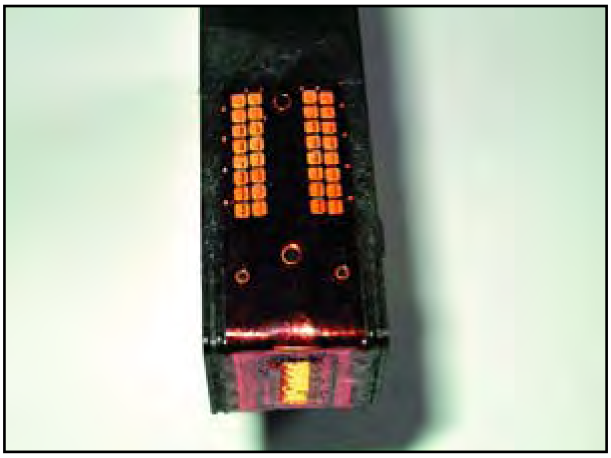
The cartridge concerned, the 51640M from HP, otherwise known as 'type-40'. According to sources on the Internet this cartridge can be refilled at least 10 times.

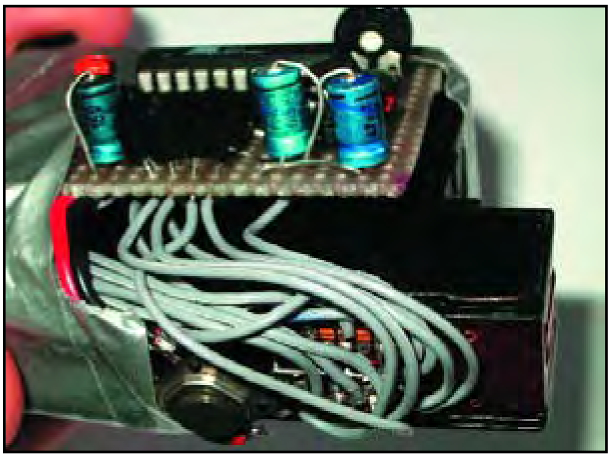


The still pristine yellow cartridge. A number of other cartridges looked much worse after many hours of fiercely attempting to figure out the function of the individual contacts.

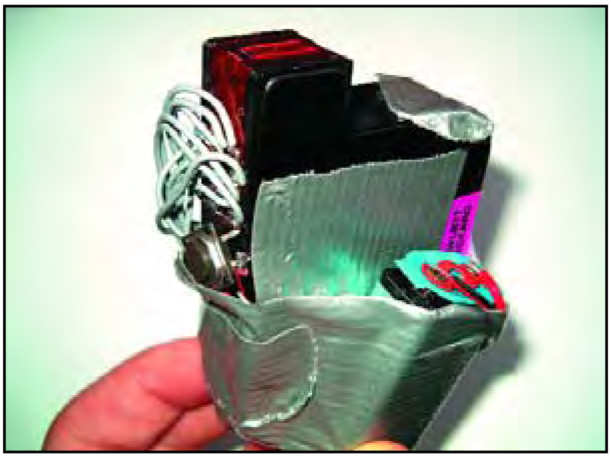
Electronic Sta

Jeroen Domburg & Thijs Beckers

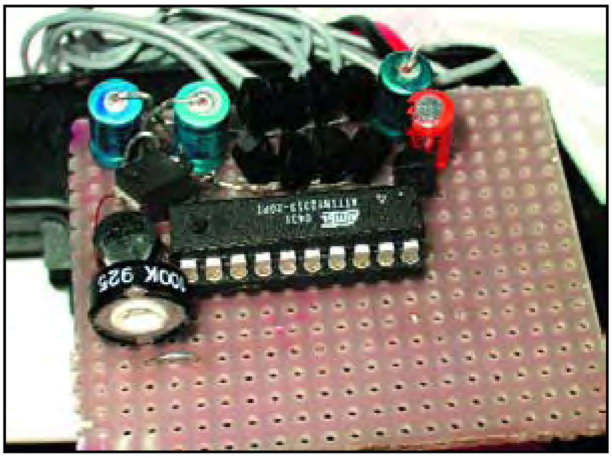
In this month's modding & tweaking article we delve a little more into the 'not so very useful, but nevertheless quite funny' types of circuit. With the circuit presented here you can write on water, for example, even if the message lasts for only a short time before it fades away. But whiteboards and other solid surfaces such as paper can be used as well. Curious how we did this? Read on...



