Behind the Portable Power Sources

Part II

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Hermetically sealed lead-acid batteries are unquestionably superior in applications like portable TV sets, video-audio cassette recorders and professional cameras. At a moderate current level, their size specification is much better than the dry cell versions. These can be easily and repeatedly recharged to a specific full charge level. Another added advantage is their ability to retain charge for long quiescent periods without any over-charging problems. They can remain in an overcharged state for weeks together without changing their basic features.

TABLE V
Typical Operating Conditions of Commonly Used Instruments

Device	Internal resistance (ohms)	Usage hrs/day	Volume/Power Density	Cutoff Voltage	Service Life wrt NICd (hours) first	second
Pacemakers	2000	24	7×10^{-3}	0.9		
Watches	1800	24	8×10^{-2}	0.8	–	–
Hearing aids	300	12	5	0.9	275	250
Mini receivers	75	4	0.5	0.9	66	60
Medium receivers	39	4	8	0.9	42	28
Tape recorders	10	1	3	1.0	4.5	3.9
Cassette players	6.8	1	20	1.0	3.5	2.9
Calculator LEDs	15	0.5	6	0.9	14	12
Calculator LEDs Programmable	5.6	1	20	1.0	2.5	1.8
Portable lighting	5	5 min	25	1.0	4.4	3.8
Toys	3.9	1	40	1.0	3.2	2.9
Portable TVs	3.3	2	60	1.0	1.8	1.2
Movie cameras	2.8	1	65	1.0	0.7	0.5

Though the process of charging is usually simple and straightforward, in the case of lead-acid cells it is advisable to follow some guidelines to ensure a long life. For a fully discharged lead-acid cell, it is ideal to charge it at 0.1C up to 60 per cent of its voltage and then increase to 0.25C till it reaches 120 per cent of its voltage level. Further, the charging rate is reduced to below 0.01C until the voltage reaches the maximum possible level. For a 12-volt pack, the first phase of charging ends at around 10 volts, the second phase around 14 volts, with the final phase converging at 16.5 volts.

Self-regulating chargers are extremely useful in lead-acid batteries especially where prolonged voltage or charge levels of the cells may not be possible. One of the popular circuits used is as shown in Fig. 8. As soon as the system is activated, SCR S1 will jump into a state of conduction thus commencing the process of charging with an appreciably high current. The battery combination can either be of three cells giving 6 volts or six cells giving 12 volts. Diode D1 conducts for each half of the input voltage, supplying more charge current to the batteries. As the potential increases, the diode combination D2 conducts, instantly putting off SCR S1. This action will be repeated whenever the battery voltage falls below the threshold value. The rest of the time, there is an effective

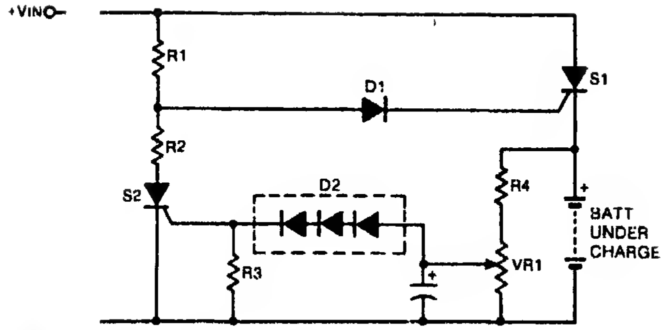


Fig. 8: Lead-acid battery charger.

trickle charging effect by which the cells can always be ready for use.

Multifunction devices

Devices nowadays are loaded with a host of functions and incredible versatility. It is axiomatic that more the functions of the device, more exasperating is the circuit and its powering methods. Portable light-weight devices often warrant regulated or unregulated negative power supplies along with the usual positive supplies. Extra batteries will naturally increase the weight.

One of the basic approaches to derive negative supply from the existing positive supply is demonstrated in Fig. 9. It makes use of an oscillator of a convenient duty cycle and frequency. Its output is rectified and filtered, and if necessary regulated to a convenient voltage level. A certain amount of loss is expected in this manoeuvre. The circuit shown in Fig. 9 uses 50 per cent duty cycle at a frequency of around 7kHz. This can provide a negative supply up to 10 mA without much change in the output voltage.

