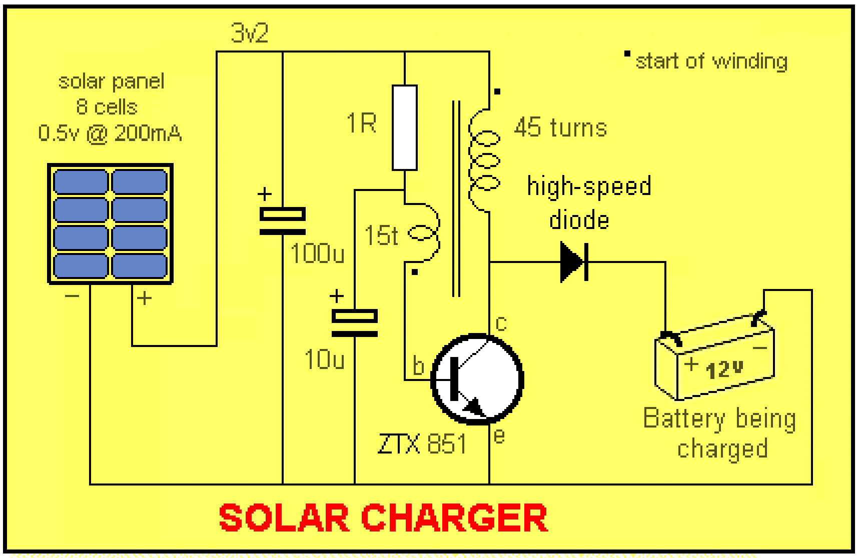
SOLAR CHARGER

A great kit for self-sufficiency

It's a very simple circuit. The skill in the design is in the transformer.
All the components and PC board: **$11.00** including pack and post.
0.5v @ 200mA solar cells $2.50 each
0.5v @ 100mA solar cells $1.50 each
Order the kit and/or solar cells from Talking Electronics

This is another kit in our self-sufficiency range. We also have a 12v fluoro inverter kit for those who need to operate 20watt to 40watt fluorescent lamps from a 12v supply.
We will be introducing a number of kits for those who have opted to live with 12v energy. With nearly everything electronic capable of operating from a 12v supply, there is no reason why anyone opting to live with a low voltage supply cannot enjoy all the electronic pleasures of those who live in the city.
Possibly there are a few products not yet available for 12v operation but inverters are available from 100watts to 4kw.



The aim of this project is to cater for the other end of the range. We are looking at charging a 12v battery, using the cheapest set of solar cells and the cheapest inverter. This also means the cheapest 12v battery - a 1amp/hr gell cell or 6v cells salvaged from old analogue mobiles!

THE PROBLEM

The problem with charging a battery from a solar panel is the SUN! It doesn't shine all the time and clouds get in the way! Our eyes adjust to the variations in the strength of the sun but a solar panel behaves differently.
As soon as the sun loses its intensity, the output from a solar panel drops enormously. No only does the output current fall, but the output voltage also decreases.
Many of the solar panels drop to below the 13.6v needed to charge a 12v battery and as soon as this occurs, the charging current drops to ZERO. This means they become useless as soon as the brightness of the sun goes away.
Our project cannot work miracles but it will convert voltages as low as 3.5v into 13.6v and keep delivering a current to the battery. Obviously the current will be much lower than the maximum, when the sun "half-shines" but the inverter will take advantage of all those hours of half-sun.

At least you know it will be doing its best ALL THE TIME.
The other advantage of the inverter is the cost of the panel. You don't have to buy a 12v panel. Almost any panel or set of solar cells will be suitable. You can even use a faulty 12v panel. Sometimes a 12v panel becomes damaged or cracked due to sun, rail, heat or shock. If one or two of the cells do not output a voltage (see below on how to fix faulty panels) the cells can be removed (or unwired) and the gap closed up. This will lower the output voltage (in fact it may increase the voltage - the faulty cells may have reduced the output to zero) but the inverter will automatically adjust.
The aim of this project is to achieve a 13.6v supply at the lowest cost. That's why the project has been released as a kit. The equivalent in made-up form is 3 times more expensive yet doesn't have some of the features we have incorporated in our kit. We have used a more efficient output circuit and the driver transistor is the latest "low-voltage" type.

