2567W

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TEXAS INSTRUMENTS

TI-2800 Paperless Printer Calculator Disassembly

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Final Summary Report

In the electronic calculator race of the 1970s and 80s, major tech companies like Texas Instruments, Toshiba, Casio, and Sharp made rapid advancements on energy use, memory capacity, precision, reliability, functionality, compact design, and displays of calculators ("Calculator Time-Line"). Their collective developments, including major innovations like Texas Instruments' "Calculator on a Chip" circuit, reduced prices and made calculators the widely accessible computational tools at our fingertips today ("The Arrival of…").. In 1987, Texas Instruments introduced the revolutionary Paperless Printer Calculator - the TI-2800! Users were able to store up to 99 single-line calculations that could be used in column calculations (like a simplified Excel). The algebraic logic between a maximum of 10 operations utilizes a Toshiba integrated chip and LCD technology that was developed in Japan, but with the calculator's release, Texas Instruments commemorated the presence of their products in countless homes. With the disassembly of TI's commercialized pioneering device, our team gained insight on the Reverse Engineering process, specific digital electronics knowledge, and a designer's understanding of the fundamentals behind complex technology today.

Before disassembly, research prepared us expect to find single-chip microprocessors, LCD displays, capacitors, batteries, and resistors as electronic components in the calculator. We found that the calculator houses two printed circuit boards (PCBs) on which two liquid crystal displays (LCDs), display drivers, a Toshiba T7724 microcontroller, and an external 2k x 8 S-RAM lay, all powered by three 1.5 Volt batteries ("Texas Instruments TI-2800…").

The printed circuit boards (PCBs) are a fundamental electronic component: they enable the connections between components by allowing components to be soldered onto the plated holes and pads on the patterned, powered wires ("Advanced Circuits").

Liquid crystal displays (LCDs), different from the energy-consuming LEDs, are matrices of pixels which can form an image once the data is converted from binary. The calculator uses a silver/gray character display, one "divided into rows of characters" to display only numbers and letters (Smith). The single line LCD has one row of eight characters (1x8) and a multi-line graphical LCD (1.5" x 2.5").

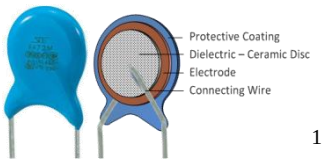
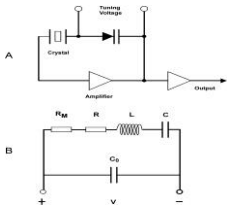
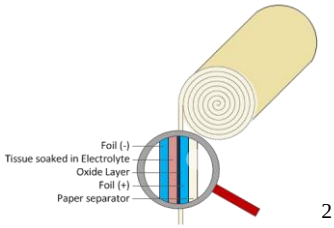
The LCD Display drivers regulate the "voltage requirements for the LCDs and work with an LCD controller … to keep refreshing pixel information to drive the circuitry" ("What is an LCD Display Driver").

The Toshiba T7724 microprocessor (different from a microcontroller) encompasses the multi-purpose programmable function of a CPU (central processing unit where calculations take place) on an integrated circuit. However, it relies on input from the external S-RAM to execute tasks according to its own memory while providing an output for the display driver ("What is a Microprocessor").

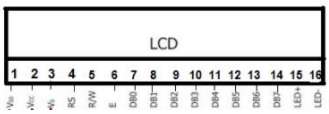
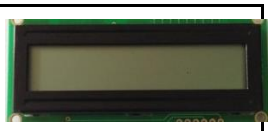
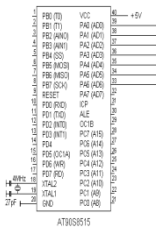
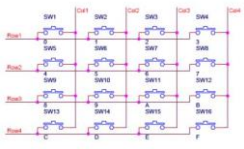
The external Toshiba TC5518FCL-20 static RAM (read-and-write memory) component is an integrated chip with a 2k x 8 (2048 words by 8 bits) capacity. The S-RAM (static random access memory) stores data as long as there is power and quickly organizes data for the microprocessor to use and to store (Christensson).