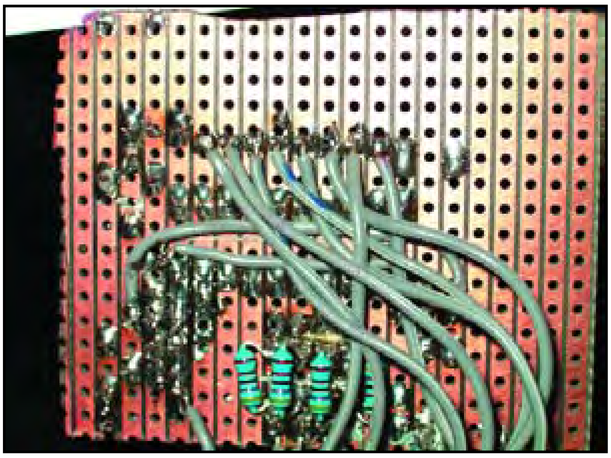
The circuit, attached to the cartridge. The activation pushbutton has been placed in an easily accessible location.



For the construction the universally applicable enclosure 'duct-tape' (a.k.a. Gaffa tape) has been used.
Also handy for holding the battery in place.



The circuit was built straight away, without doing a PCB design or such, on a prototype board.



The bottom side is witness to the experimental character of the circuit as well.

mp

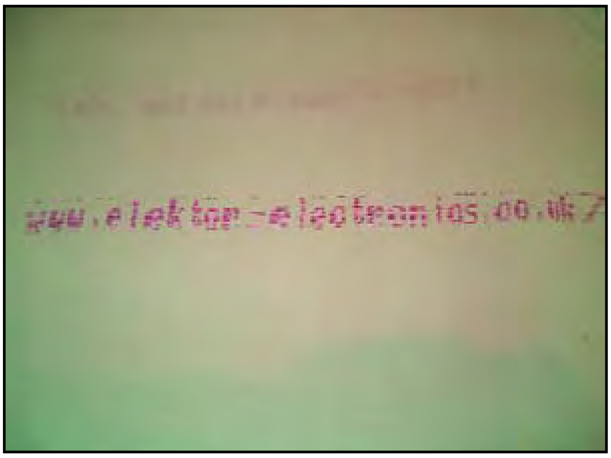
Printing without a printer

One of the nice things of having electronics as a hobby is that the things you make do not necessarily have to be useful. It is all good fun as long as you're entertained. The present project sprang from this mentality. In good Young Ones tradition, the author was very busy scrawling meaningless mottos, maxims and sayings on a flatmate's whiteboard and noticed that his handwriting was barely legible. In addition, the writing was also exceedingly slow. From the idea that it should be possible to complete the activity of vandalising someone else's whiteboard much faster, the idea of the 'electronic stamp' evolved. The function of the felt pen is replaced in the electronic stamp by an inkjet cartridge.

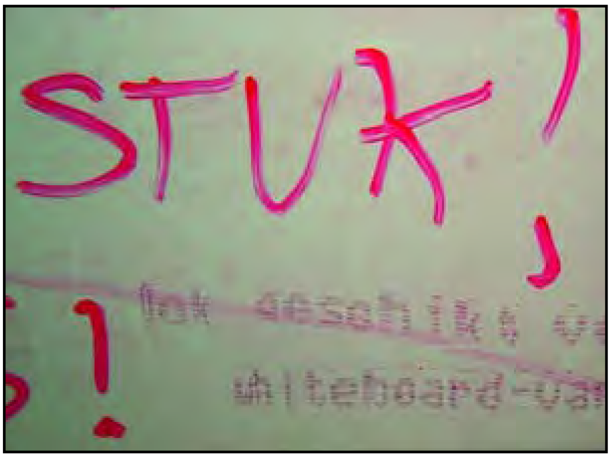
Cartridge

An inkjet printer cartridge these days is an advanced system, with perhaps hundreds of 'nozzles'. A nozzle is a small hole from which a droplet of ink is fired. The method of firing differs from manufacturer to manufacturer. In the case of the Hewlett Packard (HP) cartridge that we use in this circuit, the nozzles are operated thermally.
The print head consists of a slice of silicon, where the nozzles are channels from the ink reservoir to the outside of the print head. In the middle of each tube there is a micro-resistor. By running a relatively high current for a very short time (times of only 10 microseconds are not

This effect is created by moving the whole assembly across a piece of paper ...



