22:08 The Электроника MK-51 is a Casio fx-2500

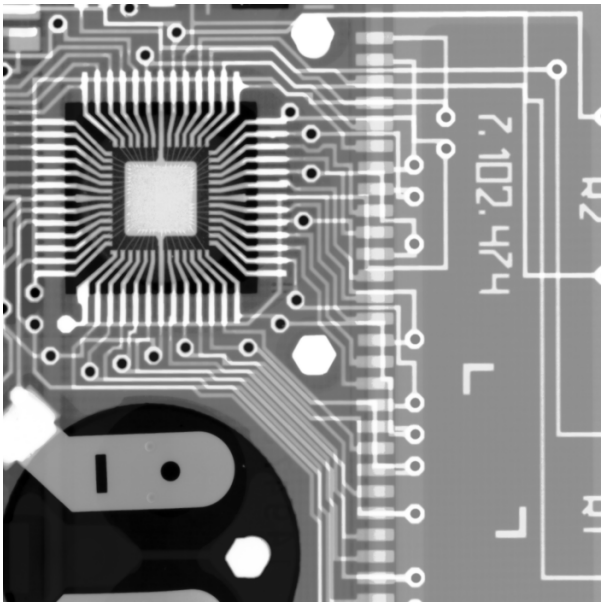
by Travis Goodspeed

Howdy y'all,

In the USSR, there was a calculator called the Электроника MK-51.[31] It looks an awful lot like a calculator from Japan, the Casio fx-2500. In this short article, I'll demonstrate that in addition to looking similar, the MK-51 is in fact a clone of the fx-2500, and that the Soviets went so far as to counterfeit the NEC microcontroller inside the fx-2500 with just minor alterations. Every last bit of the program ROMs are identical.

Let's begin with a little background. Introduced in 1978, the fx-2500 is a small scientific calculator that's held in a plastic wallet with its instruction manuals. The MK-51 joined it in 1982; manufactured until 2000, it also features a plastic wallet and instruction manuals. They both have an 8-digit LCD. The Casio is 121x67x11 mm, while the Elektronika is 130x71x8 mm. The keyboard layouts are a little different, some keys in different positions.

As I suffer from a disease late at night that involves alcohol and Ebay, it wasn't long before a few units of the Elektronika arrived from Ukraine. The Casio was surprisingly a little harder to find, but I found that one, too.



[31] Elektronika MK-51, if you don't follow Cyrillic.

I first tore down the MK-51. The zebra strip on this unit's LCD had long since turned to stone, but otherwise it seemed in decent condition for its age. The calculator is built around a single microcontroller in an epoxy blob package that rides within the plane of the PCB, a trick that I've also seen for reducing thickness on the HP-28 calculator. The blob in my calculator had no part number, both other sources online say that this chip is the К757ИП1-2. In X-ray, you can clearly see the hole cut out of the CPU to allow the CPU to fit with less thickness.

Going a little deeper, I desoldered the microcontroller, cut its legs off, and dropped it in a hot bath of HNO_3. The epoxy blob was torn off by nitric acid just fine, but it softened first in a way that Western QFP and DIP packages never do. I wonder what it's made of, but I'll leave that to professional reverse engineers of Soviet plastics rather than guess.

A full die photograph is shown in Figure 7. Nearly a third of the die is consumed by a diffusion ROM, and all pins are numbered, which was quite nice of the designers and convenient for reverse engineers.

Bits in a diffusion ROM are rarely surface visible, so I had to delayer this chip in dilute hydrofluoric acid. Ten minutes in hot Rust-Go did the job on the very first try. Bit rows are found in groups of four, with plenty of spacing between groups, but MaskROMTool – presented page 5 – was able to make short work of recognizing them.

One important trick with diffusion ROMs is that after delayering, they sometimes have no unique color, just a border line. So in addition to marking the center of each bit, I had to instruct my decoder to sample a wide stretch of pixels, recording the darkest color in each channel. This made the bits pop out, just a few dozen decoding errors.

The ROM itself is 352 columns wide and 64 rows tall, holding 22,528 bits or a little more than two kilobytes in total. While some very clever souls have decoded ROMs without knowing the architecture and instruction set, I wasn't very hopeful of doing the same. Who the hell knows what 4-bit microcontrollers were Ivan's favorite in the eighties?