Other minor electrical components help regulate the power supply and input data. In the disassembly of the TI-2800 Paperless Printer, one can observe the mechanical, electrical, and logical workings behind the technology in classrooms, facilities, cities, spaceships.

Electronic Component Data Table

Electronic Component	QTY	Function	Datasheet/ Schematic	Image
Ceramic-Disc Capacitor (30 pF ±5%)	2	Transmits electric current without conduction	 [1]	
Quartz Crystal Resonator	1	Regulate frequency and stabilize amplitude		
Aluminum Electrolytic Capacitor (10 uF 16 V)	1	Polarized capacitor with a larger capacitance due to use of an electrolyte to achieve a larger capacitance than other capacitor types	 [2]	
Zener Diodes	9	Relay data about the user's control and input using connections made with the keyboard membrane buttons; conducts electricity only one way	Zener Diode Datasheet	
Resistor (150kΩ ±5%)	1	Reduces current by adding electrical resistance to the circuit	Carbon Film Resistor Datasheet	
Surface Mounted Capacitor	1	Regulates voltage	General Surface Mounted Capacitor	

[1] http://www.capactiorguide.com/ceramic-capacitor/
[2] http://www.capacitorguide.com/electrolytic-capacitor/

Single-line LCD	1	Displays a row of 8 characters (7 segments) including operations		
Multi-line LCD	1	Displays 6 rows of 8 characters (7 segments) including operations		
Toshiba TC5518FCL-20 (or Sanyo LC3518)	1	Processes and stores data (random access organization)	Toshiba MOS Memory Product Datasheet	
Toshiba T7724	1	Programmable device which uses the external memory as input and provides results as an output to the LCD drivers once it processes the input according to the instructions stored in its memory	T7724 Datasheet unavailable;[3] chip based on Toshiba's TMC17A, TMC17C CPUs:	
LCD Display drivers	2	Provides drive signals to LCD based on function by the microprocessors	MM145456 Datasheet	
Keypad membrane (28 buttons)	1	Passes current indicating the button pressed	 [4]	

[3] http://www.datamath.org/Toshiba_IC.htm
[4] http://www.electronicdesign.com/components/basic-circuit-eliminates-numeric-keypad-polling

Switch	1	Selects mode by allowing or discontinuing current flow	General Three Position Slide Switch Datasheet	

TI-2800 Paperless Printer Calculator User Manual:
http://www.datamath.net/Manuals/PaperlessPrinter_US.pdf