... while holding the pushbutton down.



In addition to paper, this device also works quite well on whiteboards… This was the whole reason to get started in the first place.

But it is not limited to this. The object shown here is something that many students (and also many non-students) will be very familiar with.

unusual) through this resistor, the location becomes so hot that the ink that is there evaporates. Because the ink in a gaseous state occupies more space than ink in a liquid state, the (still liquid) ink at the front of the tube is pushed outside. All this happens at a very small scale, as a result if which the speed at which the drop of ink leaves the nozzle is quite high and the ink lands on the paper with high precision.

In a normal inkjet printer the print head is moved back and forth with a motor and a guiding system. If however, we want to make a manageable device then it is not convenient to integrate this entire system into an electronic stamp. That is why we use only the cartridge together with some electronics that drives the head. Moving the head itself is a job for the user. When moving it is important to hold the whole assembly straight and move with a uniform motion across the surface. After a little practice this is quite easy to do.

The cartridge that was chosen is an HP 51640M cartridge, also known as an 'HP type-40, magenta'. This cartridge is available in magenta (red-purple) as well as cyan (light blue), yellow and black. The circuit has only been tested on the magenta and cyan cartridges, but it can be assumed that all type-40 cartridges have the same pin-out, therefore also the yellow and the black. Other HP cartridges do not appear to have the same pinout, although the operating principle is probably the same.

Nozzles

In the first generation of inkjets the cartridges had only about 24 nozzles. Driving this system was simple: one side of all the nozzle resistors were tied together and connected to one pin of the connector. The other side of the little resistors each had their own connector pin. The pin-layout for such a cartridge can be figured out with a simple multimeter.

New cartridges are more awkward. The cartridge that we use here has over 100 nozzles. The number of connecting pads is a lot smaller, however. It appears that HP has built some electronics into the print head that takes care of driving all the nozzles. And now, as electronics hobbyist you are facing a problem. What's inside that

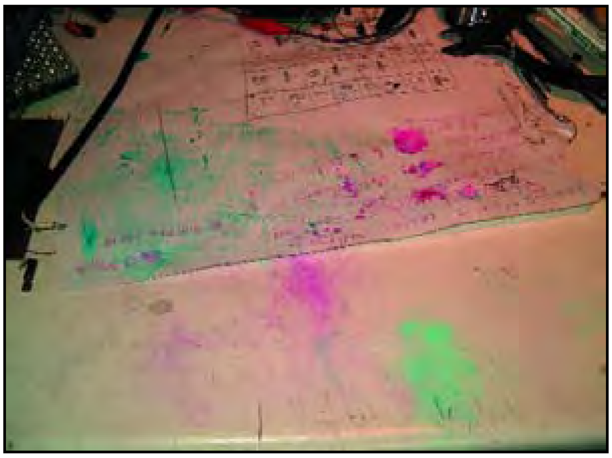
Because the drops are so small and light it is even possible to write on water!

However, the ink sinks after ten or so seconds and becomes unreadable.

You can let the circuit loose on this too. Note: the ink is probably not all that healthy.

piece of electronics? You see, there are several methods that could be thought of to enable to nozzles to be driven individually. From shift registers and multiplexers to a simple matrix to reach the nozzles one by one. The latter method can still be figured out with a multimeter, but the other methods require at least a logic analyser to discover what is going on, or a stroke of genius. Opening the printer where this cartridge belongs leads to nothing in this case. The only thing that can be seen is that a number of connections are tied to ground and the others run into an unidentified IC.