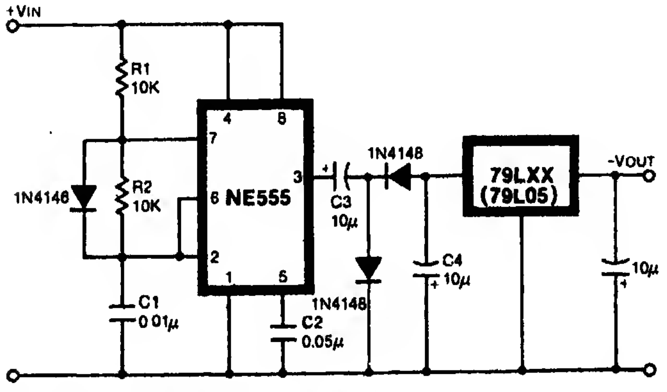


Fig. 9: DC-DC negative converter.

A more economical solution to the problem of powering op-amps from a low voltage/capacity battery is the use of DC-DC converters. As a rule, op-amps consume small amounts of current. If the current drain from any power supply is very low and if the time constant of the filter network is sufficiently large, only a small ripple will be present in the output of the supply. A complete bipolar supply regulated at both ends and derived from a small battery of very low capacity and size is shown in Fig. 10. The approach here is similar to that of the circuit in Fig. 9, with a combination of positive supply. The timer is made to oscillate at around 10 kHz with a duty cycle of about 75 per cent. The transistor is switched at this rate, producing negative as well as positive pulses at the secondary of the transformer and the collector of the transistor. These are rectified, filtered and then regulated. The suoply shows a very high stability at low currents.

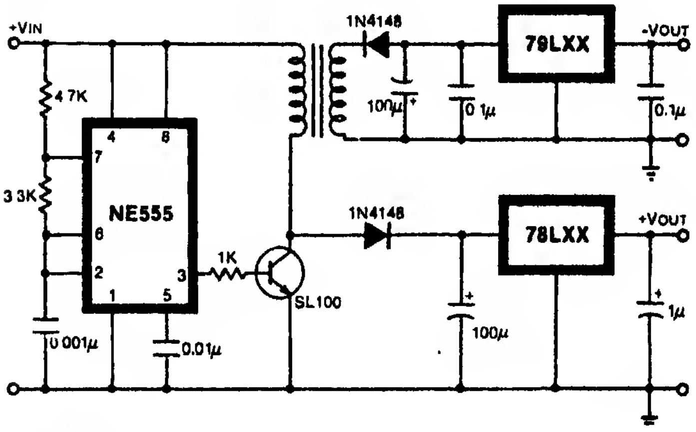


Fig. 10: DC-DC dual converter.

Fourier analysis of the waveform generated by converters reveals the presence of significantly high-order harmonic components. These harmonics can be troublesome to the high-gain op-amps used in critical stages as well as a source of radio-frequency interference to AM or FM tuners. A convenient switching rate has to be selected in such a way that the harmonics will not directly interfere with the normal operation of the device and can be notch-filtered if they arise to a menacing level at any stage of the supply.

Batteries for portable photographic devices

The electrical or electronic support to the realm of photography started sometime in 1844 with the advent of arc lamp projection microscope by Foucoult. Fox-Talbot wizardry in spark photography reported in 1851, appraised the beneficial applications of electricity in photography. By 1893, electrical ignition of flash powder helped expanding under-

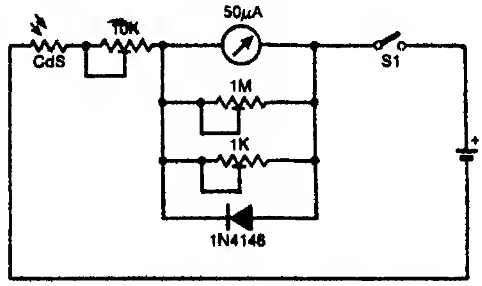


Fig. 11: Typical light intensity meter in camera.

water photography. The electronic flash designed by Edgerton and Laporte in the 1920s marked all the possible vistas in photography. Through the miracles of silicon technology, a complete camera of the size of an index finger loaded with complex lens combinations, view finders, light meters, batteries and flash guns are now available. The circuit for a typical light intensity meter in a camera is shown in Fig. 11.

