 and R3 make up a 5 V meter, with the trimpot allowing calibration. The negative terminal of the meter is connected to the output of the 723 so that it is always held at 5 V 'above' the circuit negative line. The positive end of the meter goes to a zener which will not conduct until more than 5 V appears between the circuit +ve and -ve lines. Thus the meter will not have forward current flowing through it until the voltage between the circuit +ve and -ve rails is greater than 10 V, and will read full scale when it reaches 15 V (after RV2 is set correctly).

The meter scale limits may be adjusted by setting the output of the 723 higher or lower (adjusted by RV1) and setting RV2 so that the meter has an increased or decreased full-scale deflection range.

A variety of meter makes and sizes may be used.

HOW IT WORKS

The meter, M1, is a 1 mA meter with series resistance — made up of R3 and RV2 — so that it becomes a 0-5 V voltmeter. The negative end of the meter is maintained at 5 V above the circuit negative line by the output of IC1, a 723 adjustable regulator. The positive end of the meter is connected to the circuit positive line via ZD1, a 4V7 zener diode. Thus, no 'forward' current will flow in the meter until the voltage between the circuit negative line and the circuit positive line is greater than 5 + 4.7 = 9.7 volts.

Bias current for the zener is provided by a FET, Q1, connected as a constant current source so that the zener current is accurately maintained over the range of circuit input voltage. This ensures the zener voltage remains essentially constant so that meter reading accuracy is maintained.

The trimpot RV1 sets the output voltage of the 723. This determines the lower scale voltage. Trimpot RV2 sets the meter scale range. More resistance increases the scale range, less resistance decreases it.

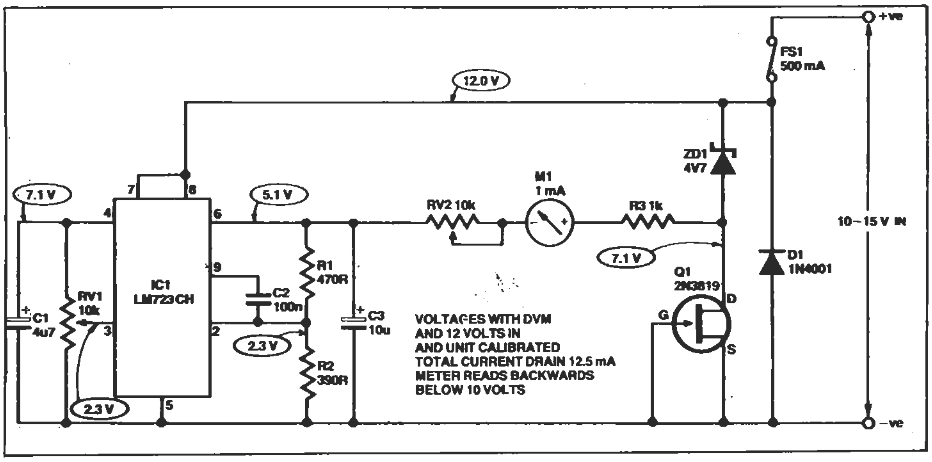
Diode D1 protects the circuit against damage from reverse connection.