HOW THE CIRCUIT WORKS

The circuit is a single transistor oscillator called a feedback oscillator, or more accurately a **BLOCKING OSCILLATOR**. It has 45 turns on the primary and 15 turns on the feedback winding. There is no secondary as the primary produces a high voltage during part of the cycle and this voltage is delivered to the output via a high-speed diode to produce the output. The output voltage consists of high voltage spikes and should not be measured without a load connected to the output. In our case, the load is the battery being charged. The spikes feed into the battery and our prototype delivered 30mA as a starting current and as the battery voltage increased, the charging current dropped to 22mA.
The transistor is turned on via the 1 ohm base resistor. This causes current to flow in the primary winding and produce magnetic flux. This flux cuts the turns of the feedback winding and produces a voltage in the winding that turns the transistor ON more. This continues until the transistor is fully turned **ON** and at this point, the magnetic flux in the core of the transformer is a maximum. But is is not EXPANDING FLUX. It is STATIONARY FLUX and does not produce a voltage in the feedback winding. Thus the "turn-on" voltage from the feedback winding disappears and the transistor turns off slightly (it has the "turn-on effect of the 1 ohm resistor). The magnetic flux in the core of the transformer begins to collapse and this produces a voltage in the feedback winding that is opposite to the previous voltage. This has the effect of working against the 1 ohm resistor and turns off the transistor even more.
The transistor continues to turn off until it is fully turned off. At this point the 1 ohm resistor on the base turns the transistor on and the cycle begins.
At the same time, another amazing thing occurs.
The collapsing magnetic flux is producing a voltage in the primary winding. Because the transistor is being turned off during this time, we can consider it to be removed from the circuit and the winding is connected to a high-speed diode. The energy produced by the winding is passed through the diode and appears on the output as a high voltage spike. This high voltage spike also carries current and thus it represents **ENERGY**. This energy is fed into the load and in our case the load is a battery being charged.
The clever part of the circuit is the high voltage produced. When a magnetic circuit collapses (the primary winding is wound on a ferrite rod and this is called a magnetic circuit), the voltage produced in the winding depends on the QUALITY of the magnetic circuit and the speed at which it collapses. The voltage can be 5, 10 or even 100 times higher than the applied voltage and this is why we have used it.
This is just one of the phenomenon's of a magnetic circuit. The collapsing magnetic flux produces a voltage in each turn of the winding and the actual voltage depends on how much flux is present and the speed of the collapse.
The only other two components are the electrolytics.
The 100u across the solar panel is designed to reduce the impedance of the panel so that the circuit can work as hard as possible.
The circuit is classified as very low impedance. The low impedance comes from the fact the primary of the transformer is connected directly across the input during part of the cycle.
The resistance of the primary is only a fraction of an ohm and its impedance is only a few ohms as proven by the knowledge that it draws 150mA @ 3.2v. If a battery is connected to the circuit, the current is considerably higher. The 150mA is due to the limitation of the solar panel.
Ok, so the circuit is low-impedance, what does the 100u across the panel do?
The circuit requires a very high current for part of the cycle. If the average current is 150mA, the instantaneous current could be as 300mA or more. The panel is not capable of delivering this

current and so we have a storage device called an electrolytic to deliver the peaks of current.
The 10u works in a similar manner. When the feedback winding is delivering its peak of current, the voltage (and current) will flow out both ends of the winding. To prevent it flowing out the end near the 1R resistor, an electrolytic is placed at the end of the winding. The current will now only flow out the end connected to the base of the transistor. It tries to flow out the other end but in doing so it has to charge the electrolytic and this take a long period of time.
These two components improve the efficiency of the circuit considerably.
You will notice the battery is receiving its charging voltage from the transformer PLUS the 3.2v from the solar panel. If the battery voltage is 12.8v (the voltage during charging) the energy from the transformer will be equivalent to 9.6v/12.8v and the energy from the solar cell will be equivalent to 3.2v/12.8v. In other words the energy into the battery will be delivered according to the voltage of each source.