Photo sensors, photosensitive switches, colour, temperature and flash meters, electronic shutters, focussing devices, remote control devices and related integrated photometric devices need reliable power sources. A good part of commercial electronic products and range of batteries are solely meant for use with the portable photographic devices. As Table VI indicates, almost all professional and semi-professional cameras rely on the silver oxide sources. They compare favourably with mercury cells in many respects except that the cell voltage is 1.5 volts. They have a very good shelf life and a capacity of 50 to 750 mAH. Application of integrated meter circuits along with silicon or gallium photodiodes are primarily aimed at the reduction of power consumption along with heightened accuracy in every measurement and subsequent operations.

TABLE VI
Practical Camera Sensors and Their Power Sources

Brand	Model	Sensor	Power Source	Voltage
Nikon	FE	Silicon diode	Silver oxide	1.5×2
Olympus	OM-2N	Si diode+Cd sulphide	Silver oxide	1.5×2
Minolta	XG9	Cadmium sulphide	Silver oxide	1.5×2
Pentax	ME sup	Gallium diode	Silver oxide	1.5×2
Canon	AI	Si diode	Silver oxide	6 volts
Fujica	AX-5	Si diode	Silver oxide	6 volts
Konica	FS-1	GaAsP	Alkaline maganese	1 5×4

Solar power sources

To date, the ultimate source of energy, the sun, is used effectively only in satellites. Mammoth solar cell arrays in space provide the necessary energy for the satellites for several years. However, the use of solar power replacing conventional chemical energy in terrestrial instruments is disproportionately small. The major drawback with most solar cells is that the potential they provide is limited to around 0.5 volt. This means that eight to ten cells are required to operate a simple radio. The standard size cell (53mm × 6.3mm) may be able to supply around 4 mA. Moreover, a majority of the cells have a structure of silicon diodes with conversion efficiency of 8 to 15 per cent.

Some solar panels manufactured presently can deliver a power of 10W at a solar irradiation level of $1\,kW\,m^{-2}$ into a load resistance of 20 ohms. But the enormous size and variability of its capacity prevents its widespread application. Each solar cell has a safe operating area limit (SOAL) which is another disadvantage. The present trend is to employ solar panels along with a storage battery pack like NiCds, so that the working equipment can draw power during over-cast days and night, when the arrays receive little or no energy. The solar sources charge the storage batteries whenever the solar cells are irradiated. Presently, calculators and wrist watches make abundant use of this technique.

Basically, solar cell can be considered as an extended form of silicon p-n junction diode. The junction barrier potential Vj is around 0.7 volts just as in the silicon diode (Fig. 12). The contacts share this potential as V1 and V2 if no light falls on the junction. Typically, V1 is around 0.5 volt. The rest will be developed across the n-region as V2. An ideal voltmeter connected across the contacts can measure only zero potential in the absence of irradiation. If the junction is exposed to radiation, electron-hole pairs are generated due to the field of Vj, making them move across the junction. Consequently, Vj falls in proportion to the intensity of irradiation. Now V1 rises to the maximum, say, 0.6 volts and V2 cancels with Vj. The p-contact potential V1 will provide the positive terminal for the external load.

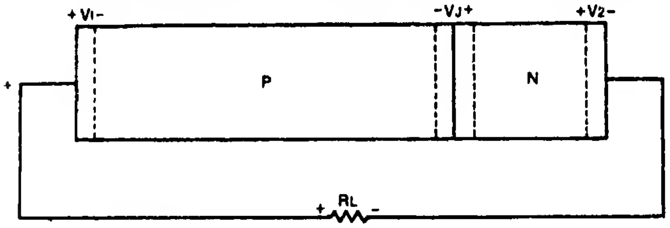


Fig. 12: Construction of a solar cell.

In low-voltage, high-current applications, the cells are arranged in parallel to each other to counteract the source resistance. Alternatively, a series combination is preferred for a low-current, high-voltage application. Usually a trade-off is adopted between the series and parallel combination of cells to make them suitable for real-life situations.