So by this stage, I had die photographs and an export of the physically ordered ROM bits, but not

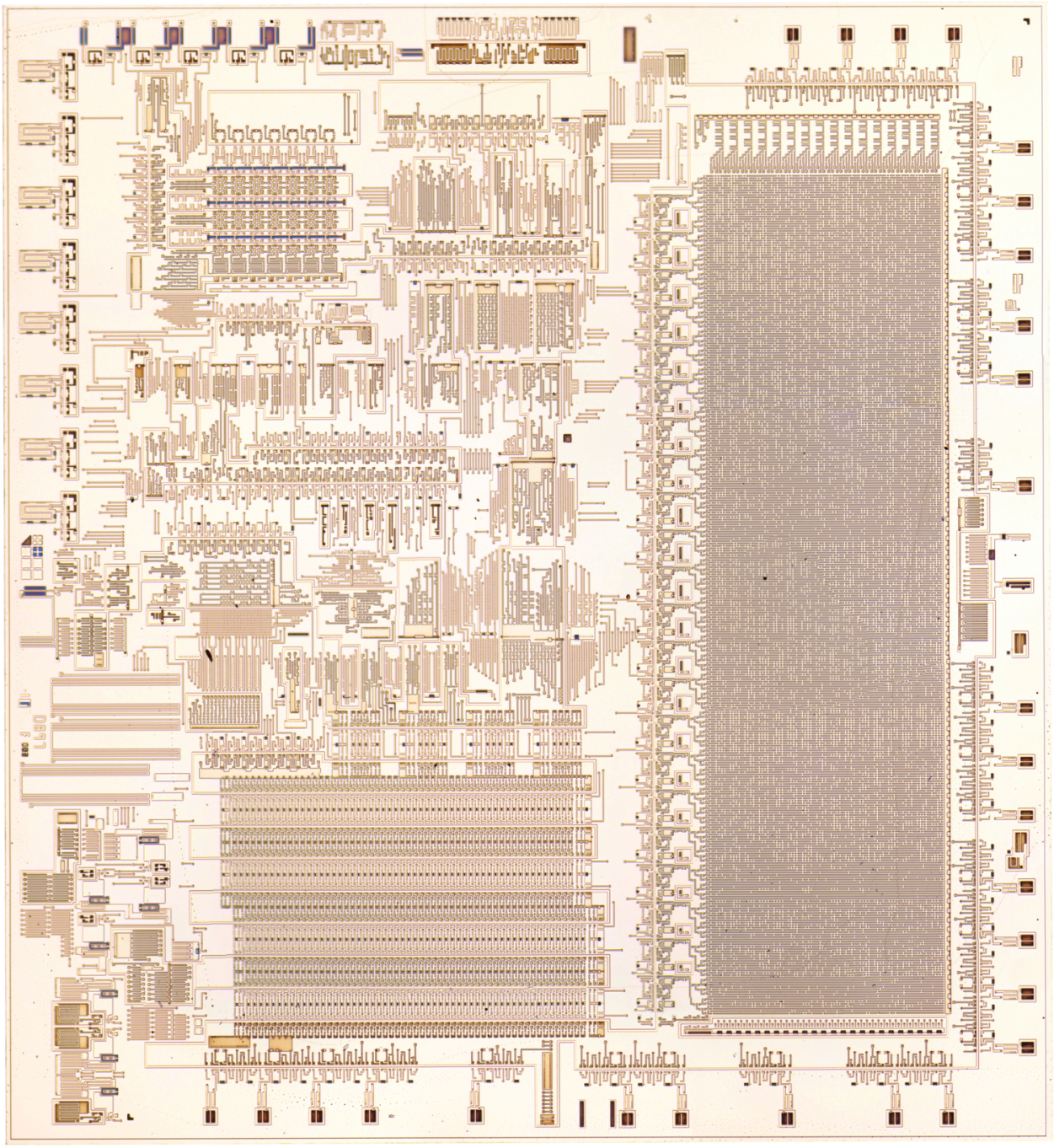


Figure 6: NEC D897G Die from the Casio fx-2500, Delayered

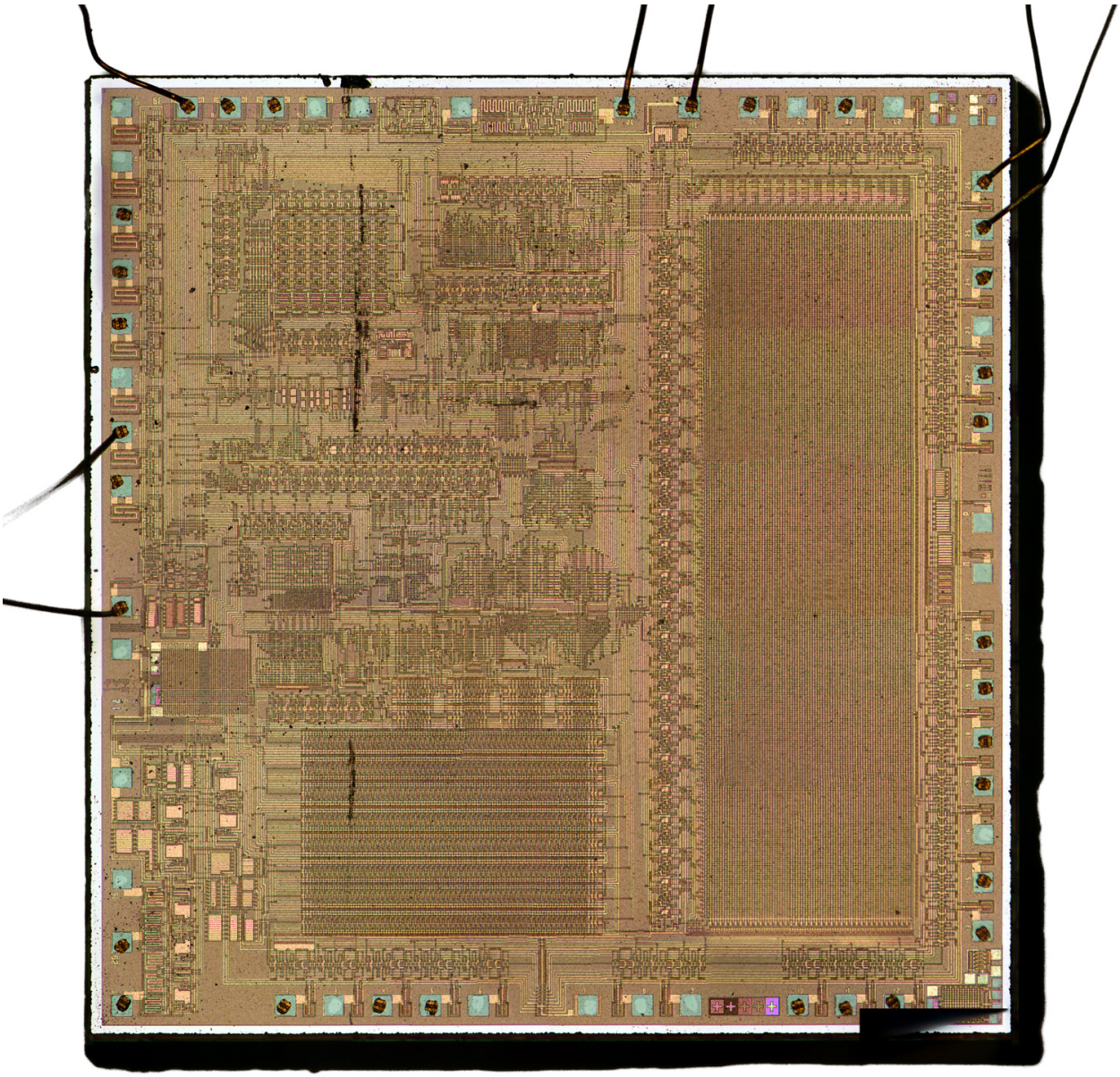


Figure 7: К757ИП1-2 from an Электроника МК-51, Top Metal