Figure a. TI-2800 Paperless Printer Calculator Whole, opened

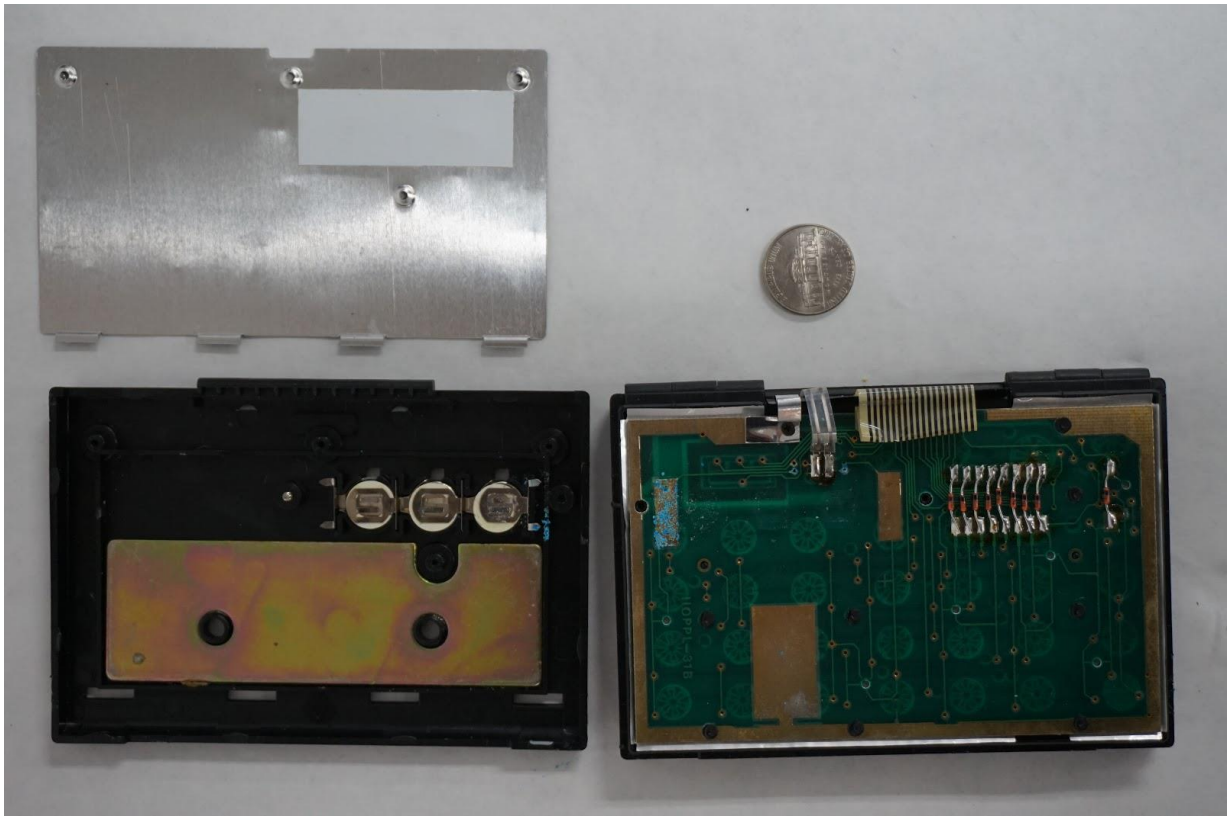


Figure b. Bottom Disassembly Layers: Back Plate, Battery Holder, keypad PCB (back)