In order to utilise the maximum available power output of solar cells, they are carefully selected and matched with respect to the open circuit voltage, short-circuit current and the maximum power point. The cells which are connected in series and parallel have the same current and voltage respectively at the maximum power output (Fig. 13). The power obtained from the cell is the product of the current through the solar cell and its terminal voltage.

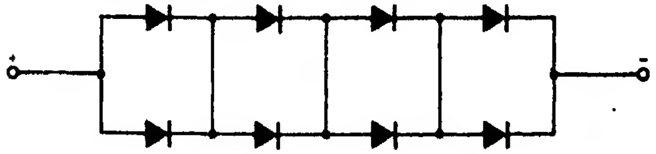


Fig. 13: Series and parallel combinations of solar cells.

The SB-250 series of solar cells from Stotron Ltd, UK, has a convenient dimension of 15cm × 8.5cm × 0.5cm which is

TABLE VII
Comparison of Zinc-Carbon and Nickel-Cadmium Performance

Load Current at 1.45 volts mA	Discharge period per day, hours	Zinc-Carbon				Nickel-Cadmium			
		Hours to reach a terminal voltage of							
		1.1	1.0	0.9	0.8	1.1	1.0	0.9	0.8
300	0.5	12	17	20	21	8	10	12	15
300	2	5	8	13	15	4.6	7.6	12	14.6
100	2	40	55	60	65	20	26	31	36
25	2	230	240	245	250	234	246	251	267
25	4	240	255	275	290	230	258	273	289
100	4	30	38	45	55	30	38	44	50
25	12	150	190	210	250	175	211	238	270

Note:
1. Ambient temperature 28°C.
2. Numbers are aggregates, tested with products from two different manufacturers.
3. Purely resistive load.

suitable for calculators and other hand-held instruments. These can be arranged in series or parallel to charge a set of NiCd batteries in a portable unit or to drive the load directly. For example, SB-2508A gives 8 volts at 95 mA and an open circuit potential of 11 volts, while SB-250-2 gives 2 volts at 500 mA and an open circuit potential of 2.5 volts. These are comparatively light (150 grams), with an energy density of 600 Wm^{-2}, on a sunny day in tropical areas.

National Semiconductors has introduced mini-packs of hermetically-sealed solar cells of TO-18 and TO-5 outline. These have a good stability, high efficiency and excellent short-circuit current linearity over a wide range of illumination. These are presently used for both power generation and light sensing applications, especially at low light levels, mainly due to their fast response time which is around 8 µs. The operating temperature range is about -60°C to +125°C. All these devices can be irradiated using a lens combination for excellent power generation.

The typical voltage that most solar cells generate in sunlight is 0.45 volt. However, in practical cases the number of solar cells required for an application is obtained by $n = Vo/0.4$. The circuit given in Fig. 14 uses two SB-250-08A cells in series but can be replaced by 40 solar cells in series, the latter being rather difficult to obtain. The current capacity of solar cells is determined by the load current, the length of time the cells are exposed to light, the duration of usage and the amount of rest time between the usage. Depending on the brightness of the sunlight, the cells can deliver 16 or more volts, while the minimum charge potential for a NiCd is around 1.35 volts. While designing the solar charger, the effects of cloudy or hazy days must be compensated for. Since diodes D1 and D2 are of equal type, the entire PD from the solar cells is developed across the zener diode. The output of the battery is then fixed using a three-terminal regulator.

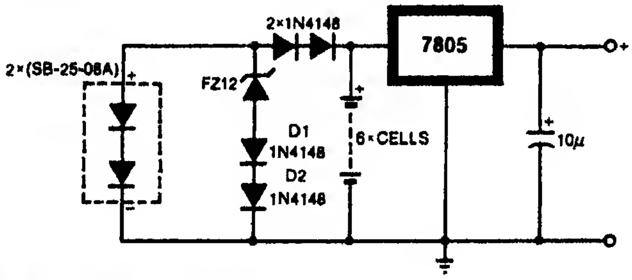


Fig. 14: Solar cell charger.

