'Some weeks ago, last Thursday
I was walking round the hall
When I met a man who was selling quite a lot
He had all sorts of odds and ends
Of no interest to me at all
And a 4 function calculator that I bought'

Now 4 function calculators are not normally of much interest. This one has just the normal 4 operations and one memory, it is not programmable or anything like that. And to make matters worse, it was badged 'Prinztronic', a brand name used by the Dixons high street camera/audio shops. Their products were not normally known for high quality.

But I thought this one looked a little unusual, so it came home with me. And the first thing I did when I got it home was, as ever, to take it apart. I did this for 3 main reasons

1. To look for any leaking batteries. It clearly ran off a rechargeable battery (almost certainly NiCd) and I wanted to limit any damage.
2. To see how well (or badly) made it was
3. To see if I was right about the unusual feature

Dismantlng it is very easy **(Take it apart while talking)**. There are 2 obvious screws on the underside, after removing those the bottom cover comes off revealing the logic board and the battery pack. The battery unclips from its mountings, there's a little 2 pin polarised plug to connect it. Then 2 more screws retain the power converter board. After removing those,the power converter comes out, there's a wire to unplug from the board that connects the metal trim to the earth line. And a 5 pin in-line connector that connects the output to the calculator logic.

Next the display module comes out, it just unplugs from the logic board. And the logic board slides up to disconnect it from the edge connector. At this stage you can remove the keyboard unit by undoing a further 2 screws, I'll not do that now as unlike the 4 I've removed so far, the keyboard fixing screws are of the self-tapping (or as a friend puts it 'self-stripping) flavour going into the plastic top case moulding and I don't want to wear out the threads unnecessarily.

Slide 1: Machine dismantled into its modules.

This is what I ended up with. The keyboard, logic board, display and power converter modules along with the empty top case.

So far I'd noticed a bit of corrosion on the battery pack connector so the cells had almost certainly leaked but the electrolyte had not really escaped and done damage. And as you've all seen by now, it is actually very well made. In fact apart from the colour of the case mouldings it's a Sharp EL-811.

So what's the unusual feature? It's the display. Now it's clear from the top case that it's green. Green LED displays do exist but I've never seen one in a handheld calculator. Green calculator displays are always vacuum fluorescent things, which might also be called 'light emitting triodes'. They work a bit like directly heated triode valves. At the front is the hot wire cathode which is run just below red heat so it does emit light and interfere with the display. Next there is the grid, unlike a normal triode valve this is normally run with a positive bias to accelerate the electrons towards the anodes located behind it, these anodes are coated with a fluorscent compound which emits green light when hit by the electrons. By controlling the voltages on the anodes you can select which ones glow and you can use the grid to blank the entire digit thus allowing several digits-worth of anodes to be connected in parallel and the entire display driven using a multiplexed scheme where each digit is enabled in turn and the appropriate anodes energised to display the correct digit.

Now you all know the 7 segment display pattern used on many digital displays. But take a look at this :

Slide 2 : Rightmost display tubes.

This shows the tubes -- one per digit -- for the right hand part of the display. The rightmost one is annunciators for -ve number, memory, constant and extra digits. The remainder are the digits. And no way is that the 7 segment pattern. The segments are curved for one thing. And not counting the decimal point, there are 8 of them.

That's the unusual feature. That 8 segment display. And of course the digits are somewhat unusual patterns.

Slide 3 : Digits 1-8

Since there are only 8 display digit locations I can't show all 10 characters at once. So here are 1 to 8.

Slide 4 : Digits 7-0

And here are 7 to 0. Unfortunately, now we're all accustomed to the 7 segment display, this one, although some of the characters are closer to the hand-written forms, is hard to read I find.

Slide 5 : Display module schematic

This shows the circuit diagram of the display module, which is just the 9 tubes. Electrically the tubes are split into 3 sets of 3 -- the leftmost 3, the middle 3, and the rightmost 3. The calculator logic selects the corresponding tubes in each set using the grids and outputs the correct segment patterns to the anodes.

One minor oddity is the filament wiring. The filaments are powered by the `VH' line from the power converter board. There are then 2 series strings of filaments in parallel back to the 'VD' line. One contains 5 tubes, the other 4, which had me thinking for a few moments. But note that it's 5 digit tubes in one string and 3 digit tubes and the annuncator tube in the other

Back to Slide 2 for a moment

I am not sure if this is clear in the picture but the digit tubes have a single filament wire down the front whereas the annunciator tube has 2 wires in a 'V' formation. It's therefore quite likely that the latter needs twice the filament voltage of the former and that the 2 strings are balanced. This brought back memories of the Dx96 valves used in portable radios where the DL96 output valve had 2 filaments (which could be wired in series or parallel) as compared to a single filament in the other valves.

Now let's look at the keyboard. As I said I don't want to remove it from the casing now, but I did when I was working on the machine on my bench.

Slide 6 : Keyboard front

This shows the keys on the front of the keyboard module There are 20 of them, 10 digits and 10 `othes'.

Slide 7 : Keyboard bits

After removing a few screws, the card guides for the logic board and the keyboard PCB separate from the key frame. And I found this is a very well-made keyboard because ...

