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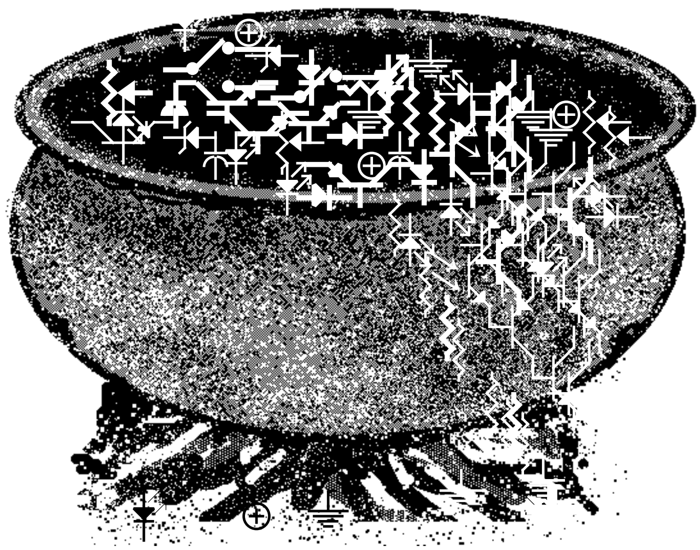


Recharging Small Nicads using a "Pulsar"

Richard Perez & Chris Greacen

Rechargable nicads are today’s solution to the expensive and environmentally nasty addiction to “use-’em-once-and-throw-’em-away” alkaline batteries. Here at Home Power we use nicads universally to power flashlights, instruments, portable radios, and Karen’s business calculator. While a nicad holds about 1/2 the energy of an alkaline “disposable” cell of the same size, you can use your nicad over and over, 200 – 1000 times depending on the quality of the cell and how the cell is recharged. This circuit is a nicad battery charger which is user programmable to fit any of the small nicad battery sizes, either in singles or assembled into packs. It is efficient and extends the battery's lifetime by proper recharging. Read on for how to build your own "Pulsar".

Requirements for recharging nicads

Any machine that is designed to recharge nicads must perform one basic function. It must limit the amount of current flowing into the nicad. This is essential to keep the nicad from overheating, overcharging, and eventually being destroyed. The simplest method uses a resistor to limit the amount of current flowing into the nicads. This is the method used by most commercially available chargers. It has two disadvantages: it wastes a lot of energy as heat, and in most situations, charges in a way which reduces cycle life. This charger takes a different approach to the problem. It charges the cells with rapid pulses. Electricity is not excessively wasted as heat, and the cells are charged in the healthiest way we know.

Using pulses to control power

The concept involved here is really quite simple. Let's consider this analogy. Imagine a lightbulb hooked up to a battery with a switch in line. This situation is exactly the same as the lighting circuits you use in your home. Turn the switch on and the lightbulb lights. Turn the switch off and the lightbulb ceases its operation.

Now consider turning the switch on and off rapidly, say about 200 times per second. Let's say that the switch spends half its time ON and half its time OFF. The result will be a dimming of the light as the switch is rapidly turned ON and OFF, or pulsed, in electronic jargon. The lightbulb has the amount of power flowing through it controlled because the light is only consuming power half the time. For the remaining time, the light is off. This technique of controlling power by rapidly switching the load on and off is called Pulse Width Modulation (PWM). Now, 200 times a second is a little too rapid for a manually operated switch. Besides, it's just plain boring to stand there and switch something continually ON/OFF just for control. So instead of a manual switch, let's use a transistor as a switch. PWMs, using transistors, are extensively employed in the electronic power control of many devices/processes like lighting, motors and in our case, recharging batteries.

Power is controlled by the amount of time that the electronic switch spends on in relation to the amount of time the switch spends off. This ratio is called "duty cycle" and is expressed as a percentage of ON time divided by ON time plus OFF time, or in algebraic terms:

Duty Cycle = ON time / (ON time + OFF time)

If the electronic switch spends half its time ON, and consequently half its time OFF, then its duty cycle is 50%. If the switch is ON 1/4 the time and OFF 3/4 of the time, then the duty cycle is 25%. And so on…

The actual amount of power available from a PWM is influenced by one more factor, the voltage (or amplitude of the pulse). This is the voltage that the pulse attains when in the switched ON condition. A pulse may attain any ON voltage that we desire, it could be 1 volt, 5 volts, 10 volts, or whatever. Consider two separate pulse trains, each with a 50% duty cycle. A sequence of regularly spaced pulses is called a pulse train. One pulse train has 5 Volts supplied to the switch, while the other has 10 Volts available for switching. Given the same duty cycle, the power content of the pulse train switching 10 Volts is twice that of the PWM supplied 5 Volts.