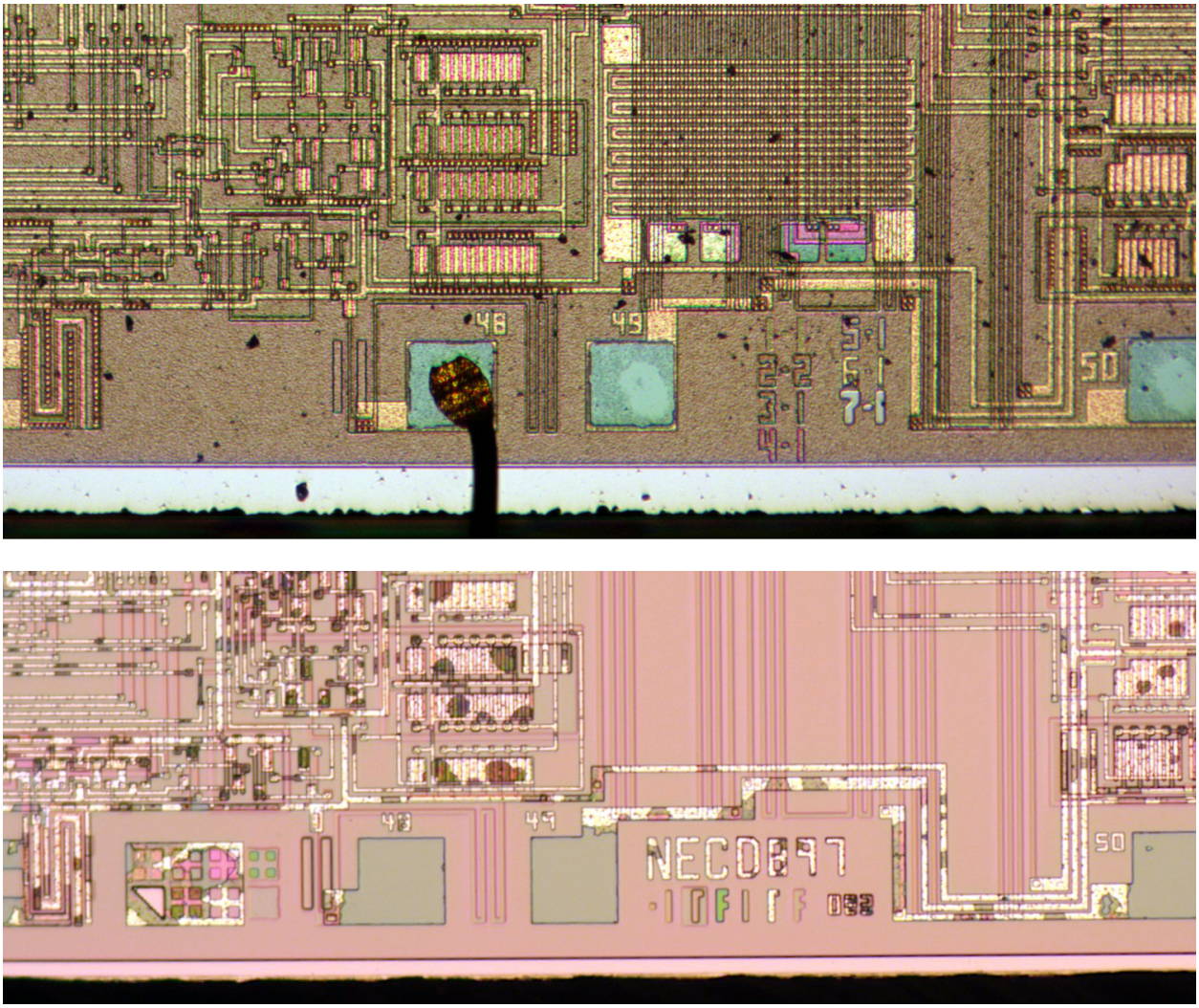


Figure 8: Mask Labels from Электроника МК-51 (top) and NEC D897G (bottom)

yet a decoding into logical bytes or error correction of the marked bits. To get further, our story leaves the Soviet Union and moves next door, to Japan.

My sample of the Casio fx-2500 arrived a week after the Elektronika. From the very first glance, it's clear that the exterior casing of one was modeled after the other. Minor differences in size and plastic quality were visible, and some of the button rows are in a different order.