THE BLOCKING OSCILLATOR

The operation of the circuit has been covered above but the term **BLOCKING OSCILLATOR** needs more discussion. By simply looking at the circuit you cannot tell if the oscillator is operating as a sinewave or if it is turning on and off **very quickly**.
If the circuit operated as a sinewave, it would not produce a high-voltage spike and a secondary winding would be needed, having an appropriate number of turns for the required voltage.
A sinewave design has advantages. It does not produce RF interference and the output is determined by the number of turns on the secondary.
The disadvantage of a sinewave design is the extra winding and the extra losses in the driving transistor, since it is turned on and off fairly slowly, and thus it gets considerably hotter than a blocking oscillator design.
The factor that indicates the circuit is a blocking oscillator is the absence of a **timing capacitor**. The circuit gets its timing from the inductance of the transformer. It takes time for the current to start to flow in an inductive circuit, once the voltage has been applied. In technical terms **CURRENT LAGS IN AN INDUCTIVE CIRCUIT.**
The **timing feature** is hidden in the circuit, but it has nothing to do with the feedback winding or the transistor. If we simply place the 45 turn coil (the transformer) across a voltage source, current will flow in the coil and this will produce magnetic flux. This flux will cut **all the turns** of the coil and produce a back-voltage in each turn that will **OPPOSE** the applied voltage and reduce the voltage being applied to the coil. This will cause less current to flow. During the time when the magnetic flux is increasing (expanding) the current is also **increasing** and the full current does not flow until the magnetic flux is STATIONARY. When this effect is viewed on a set of voltmeters and ammeters, it appears that the current is LAGGING. In other words it is taking time to reach full value.
This is the delay that creates the timing for the oscillator.
The voltage generated across the primary winding at the instant WHEN THE TRANSISTOR IS TURNED **OFF**, is called a FLYBACK VOLTAGE. The value of this voltage is determined by the inductance of the transformer (coil), the number of turns and the strength of the magnetic flux.
In our case we are taking advantage of this energy to charge a battery but if we did not "tap-off" this energy, it would enter the driver transistor as a high-voltage spike and possibly damage it.
(A reverse-biased diode can be placed across the winding to absorb this energy).

WHAT? NO VOLTAGE REGULATION?

Our simple circuit does not employ voltage regulation. This feature is not needed with a trickle charger. The charging current is so low the battery will never suffer from overcharge. To be of any benefit at all, voltage regulation must be **accurately** set for the type of battery you are charging. For a 12v jell cell, it is 14.6v. For a 12v Nicad battery, it is 12.85.
This is the way it works: When a battery is charging, its voltage rises a small amount ABOVE the normal voltage of the battery. This is called a "floating charge" or "floating voltage" and is due to the chemical reaction within the cells, including the fact that bubbles are produced. When the battery gets to the stage of **NEARLY FULLY CHARGED**, the voltage rises even further and this rise is detected by a circuit to shut-down the charger.
A voltage regulated charger is supposed to have the same results. When the voltage across the battery rises to it fully charged state, the output voltage does not rise above this and thus no current is delivered.
Ideal in theory but in practice the voltage must be very accurately maintained. If its not absolutely accurate, the whole concept will not work.

In our case we don't need it as the charging current is below the "**14 hour rate**" and the battery is capable of withstanding a very small trickle current.

PARALLEL OR SERIES?