In the end, the author, after thinking long and measuring a lot, arrived at a method copied from gene technology. Make a gene defective, observe what changes in the organism and then you know what that gene does. This is also possible with inkjet cartridges: cover some connector pads with sticky tape and look at what goes wrong. After much messing about, it appeared that with exactly three pins (one of which is ground) just one thin line was drawn by the printer. These pins are therefore enough to drive one nozzle. With this information and



A final tip: should you have a go with inkjet-cartridges yourself, then work on a surface where it will not be a problem if it gets a bit messy.

some tinkering with a microcontroller and a lab power supply set to 20 V, it was possible to discover the exact workings of the cartridge.
In the end it appeared that the cartridge is divided into eight sectors with 17 nozzles each. The print head itself consists of two rows of holes. Each row of holes has four sectors. And each sector has its own power supply pin. When 20 V is applied to this the nozzles in that sector can be activated. Whether they actually do this depends on the nozzle inputs. When a positive voltage is applied an actual drop of ink will come out of the nozzle. If no voltage is applied to the nozzle input then nothing happens. Figure 1 shows the positions of the various inputs.

Voltage

The remainder of the circuit consists of nothing more than a microcontroller (ATTiny2313), some electronics to ensure smooth communication with the cartridge, a DC/DC converter to generate the required 20 V for the nozzles, a 78L05 for the power supply for the microcontroller and a 9-V battery as a power supply (see Figure 2).
The DC/DC-converter consists of L1, D1, T1, C4, R1 and the PWM hardware of the microcontroller. These parts together form a simple ‘boost’ converter. This works as follows. The microcontroller attempts to keep the voltage at PD6 at 2.5 V. It does this by making the pulses it generates on PD5 longer or shorter. These pulses cause T1 to conduct which results in a current through L1. When T1 blocks, that current continues to flow for a short time due to L1. C4 is now charged via D1. The current that flows into C4 allows the voltage across C4 to be higher than the power supply voltage. This voltage is divided via R1 and supplied to PD6. In this way the microcontroller regulates the voltage across C4 to a set value. R1 is used to adjust the voltage across C4 to the required 20 V. Start with the potentiometer in the centre position and turn towards the ground connection to increase the voltage to 20 V.
The power supply for the microcontroller is handled by the 78L05 and the necessary decoupling capacitors around it.

Control

In addition to the PWM logic that is programmed into the microcontroller, there is also a simple character generator built in. Even though it is possible to obtain quite a high resolution (32 nozzles are being controlled) the font uses just 8x8 pixels per character. This low resolution was deliberate because there is only 2 k of flash ROM available in the microcontroller. By selecting a microcontroller with more ROM a better font could be used. A considerable amount of rummaging through the junkbox was involved for this project and unfortunately the author did not have a ‘bigger’ microcontroller on hand.
The characters are generated based on a small sentence in the flash ROM. These are then sent to the nozzles. The sectors are made active one by one and when a sector is active only one nozzle is activated. The reason that this is done for each individual nozzle is that the print head would otherwise create a local vacuum for itself. This would result in (temporarily) no ink from the print head. By changing the nozzles, the nozzles that are not driven are given time to fill with ink again.
The sector lines of the cartridge (C1 to C4) have to be powered with a voltage of 20 V to make a sector active.

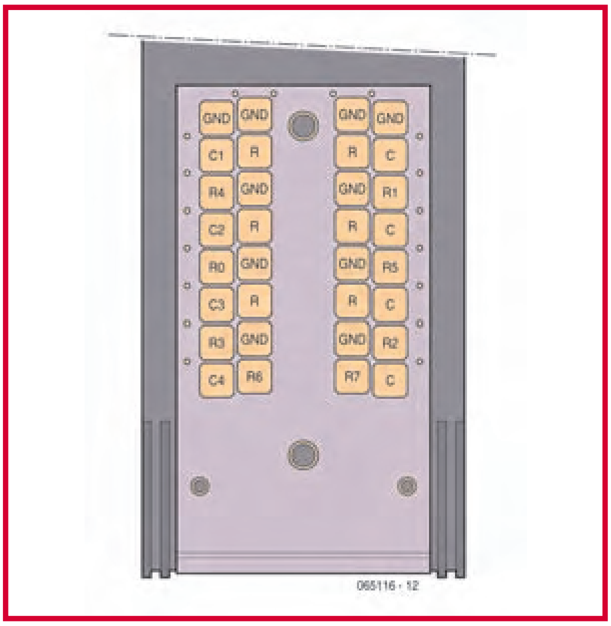


Figure 1. Here we see the layout for the print head used. Only R0 to R7 and C1 to C4 are used, the other connections are not required for this project.