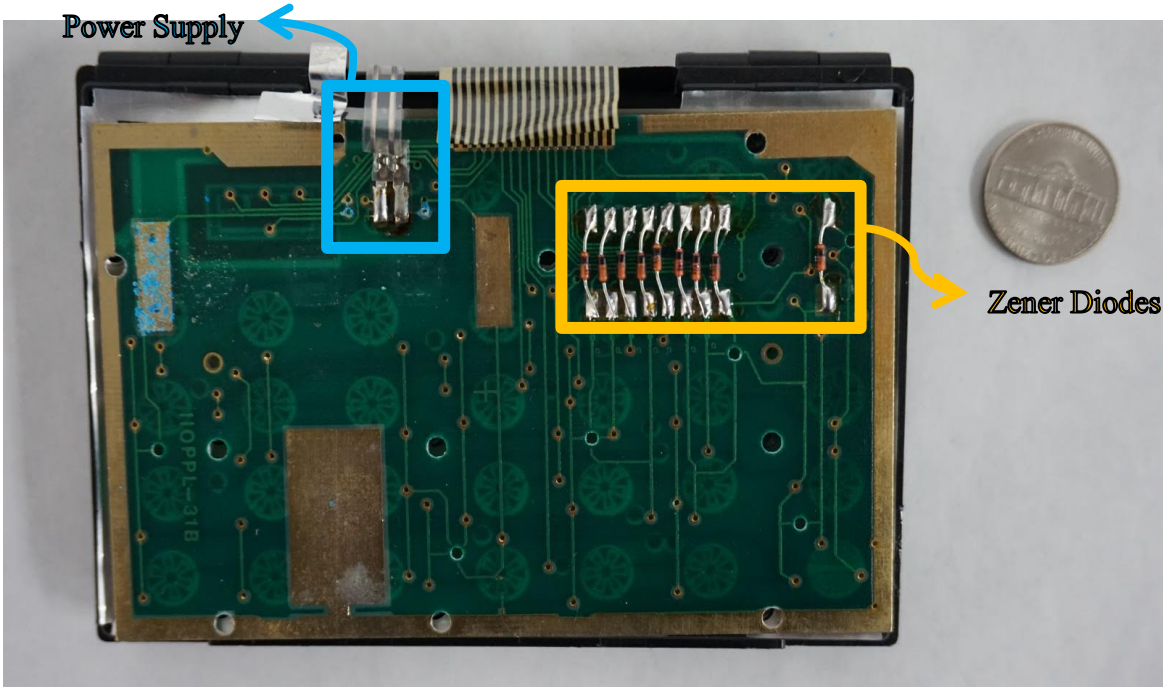


Diagram c. Keypad PCB with Diodes

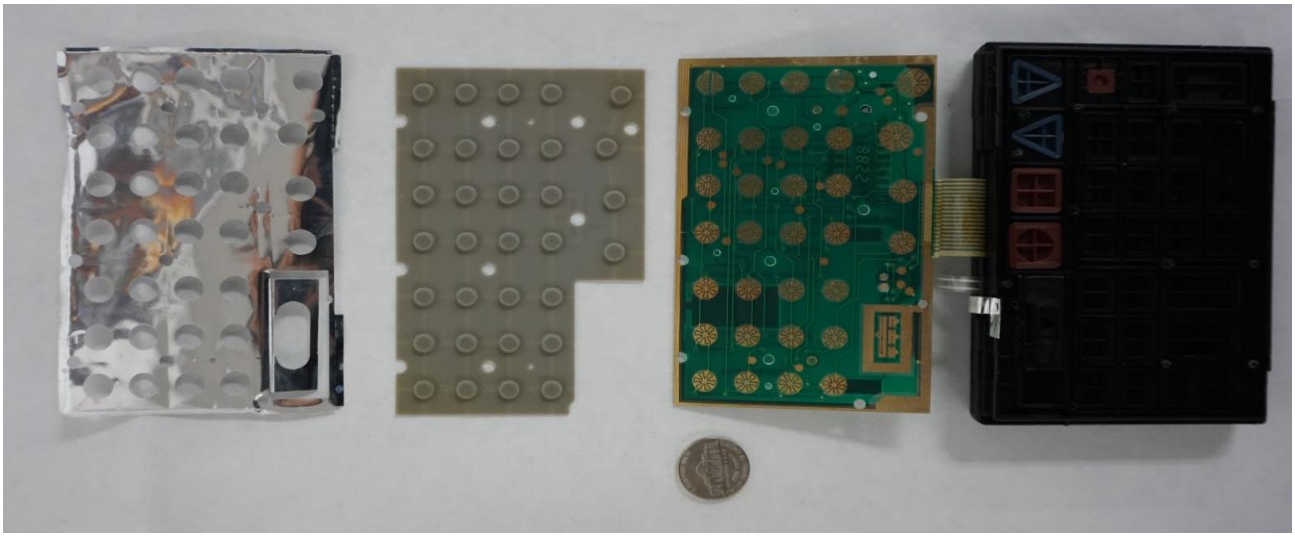


Figure d. Keypad Layers: (from left to right) Membrane Sheet, Membrane, Sensors, Case