Portable solar power sources are mainly used in calculators, wrist watches, mini radios, light meters and toys. Specially designed integrated circuits like ZN415 (from Ferranti Semiconductors, UK) can operate from 1.5 volts consuming a maximum power of 120 mW. An 8-pin DIL IC, ZN415 consists of an RF tuner and a two-stage amplifier covering a frequency range of 150 kHz to 3 MHz which is enough for medium- and long-wave reception. A simple solar-powered receiver using ZN415 is shown in Fig. 15. This receiver delivers about 1.5 mW at 1 volt into a load of 64 ohms.

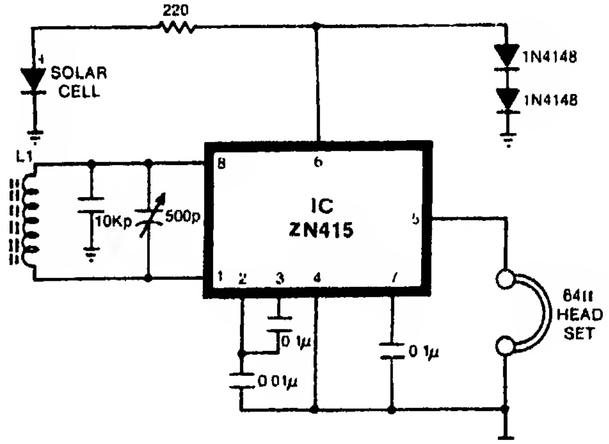
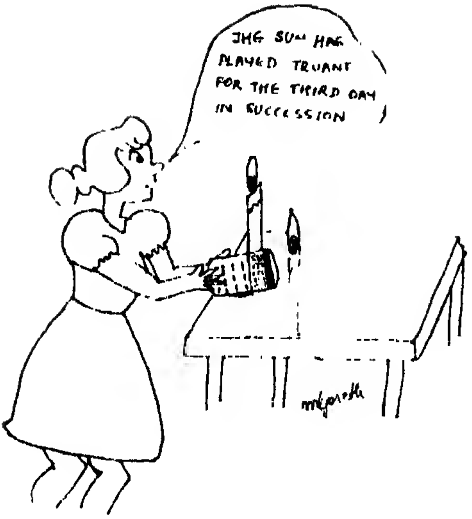


Fig. 15: Typical solar cell radio.

Alternate sources

All trends indicate that leading manufacturers are considering the possibilities of alternate portable power sources like thermoelectric and atomic batteries. In thermoelectric cells, the principle of thermocouples is employed but the



metal poles are replaced by n and p type semiconductors. Heat energy can be applied to the junctions by mini-burners made out of gas or petrol or both. It may then resemble a cigarette lighter with piezoelectric sparkers concealed in a suitable enclosure. The idea looks elegant but its practicality still remains to be seen.

Frenetic attempts have been made to convert radioactive energy directly into electrical energy in a capsule form, but only a bleak note has surfaced so far. Atomic batteries are supposed to have an outline similar to that of thermoelectric batteries, where thermal energy is produced by the decay of radioactive isotopes like Strontium-90. So far, Strontium-90 is the only contender in this field mainly due to the fact that its half-life is around 28 years. At present, such devices are used in unattended installations like clandestine transmitters and transponders in desolate high-altitude regions. Its availability for common use is not expected in the immediate future.

The alarm over the growing poisoning due to mercury and lithium batteries has been increasing for some time now. There is also evidence that the poisoning is real, that it is growing, and that it may reach an alarming proportion if nothing is done to alleviate it. Yet, the available experimental evidence on chronic human health effects due to mercury cell sources is limited and inconclusive. At present, one can neither unambigously demonstrate the existence of effects nor disprove their existence.

Lithium presents formidable safety hazards because of its high activity level. To top it all, lithium chloride is readily soluble in many organic compounds which human beings tend to use. In extremely low concentration, the same lithium is not only considered harmless but inevitable for many reactions. Lithium cells are often packaged as miniature button cells so that it is hard to recover from the waste dumps for reprocessing or safe deposition. However, substantial research efforts are now under way on this issue, and a solution should emerge soon. □