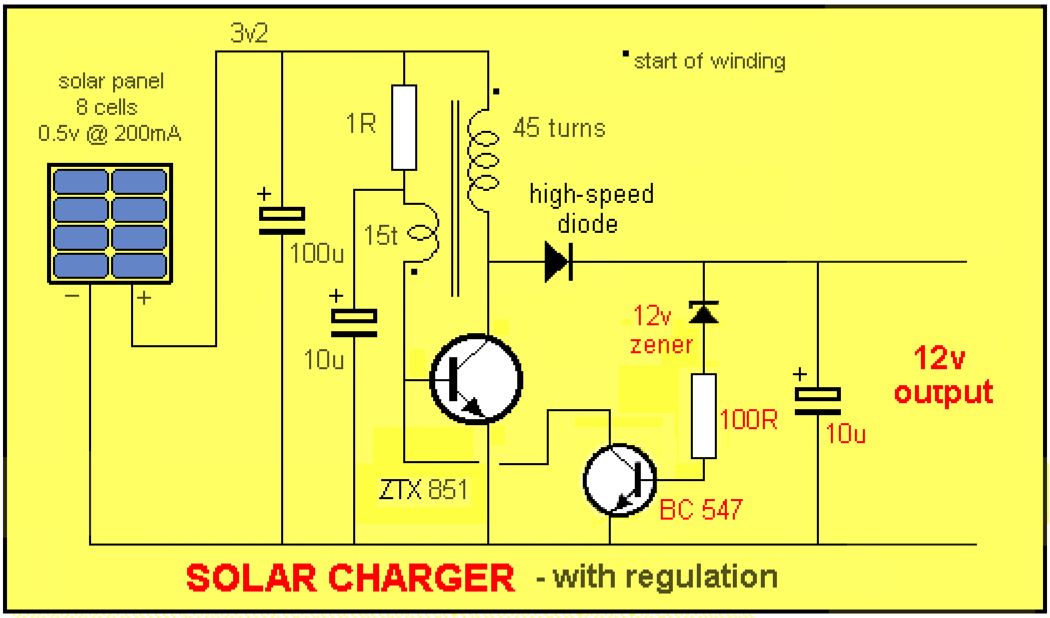
One of the questions you will be asking is: Should be solar cells be connected in parallel or series?
Most individual solar cells are made from small pieces of solar material connected together and placed under a light-intensifying plastic cover. The output of the solar cells used in the prototype were 0.5v and 200mA (with bright sunlight). The circuit has a minimum operating voltage of about 1.5v so any voltage above this will produce an output. In our case the cells should be connected in series to get the best efficiency.

REPAIRING FAULTY SOLAR PANELS

You may have a solar panel or individual solar cells and need to know if they are operating correctly.
All you need is bright sunlight and a place where the entire panel can be exposed to uniform sunlight.
The main problem is being able to access each of the cells with the leads of a multimeter while the panel is exposed to sunlight. To measure the efficiency of each cell, the panel must be delivering its energy to a load. You can place a switch on one of the lines and measure across the switch (when it is open) to determine the current being delivered.
The cells in our prototype measure 3cm x 5cm and deliver 150 mA with full sunlight. Smaller cells (2cm x 4cm) deliver 70mA.
When the cells are delivering their full rated output current, the voltage produced by each cell is about 0.4v to 0.45v Any cell producing less than 0.35v is faulty.
If the output current of your cells or panel is known, (read the specifications on the panel) you can check the output by measuring across the switch, as mentioned above. If the output is considerably less than this, you can short-circuit each cell in turn to see if the output current of the whole panel increases. The problem is made more difficult if two or more cells are faulty. Checking the voltage produced by each cell will detect two or more faulty cells in an array.
If you cannot get to the wiring between each of the cells, you can sometimes get to the wiring at the opposite end of the panel by cutting into the backing. This way you can check the left and right sections separately and work out if one side is operating better than the other. From there you can cut into one side of the panel and maybe get 75% of the panel operational. 75% of a panel is better than 100% of a dead panel.
This project is especially designed for a low-voltage panel. If you have a panel slightly below par, it is better to buy a few extra cells and increase the voltage so the panel can be connected directly to the battery. This way you will deliver 100% of the output to the battery. Our inverter has a maximum efficiency of 75%, so a panel that produces nearly 13.6v should have a couple of extra cells fitted so it can be connected directly to a battery.

9v to 12v OUTPUT

If you require 9v to 12v output, you will need to add the four voltage-regulating components shown in the diagram below.