Slide 8 : Keyboard PCB

The key contacts are actually sealed dry reed switches which will be very reliable.

Slide 9 : Keyboard magnets

This shows the magnets to operate those reed switches on the bottom ends of the key plungers/

Now it turns out there are 12 connections from the keyboard to the logic PCB. And with 20 keys that immediately suggested to me a 10*2 matrix of switches.

Slide 10 : Keyboard Schematic

A little bit of testing showed that guess was correct. Moreover, the digits were in one row and the rest of the keys were in the other.

Slide 11 : Logic PCB

I'm going to say a little about the logic circuit board shown in this photo. There are 6 ICs in total, the 2 device that form the calculator chipset, the 3 display drivers and one other IC that turned out to be part of the keyboard interface. I shall say nothing about the calculator chipset itself. I know nothing about it.

Slide 12 : Logic PCB Schematic 2

This shows the display anode (segment) driver IC. There are 3 of them, one for each of the 3 sets of tubes. Each IC is essentially a 9-stage shift register to drive the 8 segments and the decimal point of the tubes. They're interconnected to form a 27 stage shift register so the segment patterns are loaded bit-serially from the calculator logic.

Slide 13 : Two Phase Clock

This shows the 2-phase clock signals needed by the display driver shift registers. It also shows my favourite HP handheld.

Slide 14 : Logic PCB Schematic 3

These 3 discrete transistors drive the display tube grids to select the individual tube in each set of 3.

Also on this diagram is the keyboard interface. Remember there are 10 keyboard row lines. They all go to this IC and 4 of them, which just `happen' to be the ones for the digit keys 1,2,4 and 8 go on to these termination networks and the calculator logic chipset. So this chip is some kind of keyboard encoder for the other 6 lines. And now notice that while it connects to the -ve supply line (`VD'), there is no +ve supply to it.

The former is something of a red herring. When you make the doped semiconductor regions of the bipolar IC, you end up making extra 'parasitic' diodes simply by having p-type and n-type regions next to each other. To avoid problems the circuit is arranged so these diodes are always reverse biased and in this case simply connecting the IC substrate to the -ve rail does that.

But without a supply rail this IC can't be very complex -- not much will work without power]

Slide 15 : Diode Array

In fact it's just diodes which assert the 1,2,4,8 lines in the obvous binary pattern for the other column inputs. For example pressing the '7' key will assert 1,2 and 4. Perhaps I should have said 'mostly obvious'. The '0' key would logically assert nothing which is not too useful. In fact it's given the value '10' and asserts '8 and '2'. This of course reminded me of the other obvious system where '0' is represented by '10', namely loop-disconnect telephone dialing.

I shall say nothing about the power converter board as it's not particularly interesting. But if you want to know how it works, ask me after the talk. I shall end by describing the battery pack which of course had to be rebuilt as the original cells had failed and were now leaking. In many ways it's easier to rebuild that most HP batteries.

Slide 16 : Battery Rivet

The battery pack housing is a plastic clamshell originally held closed by a hollow rivet. I managed to squeeze this with pliers and extract it.

Slide 17 : Battery pack open

Then the housing hinges open, revealing the 6 NiCd cells inside. It's just a plastic web hinge so it won't last for ever but it is easily good enough for this.

Slide 18 : Removing the leakage

I then cleaned up the battery pack parts in a bath of dilute citric acid. The leakage is potassium hydroxide mostly which reacts with carbon dioxide in the atmosphere to form potassium carbonate. It thus fizzes a little in the acid, releasing carbon dioxide.

I then found a problem. The electrolyte leaking from the cells had crept along the wires to the moulded socket on the battery pack (this was the cause of the corrosion on the plug pins on the power converter cable that I noticed when I took the machine apart). I therefore had to cut back most of the wiring to the socket in order to find a bit of wire that would take solder.

Slide 19 : Power converter test

For the intial tests I wired 5 AA primary cells in series to the socket (giving 7.5V rather than the 7.2V of the original NiCd pack, which makes no difference). Here I have connected the power converter to that battery and am checking the output.

While this was a good way to test the machine, it was clearly impractical as a permanent solution. But I would use the machine so infrequently that NiCd cells would quickly become over-discharged and damaged. The original charger unit which I got with the machine outputs a pulsed DC waveform, the battery has 2 main functions : it acts as a energy store; and it acts as a shunt regulator to limit the voltage applied to the calculator.

Slide 20 : PSU modification tests

I tried connecting a capacitor across the output of the charger to act as the energy store and a zener diode as the shunt regulator. Here they are messily soldered to the charger PCB. Amazingly this is all that's necessary to run the unit off the mains supply (only).

Slide 21 : Capacitor and Zener in battery pack

Since these component were effectively connected across the battery terminals, the obvious place to fit them was inside the shell of the battery pack. I mounted them rather more tidily on a piece of stripboard, wired them to the socket and fitted the result into the battery pack casing. I then found the the hole for the rivet had a 5mm hex counterbore on each side, ideal for fitting an M2.5 nut and bolt to hold the housing closed. This I did, making it easy to open the housing for repairs or if I decide to fit NiCd cells in the future.

All that remained was to put it all together **(Do that)**.