Construction

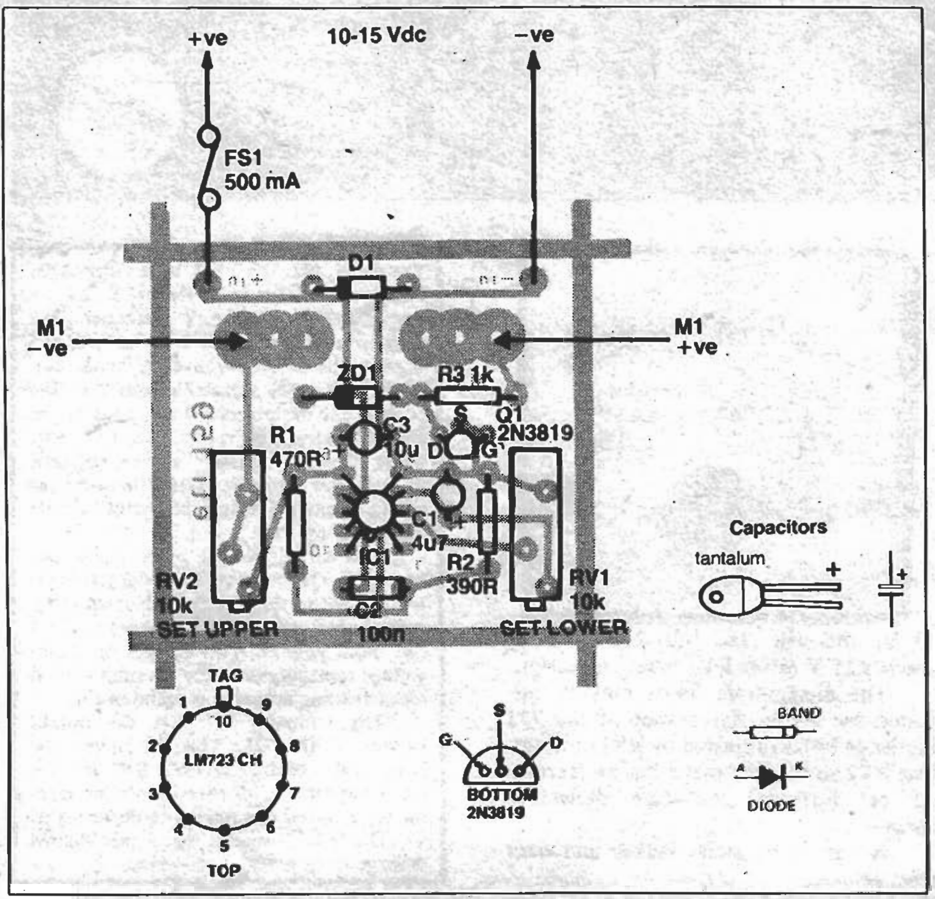
Mechanical construction of this project has been arranged so that the pc board can be accommodated on the rear of any of the commonly available moving coil meter movements. We chose a meter with a 55 mm wide scale (overall panel width, 82 mm). A meter movement with a large scale is an advantage as it is considerably easier, and more accurate, to read than meters with a smaller scale. It also pays to buy a 2% fsd accuracy meter for best accuracy.

Having chosen your meter, drill out the pc board to suit the meter terminal spacing first. The components may then be assembled to the board in any particular order that suites you. Watch the orientation of the 723, ZD1, the FET and particularly D1. The latter is an 'idiot diode'. That is, if you have a lapse of concentration or forethought and connect your project backwards across a battery, the fuse will blow and not the project. Fuses are generally found to be cheaper than this project!

Seat all the components right down on the pc board as the board may be positioned on the rear of the meter with the



VOLTAGES WITH DVM
AND 12 VOLTS IN
AND UNIT CALIBRATED
TOTAL CURRENT DRAIN 12.5 mA
METER READS BACKWARDS
BELOW 10 VOLTS



components facing the meter. The size of C2 may give you a little trouble. We used a 'Monobloc' type capacitor — as commonly used on computer pc boards as bypasses. Alternatively, a 100n tantalum capacitor (+ve to pin 2 of IC1) may be used. The actual value or type of capacitor is not all that critical.

We have used multiturn trimpots for RV1 and RV2 as they make the setting up a whole lot easier.

PARTS LIST

Resistors (All ½W 1% or 2% metal film)

R1	470R
R2	390R
R3	1k
RV1,RV2	10k cermet multiturn horizontal trimpot

Capacitors

C1	4u7/10 V tant.
C2	100n ceramic
C3	10u/10 V tant.

Semiconductors

IC1	LM723CH
ZD1	4V7, 400 mW or 1W zener
Q1	2N3819
D1	1N4002 or similar

Miscellaneous

M1	1 mA meter (see text)
FS1	500 mA fuse and in-line fuse holder

pc board; meterscale to suit meter.

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Battery Condition and Terminal Voltage

The 12 V battery, in its many forms, is a pretty well universal source of mobile or portable electric power. There are lead-acid wet cell types, lead-acid gel electrolyte (sealed) types, sealed and vented nickel cadmium types, and so on. They are to be found in cars, trucks, tractors, portable lighting plants, receivers, transceivers, aircraft, electric fences and microwave relay stations — to name but a few areas.

No matter what the application, the occasion arises when you need to reliably determine the battery's condition — its state of charge, or discharge. With wet cell lead-acid types, the specific gravity of the electrolyte is one reliable indicator. However, it gets a bit confusing as the recommended electrolyte can have a different SG depending on the intended use. For example, a low duty lead-acid battery intended for lighting applications may have a recommended electrolyte SG of 1.210, while a heavy-duty truck or tractor battery may have a recommended electrolyte SG of 1.275. Car batteries generally have a recommended SG of 1.260. That's all very well for common wet cell batteries, but measuring the electrolyte SG of sealed lead-acid or nickel-cadmium batteries is out of the question.

With NiCads, the electrolyte doesn't change during charge or discharge.