With the voltage-regulation components added, the circuit produces a 9v or 12v output. This arrangement is only suitable if you have a constant, reliable, source of sun as any clouds will reduce the output to below the regulated voltage. (If a 9v1 zener diode is fitted, the output voltage will be 9v.) The BC 547 prevents the ZXT 851 oscillator transistor turning **on** when the voltage is slightly above 12v (or 9v). The 10u on the output stores the "reference voltage" and keeps the BC 547 turned on during the time when the output voltage is above 12v. This effectively stops the oscillator, but as soon as the output voltage drops below 12v, the circuit comes back into operation, "charge-pumping" the 10u on the output.
The 12v zener works like this: No voltage appears on the anode end (the end connected to the 100R resistor) until 12v is on the cathode. Any voltage above 12v appears on the anode and this voltage passes through the 100R to the base of the BC 547. For instance, if 12.5v is on the cathode, 0.5v will appear on the anode. When the base sees 0.7v, the transistor turns on, so slightly more than 12.7v is needed to turn on the transistor.
The regulation components are not really necessary as a reliable output will only be present when strong sunlight is seen by the solar panel. For the cost of a rechargeable battery or set of rechargeable cells, you get a much more reliable arrangement by removing the regulation components, using the first circuit in the article, and allowing the battery to deliver the 9v or 12v. The battery appears as a **HUGE** electrolytic on the output, delivering a constant voltage and is capable of delivering a high current.

OUR PROTOTYPE

Our prototype consisted of 8 solar cells charging two 6v batteries in series. These were obtained from old analogue phones and were purchased for $5.00 each but if you want to spend a lot more, you can get individual AA cells or a 12v jell cell.
The solar cells in our prototype are rated at 0.5v and 200mA
The array produced 3.2v @ 150mA with bright sunlight and the output of the inverter was 12.8v @ 31mA during the initial charging period. This reduced to 22mA as the battery became charged. As more cells are added, the charging current increased. We also tried 10 cells and 12 cells and the results are shown in the table below:

No of solar cells	Charging current (for 12v battery):
8 cells	22mA
10 cells	xxmA
12 cells	yymA

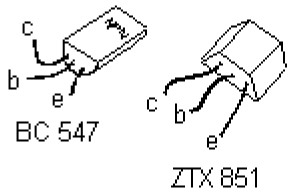
WINDING THE TRANSFORMER

The primary winding consists of 45 turns of 0.7mm wire on a 10mm dia ferrite rod. Wind 40 close-wound turns on the rod then 5 spiralling turns to get back to the start. Twist the two ends

together to keep the coil in position.
The feedback winding must also be wound in the same direction if you want to keep track of the start and finish as shown in the circuit diagram. It consists of 15 turns spiral wound so that it takes 8 turns across the rod and 7 turns back to the start. Twist the two ends together to keep the coil in position.
The result is called a transformer. It's a feedback or blocking oscillator transformer with a flyback feature. The output is taken across the primary via a high-speed diode.
The oscillator will only work when the feedback winding is connected around the correct way. The correct way is shown in the diagram, with the start of the primary and secondary as shown in the diagram. For this to work, both windings must be wound in the same direction.
You can keep track of the start and finish of each winding or simply connect the transformer and see if it works. If it doesn't work, reverse the feedback winding (reverse only one winding - **NOT** both).
Nothing can be damaged by trying this method as the solar panel does not deliver enough current to damage the transistor.

THE TRANSISTOR

One of the special features of this design is the driver transistor. It is one of the new style of transistors, having a very low collector-emitter resistance (voltage drop) when saturated. It is also capable of handling a very high current (3 amps) and peaks of 20 amps. When used in a high-speed saturation mode such as this, the losses in the transistor are extremely small and it does not require heat-sinking. Other transistors will work but the ZTX 851 transistor added 6mA to the output current due to its characteristics.



Transistor Pinouts

CONSTRUCTION

Wind the transformer as explained above and have it ready for fitting to the PC board. Fit the other components according to the overlay on the board making sure the transistor and diode are around the correct way. The two electrolytics must also be fitted around the correct way.
Now comes the transformer. As we have already mentioned, the easiest way to fit the transformer is to solder it in position and try the circuit. If it is around the wrong way, the circuit will not produce an output. Reverse one of the windings and the job's done.