This then is the whole story: power can be controlled by two factors in a PWM. The first is the duty cycle of the pulse train, and the second is the voltage of the pulse when it is switched ON. Now, the math involved here can get sticky (it is best described by calculus), but the idea can be very simply expressed in a diagram. Consider the illustration below.

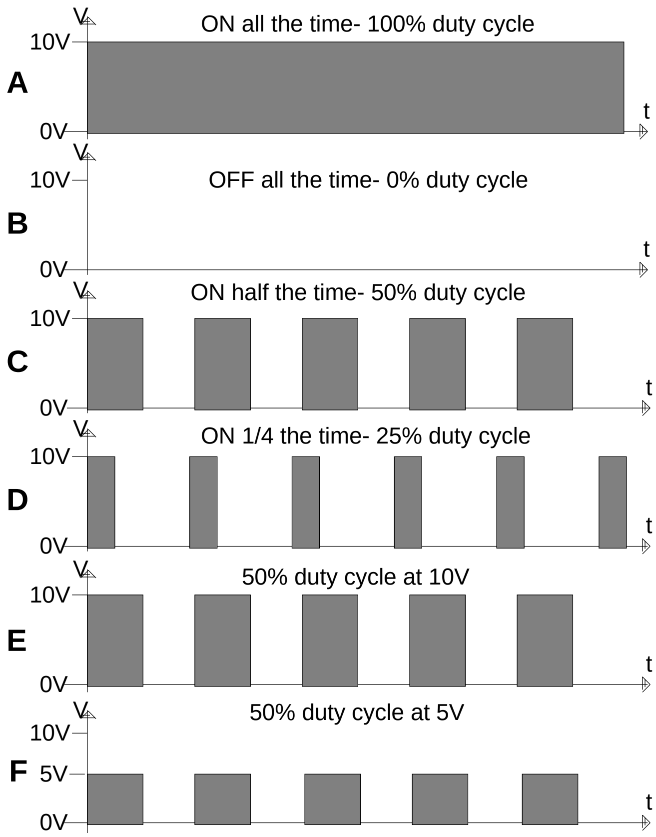


Fig. 1- The Power Content of Pulse Trains

This illustration is a graphical representation of the pulse situation. The vertical axis of the graphs represents voltage, while the horizontal axis represents time. The Section marked A shows the switch in the always ON, i.e. a duty cycle of 100%. The power of the pulse train is represented by the shaded area of the pulses. Section B illustrates the OFF condition, where there is no shaded area as the power is always OFF. Section C shows a pulse train of 50% duty cycle, i.e. the pulse is ON to the voltage level of 10 Volts for one half the time and OFF the remaining one half of the time. Section D illustrates the situation for a pulse train of 25% duty cycle. Sections E & F of Figure 1 show two pulse trains, each with a duty cycle of 50%. The pulse train in Section E has an amplitude of 10 Volts, while the pulses in Section F have an amplitude of 5 Volts. The shaded area in Section E is twice that in Section F, and the same is true for the power content of the respective pulse trains. The main idea to be gained from these illustrations is that power can be represented by the area under a curve, in this case the area under a series of rectangles. The secondary idea is that power can be controlled by time, by the duration over which the power is applied.