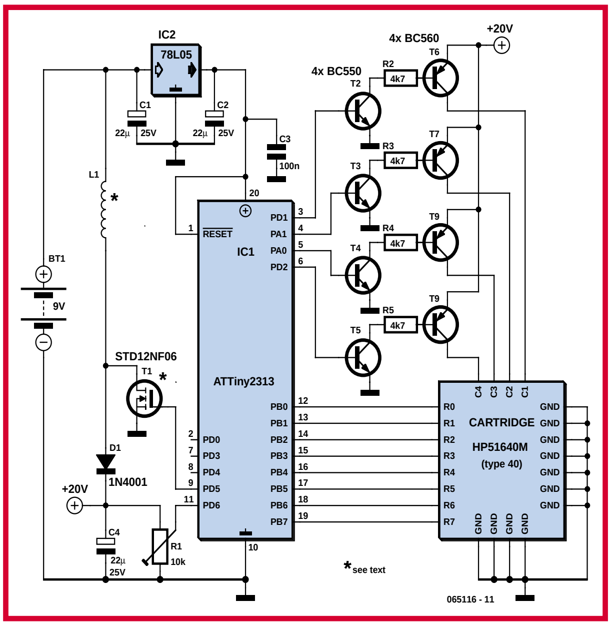


Figure 2. The circuit is not all that big and can easily be built on a prototyping board.

We do this with T2 to T5 and T6 to T9. This double transistor stage looks superfluous at the first instance. Why not connect T6 to T9 directly to the microcontroller? This would cause problems however. In the microcontroller there are built-in ESD diodes that conduct voltage above or below the power supply voltage to 5V and ground respectively. If T2 to T5 were left out, current would flow from the emitter via the base to the 5-V power supply and this is not the intention. Hence the addition of T2 to T5 in the circuit.

Construction

The author built the circuit on a piece of experimenting board, using parts available from the closet. That is why, for example, MOSET T1 is a rather strange type. In principle any P-channel MOSFET can be used for this, as long as it can cope with the peak current of about half an amp. The coil L1 does not have a critical value either. The author's coil comes from a backlight-inverter, but any slightly hefty coil will do. If the 20-V power supply is actually in the vicinity of 20 V, then all is well.

Additional possibilities

There are a few aspect of the circuit that could be improved. Firstly, the nozzles that have been used are not spread evenly across the cartridge. It is however quite a lot of work to figure out exactly how to drive all the nozzles and the pins used here already produce a quite legible text. Secondly, the current consumption is not really suited to a little 9-V battery. With long texts this battery is temporarily exhausted quite quickly. It is of course possible to replace it with a 9-V NiCd or NiMH battery. These have no problems delivering short-duration current spikes. Thirdly, the text that the stamp produces is fixed, defined by the code in the microcontroller. With a little bit of work it can be changed to use the EEPROM instead and be made adjustable via, for example, a serial cable.

All this is not necessary for vandalising someone else's whiteboard and is left as an exercise for the reader. The author is keen to see any improvements in the circuit or firmware, so that others can also benefit from these. The firmware, source code and any potential updates are available for free downloading, of course ([1] and [2]).

Now a final remark: inkjet cartridges are not really designed to be used continuously in the open air. It can happen that the head becomes blocked with dried ink. In that case it helps to shake the whole thing vigorously a few times (watch out for splattered ink everywhere) and to suck up the ink with a tissue from the head afterwards. It certainly helps if the cartridge is stored with the print head facing downwards as much as possible.

(065116-1)

Internet addresses

[1] http://sprite.student.utwente.nl/~jeroen/projects/stempel

[2] www.elektor-electronics.co.uk

About the author

Jeroen Domburgh is a student at Saxion Technical University in Enschede, the Netherlands. Jeroen is an enthusiastic hobbyist with an interests in microcontrollers, electronics and computers.

On the monthly Modding & Tweaking pages Jeroen shows his tinkering, modifications and other interesting stuff, for which usefulness and absolute safety are not requirements while no attempt is made to win a prize for beauty of the design. Jeroen strives to create or modify circuits to achieve no more than the desired degree of functionality. Forewarned is forearmed!