PARTS LIST

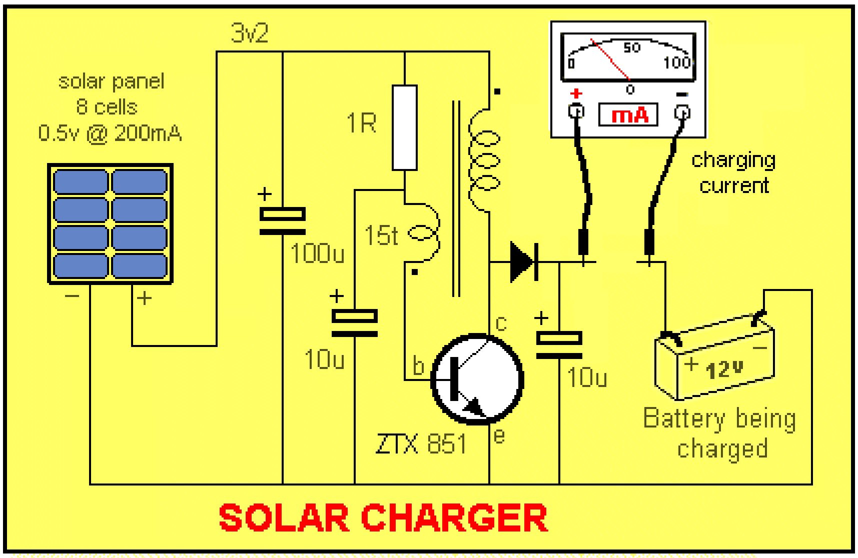
1 - 1R 1/2 or 1watt resistor
1 - ZTX 851 transistor
1 - BY 207 or equiv high-speed diode
1 - 10u 16v electrolytic
1 - 100u 25v electrolytic
30cm - 0.5mm enamelled wire
100cm - 0.7mm winding wire
1 - 10mm dia ferrite rod 5cm long
1- Solar Charger PC Board

Regulation components (not in kit)
1 - 100R
1 - 10u electrolytic
1 - 9v or 12v zener diode
1 - BC 547 transistor

TESTING THE CIRCUIT

The output current of the project can be measured with a multimeter set to milliamps. Place the meter between the battery and output of the circuit as shown in the diagram below. You can add an electrolytic to the output to smooth the pulses to get a more-accurate reading. Select a scale such as 0-100mA (for analogue multimeters) or 0-199mA (for digital multimeters). Note how the multimeter is connected, with the positive lead to the output of the circuit and negative to the battery.

There are many ways to "visualise" how the meter should be connected. The best way to remember is this: think of the meter as going directly across the output, to measure the current. Which way would it be placed? Obviously, the positive of the meter to the output and negative to ground. But you must **NEVER** place an amp-meter (or milliamp-meter) directly across the output of a supply as this will either damage the supply or the meter. So, include a resistor (or in our case, the battery being charged), and you will measure the "current flowing."



SUMMARY

You can now see how the circuit works. It generates a voltage higher than the battery voltage and that's how it can deliver energy to the battery. The energy comes in the form of "pulses" and we can measure the "average" or "equivalent to DC value" on a milliamp meter (a multimeter set to milliamps).

A FEW NOTES ON TRANSFORMERS

Transformers are one of the versatile components in electronics. They can be large, small, high-frequency, low-frequency, single winding, multi-winding, step-up or step-down (voltage) high-current, isolating, extremely-high voltage, voltage-reversing or even a combination of any of the above. They can be technically very complex, or very simple to design and you could spend a life-time studying their construction.

On the other hand you can learn how to construct them very quickly. Simply copy a design and maybe modify it a little. By copying a design you "home-in" on the essential features such as wire-size, core size, number of turns etc and you can change any of the features to suit your own requirements.

Before we start, let's point out the two main mis-conceptions of a transformer. Firstly, a transformer only operates on a voltage that turns on and off. This is commonly called AC (it stands for Alternating Current but this also means the voltage is ALTERNATING). The voltage can also be a DC voltage that turns on and off - commonly called chopped DC.

A battery cannot be connected directly to a transformer. It will not work. An oscillator (an oscillator circuit) is needed to convert the DC into pulses.

Secondly, the energy into a transformer (called watts) is equal to the watts output of the transformer (minus some losses). If a transformer on 240v AC (or 110v) produces 240 AMPS output, the output voltage must be low because the maximum input wattage for 240v is 2400 watts. This means the maximum output voltage is 2400/240 = 10 volts. Even though a transformer performs amazing things, it abides by the laws of physics. In general terms, if an output voltage is higher than the input voltage, the current will be lower.