Fortunately, the terminal voltage is a good indicator of the state of charge or discharge. In general, the terminal voltage of a battery will be at a defined minimum when discharged (generally between 10 and 11 volts), and rise to a defined maximum when fully charged (generally around 15 volts). Under load, the terminal voltage will vary between these limits, depending on the battery's condition.

Hence a voltmeter having a scale 'spread' to read between these two extremes is a very good and useful indicator of battery condition. It's a lot less messy and more convenient than wielding a hydrometer to measure specific gravity of the electrolyte!

The charge and discharge characteristics of typical lead-acid and sealed NiCad batteries are given in the accompanying figures.

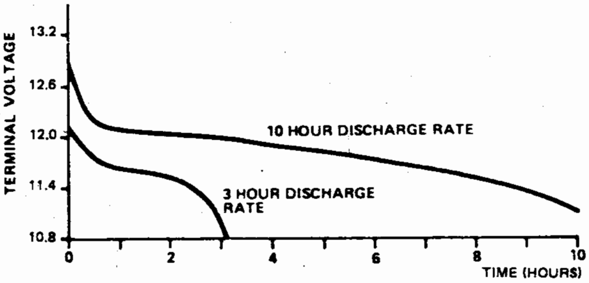


Fig. 1. Typical discharge characteristics of a 12 V (nominal) lead-acid battery.

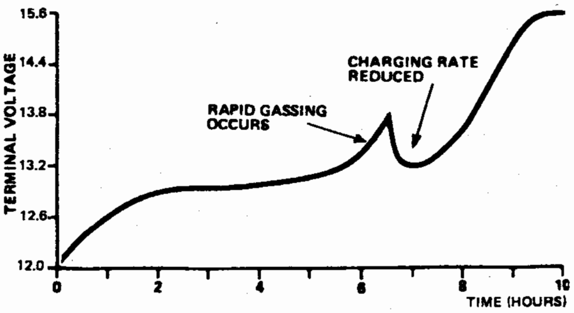


Fig. 2. Charging characteristics of a 12 V (nom.) lead-acid battery. The 'kink' in the curve near 6 hrs is explained in the text.

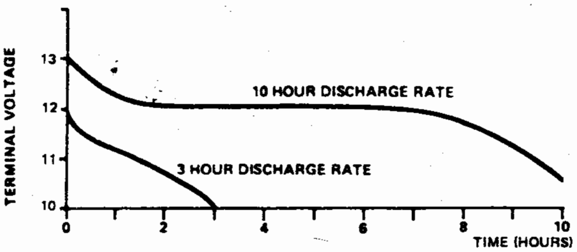


Fig. 3. Typical discharge characteristics of a 12 V (nom.) nickel-cadmium battery (usually consisting of 10 cells in series).

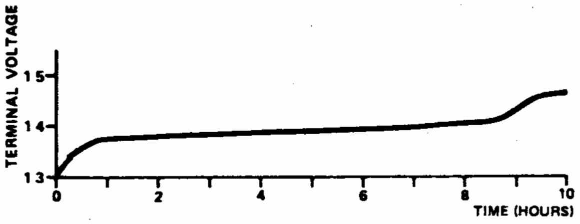


Fig. 4. Typical charging characteristics of a 12 V NiCad battery (10 cells) charged with a constant current at one-tenth rated capacity (0.1C).

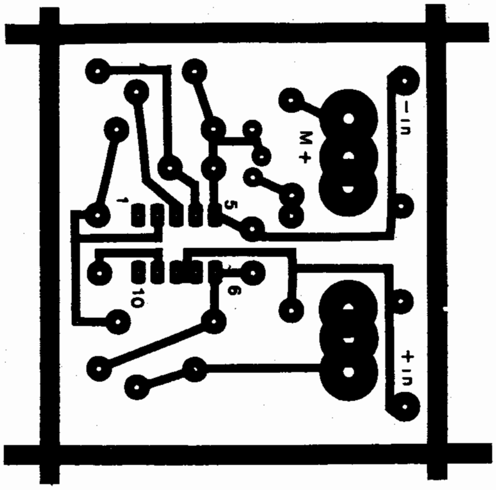
Note that the fuse (to protect the project) is inserted in an in-line holder in the external connecting leads.

Calibration

For this you will need a variable power supply covering 10 to 15 volts and a digital multimeter (borrow one for the occasion).

First set the 10 V point. Connect the digital multimeter across the power supply output and adjust the power supply to obtain 10.00 volts. Set the mechanical zero on the meter movement to zero the meter's pointer. Connect the unit to the power supply output and adjust RV1 to zero the meter needle.