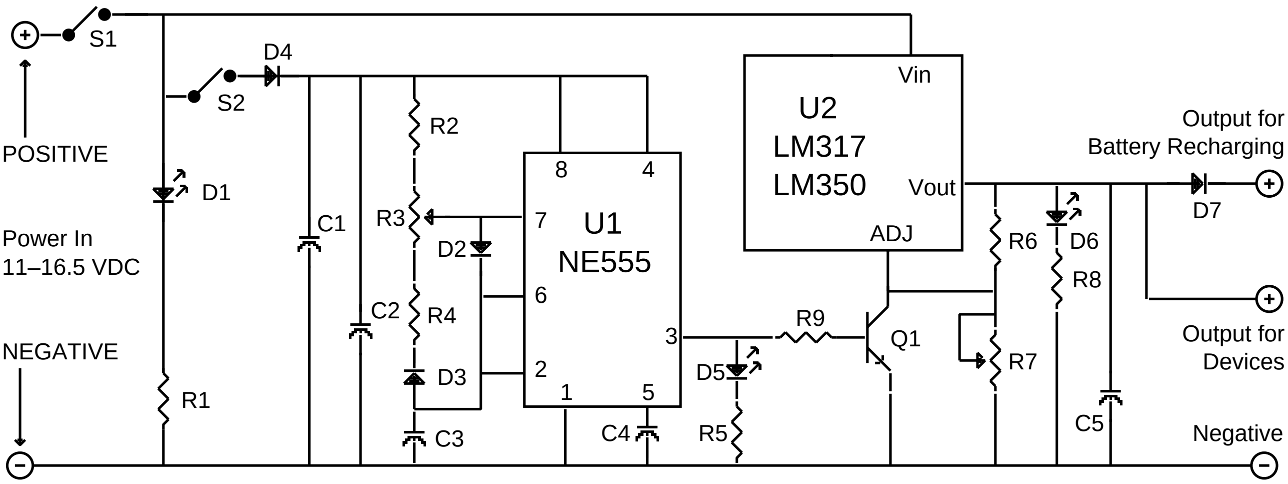
So why go to all this trouble?

One reason to use pulses is efficiency. Consider the amount of power being consumed in Section C of Figure 1. This pulse train is transferring NO energy during its OFF time. The switch is completely shut off. The use of a resistor involves continual loss as it always has electrons flowing through it. The pulse train enables us to control the energy flow without high loss.

Pulse trains have added benefits when it comes to recharging nickel-cadmium batteries. The nicad has very low internal cell resistance. As such, it is possible to run very large amounts of current through the cell without damage, *provided* that the duty cycle of the pulses is small. The high current (and voltage) of the pulse zaps the interior of the cell into increased electrochemical activity. If this pulse train had a duty cycle of say 90%, it would overcharge and ruin the cell. But if we keep the duty cycle of the pulse train from around 5% to 40%, then we can have the benefits of high current recharging without the danger of cell damage.

I've been using pulse trains to recharge nicads since 1977. My experience is that a properly sized and applied pulse train can more than triple the life of sintered plate nickel-cadmium cells. I've used pulses on AA, C, and D sized sintered plate nicads. By proper application of high current pulses, it is even possible to rejuvenate nicads suffering from dendrites. These dendrites are whiskers of nickel that grow within the cell as the cell ages. The dendrites may grow long enough to make a short circuit between the poles of the cell. Then the nicad will no longer hold a charge because it discharges itself through the dendrites. The high current pulses employed in recharging can vaporize the ultra thin whiskers before they become substantial enough to ruin the cell. Sintered plate nicads are also infamous for their memory effect. If you partially discharge the cell, and then recharge it, the capacity of the cell is diminished on the next discharge. An incomplete charge also seems to reduce capacity on the next charge. This memory affect is the root of the mysterious but successful “complete discharge–full charge” ritual followed by adept nicad users. Charging with high voltage, high current pulses pushes the cell’s electrochemical bonds to a high level. This reduces the sintered plate nicad’s memory effect.

NiCad Pulsar
Battery Charger & DC/DC Power Supply



Parts Listing

Integrated Circuits
U1- NE 555 Timer (8 pin DIP)
U2- LM 317 or LM 350 Adjustable Voltage Regulator

Transistors
Q1- 2N2222A NPN Silicon

Diodes
D1- Red LED
D2 & D3- 1N914
D4- 1N4001
D5- Yellow LED
D6- Green LED
D7- 3 Amp. Diode, heatsunk

Resistors (1/4 W.)
R1 & R5 & R9- 1 kΩ
R2 & R4- 2.2 kΩ
R3- 50 kΩ Potentiometer
R6- 240 Ω, 1/2 Watt
R7- 2 kΩ Potentiometer
R8- 500 Ω

Capacitors (25 VDC rated)
C1 & C3 & C4 & C5- .1 µf.
C2- 100 µf. Electrolytic

Switches
S1 & S2- SPST use >2 Amp rating

Enter the Pulsar

In 1983, I built a machine that custom tailors pulse trains for the recharging of small nicad batteries. I called it the "Pulsar". It generates pulse trains of duty cycles between 5% and 95% with ON voltages from 1.2 VDC to 10 VDC (assuming 12 VDC as input power). The current output of the pulse train is 1.7 Amperes in one model, and 3 Amperes in the other. While the schematic may look complicated, the Pulsar is really very simple and many have been homemade here on Agate Flat.