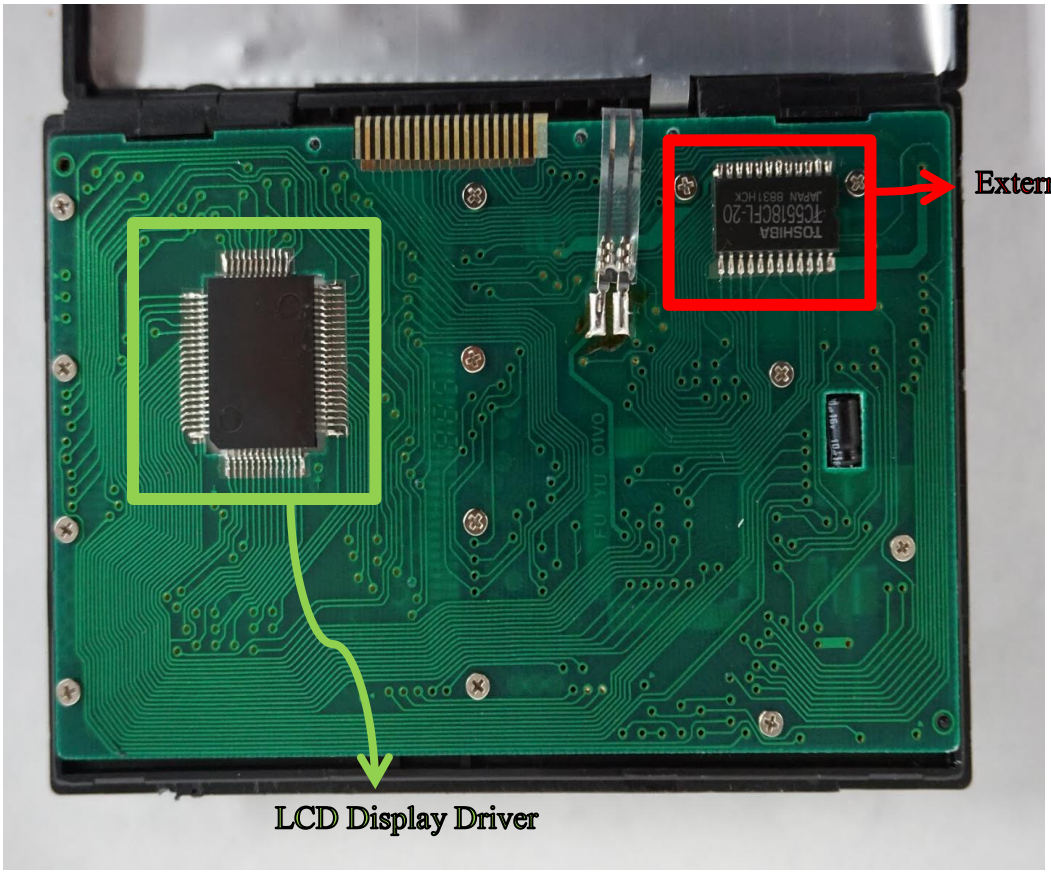


Diagram e. Display PCB (back)

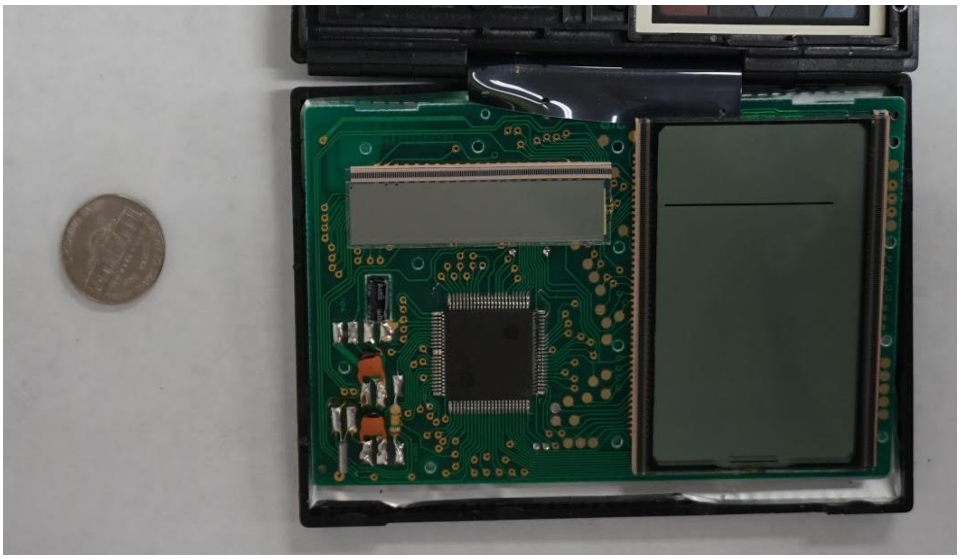


Figure f. Display PCB (top)