Inside the case, the Casio also uses a single microcontroller, but this is attached to the PCB as a normal QFP package, rather than sitting in a cutout of the PCB. It has a visible part number of NEC D897G.

I decapped and then delayered it in the same way as I did the Soviet chip, then delayered it to get Figure 6. Both chips have pin numbers around the perimeter; both chips have layer labels between pins 49 and 50; and, both chips have a diffusion ROM that's roughly a third of the surface area.

The mask ROM of the NEC chip also contains groups of four rows, and it also contains exactly 22,528 bits in exactly 64 rows and 352 columns. The bits are identical, and I was able to correct the few dozen bit errors that I made in the Elektronika extraction by having MaskROMTool flag all differences with the Casio as errors. This shows that not only are these two calculators running the same architecture, but they have exactly the same firmware.

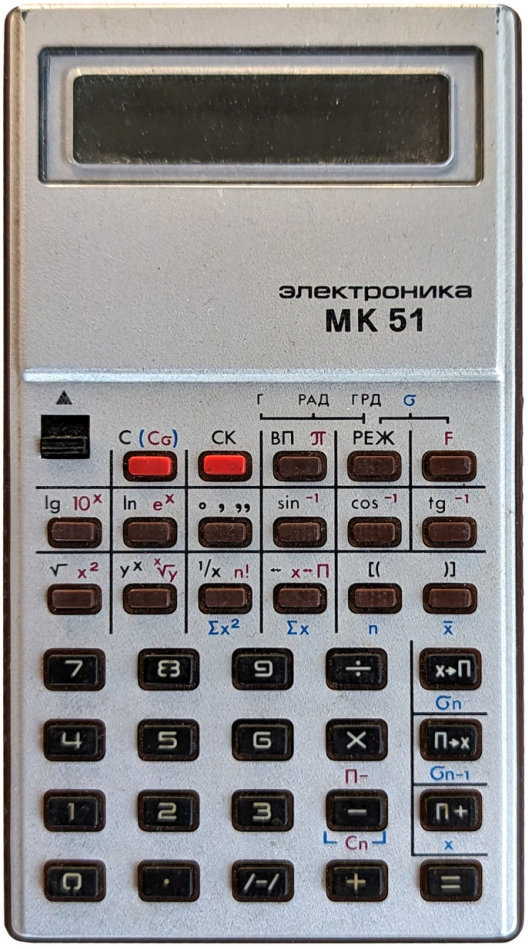
Unlike the Электроника calculator, which lacks a part number on the die, the NEC chip is labeled with D897G. This part number isn't in my databook collection, but the naming convention fits members of NEC's μCOM43 family that appeared in 1977, just a year before the calculator.

I grabbed Computer Gin and Fabulous Fred, μCOM43 chips which had been decoded by Sean Riddle. Between those and my handy NEC databook, I found that Fabulous Fred begins with `8f, 91`. `8f` is an `LDZ` instruction, loading `0f` into the data pointer. `91` is an `LI` instruction, loading `01` into the accumulator. Computer Gin begins with `15, 3e`. `15` is `ADC` instruction, and add with carry. `3e` is an `XI` instruction,

Plugging these instruction pairs into MaskRomTool's byte solver, it recommends a solution similar to the Riddle's ROMs.[32] With that decoding, the ROM begins to look something like μCOM43 machine language!

```
0:00:  db      JCP   0x1B    Call a function
0:01:  15 5d   LDI   0x5D    Load the DP
0:03:  63      RPB   3       Clear I/O pins
0:04:  3d      XMI   1
0:05:  66      REB   2
0:06:  28      X             Move DP to A
0:07:  69      RMB   1       Clear bit of RAM
0:08:  01      DI            Disable Ints
```

Today I've not only shown that the Электроника MK-51 and the Casio fx-2500 not only look and behave similarly, but also that the MK-51 has a clone of the NEC microcontroller from the fx-2500, that the firmware is identical between the two calculators, and that the firmware is similar if not identical to that of the NEC μCOM43 architecture. With time this ROM dump might be built into an emulator, though we will have to figure out after which calculator to name the MAME module!



[32] `gatorom bits.txt -o rom.bin --decode-cols-downl-swap -i -r 90`