Next, set the power supply to obtain 15.00 V. Now adjust RV2 so that the meter needle sits on 15 V (full scale). Check the meter reading with the power supply output set at various voltages across the range. We were able to obtain readings across the full scale within ± half a scale reading (± 50 mV). With a 2% meter, the worst error may be about ± one scale division.



When set up, our unit drew 12.5 mA maximum current drain, which is probably typical, but current drain may be around 20 mA or so maximum. Note that, when the input voltage is below 10 V, the meter needle will move in the reverse direction.

ETI

Voltage-regulator IC biases expanded scale meter

by Alan D. Wilcox
University of Virginia, Charlottesville, Va.

To monitor the state of charge of a standby storage-battery system, only voltages between 12 and 15 volts need to be read. A conventional test meter reading 0 to 15 V full scale will suffice, but readings can more easily be observed when the voltmeter has an expanded scale that reads from a minimum of 10 V to a maximum of 15 V.

One such expanded-scale circuit is shown in the figure. The battery provides a 10-V bias to the meter so that when a voltage source of 10 to 15 V is applied to the combination, the meter shows the difference of 0 to 5 V. But this arrangement is unsatisfactory, both because it must have a battery for operation and because its accuracy depends on the battery having a potential of exactly 10 V.

There is a better way. Since the voltage to be monitored will be above 12 V, a National Semiconductor LM723 voltage regulator can be used as shown in the figure to provide a stable 10-V bias. A 500-microampere meter and series resistor R_2 constitute the 0-to-5-V voltmeter. If the battery voltage should drop below about 11.7 V, regulation falls off, but this inaccuracy can be corrected by using a 1.5-V dry cell if readings below 12 V are necessary. The dry cell does not affect the accuracy of the meter calibration—it simply extends the reading range down to about 10.2 V.

The unit draws about 3 milliamperes and can be used continuously across the storage-battery system. The entire circuit can be constructed on a small circuit board and mounted on the terminal posts of the 500-μA meter.

The circuit is calibrated by applying 15 V to the input and adjusting R_1 for 10 V at the output of the 723. Then, R_2 is set for a full-scale reading on the meter. For the 500-μA meter, 200 μA corresponds to 12 V, 300 μA to 13 V, etc. Normal battery voltage reads near center scale, and small deviations can be seen at a glance.

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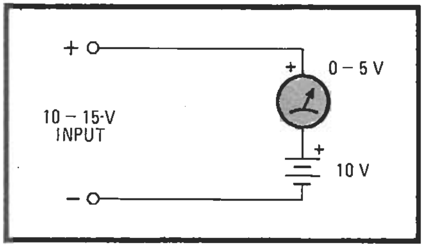

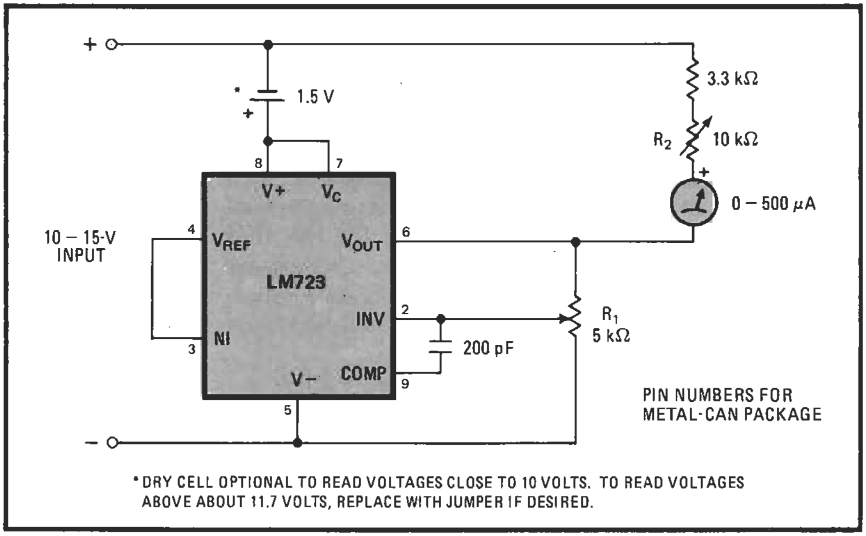

The right idea. This circuit displays very precise readings of 0 for 10-v input, 100 for 11-v input, and so on up to 500 for 15-v input. Adjustment of R_1 and R_2 calibrates it accurately. Circuit shown in inset also displays voltage in the 10–15-v range but requires a battery of exactly 10 v for accurate reading. Note that the 1.5-v dry cell used in the main circuit does not affect its calibration and is not necessary for readings above 11.7 v.