The Pulsar uses two integrated circuits. U1 is a NE 555 electronic timer wired up as a variable duty cycle pulse train generator (a PWM really). U2 is an adjustable voltage regulator using either the LM 317 (1.7 Amps out) or the LM 350 (3 Amps out). The Pulsar accepts power input from 11 VDC to 16.5 VDC. Switch S1 turns on the unit, while switch S2 disables the pulse generator and makes the unit into a battery eliminator. With S2 open, the unit can make any DC voltage (not pulsed) between 1.2 and 10 VDC from a 12 VDC battery. It can directly power cassettes, radios, and other electronics than require 10 VDC or less to operate. With S2 closed, the pulsar is operational and the power output of U2 is a pulse train for recharging nicads or small lead acid gel cells. Note that there are two outputs. The one with the series diode is for battery recharging, while the one without the diode is for directly powering appliances with the pulse generator disabled (S2 open).

Resistor R3 is a potentiometer that controls the duty cycle of the pulse train. Resistor R7 controls the voltage (amplitude) of the pulse train, or the regulated DC voltage if the unit is used as a battery eliminator.

U2 is a very rugged device, being internally protected from short circuit and overtemperature. The LM 317 is available in two different packages. The LM 317T has the smaller TO-220 case, while the LM 317K has the larger TO-3 case. In any case, the LM 317 must be heatsunk and the larger TO-3 case gets rid of heat better. While very much more expensive, the LM 350K gives the ability to move up to 3 Amps of current through the device.

Most of the parts can be purchased from Radio Shack. We encourage you to build your own. Or take the info to your local electronics head for help.

Using the Pulsar to recharge Nicads

In addition to the Pulsar, you will need the appropriate metering for information about the recharging process. A DMM with a shunt or ammeter is sufficient. To recharge a battery or a battery pack use the following procedure. 1) Turn the voltage control pot (R7) until the voltage is as high as possible. 2) Turn the amperage control (the duty cycle control–R3) to the minimum. 3) Connect the unit to the battery to be recharged via the diode (D7) output, and use an ammeter or shunt in this line to measure the amount of current flowing into the battery. 4) Close S2. 5) Close S1- The unit is now operating and recharging the battery. 6) Adjust the amperage control (R3) until a C/10 rate is flowing into the battery. 7) If the batteries are completely empty, then leave them under charge for 15 hours and they'll be full. When the nicad cell is totally full, its voltage peaks at 1.62 to 1.65 Volts (this is for a C/10 rate) and slowly drops. This is because the cells start to turn more of the electricity into heat, and the heat lowers the impedance of the cell. We set a Fluke 87 on min-max recording mode, and when the cell's voltage stops rising, we know we're done. Even with a pulsar you don't want to overcharge nicads.

The current that we are measuring is averaged out by the way that we are measuring it. Neither the DMM or the analog ammeter has the speed to measure the instantaneous amperage output of the pulse. What we see on the meter is a time-averaged version. This is also how the nicad cell sees the pulse, as an average charge current. For example, if our meter shows 0.1 Amps as the charge rate, and the duty cycle is say, 10%, then the instantaneous amperage of the pulse is about 1 ampere. While the instantaneous amperage is very high, the average is within the operational range for recharging the cell. So just use any old ammeter and set the recharging current for the C/10 rate for that particular cell or pack. If you are recharging very small capacity nicads and are unable to get the current low enough via the amperage control (R3), then reduce the voltage control (R7) until you get a C/10 rate into the battery.

Using the DC/DC Converter

If S2 is left open, then the Pulsar operates as a straight DC regulator; its output is smooth DC rather than a pulse train. Consider all the small electronic devices we use that employ internal batteries. In DC mode, the Pulsar can power your Walkman™, stereo, radio, or what-have-you directly from your larger 12 VDC battery system. This is really an added benefit. All that is required is the addition of one switch (S2), and the device becomes dual purpose. It recharges batteries or it directly powers devices without using their internal batteries.

To use the Pulsar as a DC/DC converter simply open S2 (disabling the pulse generator) and adjust the voltage on R7. Use the output bypassing D7 for greater efficiency.

Access

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