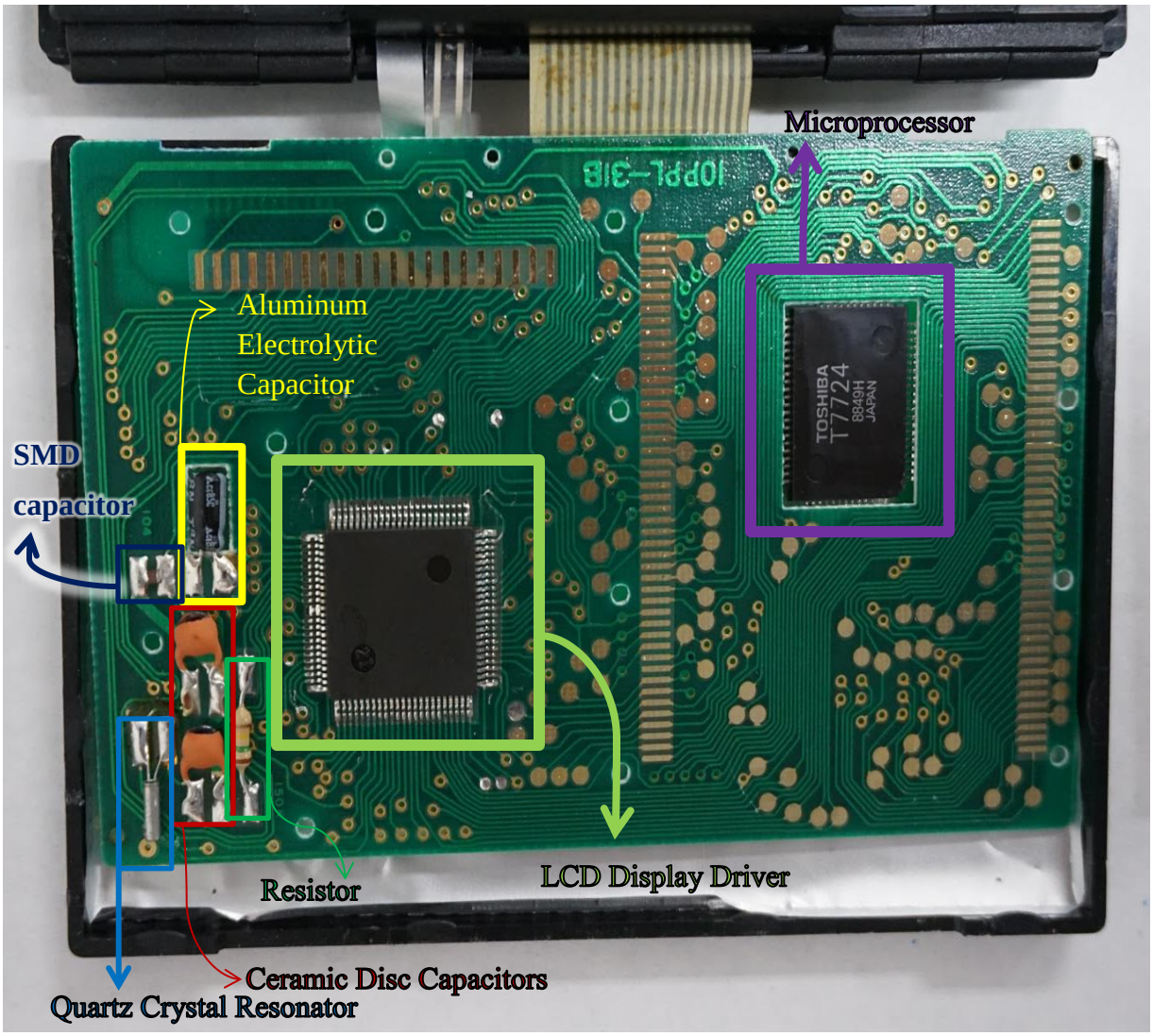


Diagram g. Display PCB under LCDs

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