The device is a Cavro Scientific Smart Valve Controller from 1992. I found this board in a box at the local maker space and was intrigued by its beautiful and high-quality construction. Cavro, now owned by Tecan, specializes in laboratory robotic liquid handling. The Smart Valve is a serial-controlled stepper motor valve for switching liquids between tubes. This board is divided into 4 distinct areas: power, computation, communication, and motor control.

An NEC D78C10AGQ 8-bit microcomputer loads a program from a 256k Read-Only Memory using two 8-bit buses for addressing and data. This bus is shared with 8k of Static Random Access Memory (V62C51864L). The address bus runs through a Texas Instruments 74HC573 Tri-State Octal Latch.

This latch consists of 8 flip-flops triggered by a Latch Enable pin, allowing data storage, and switches triggered by an Output Enable pin, allowing the outputs to be disconnected. These latches are useful in data buses where data must be held for the next instruction, but having multiple chips connecting the same wires to GND or 5V can cause a short circuit.

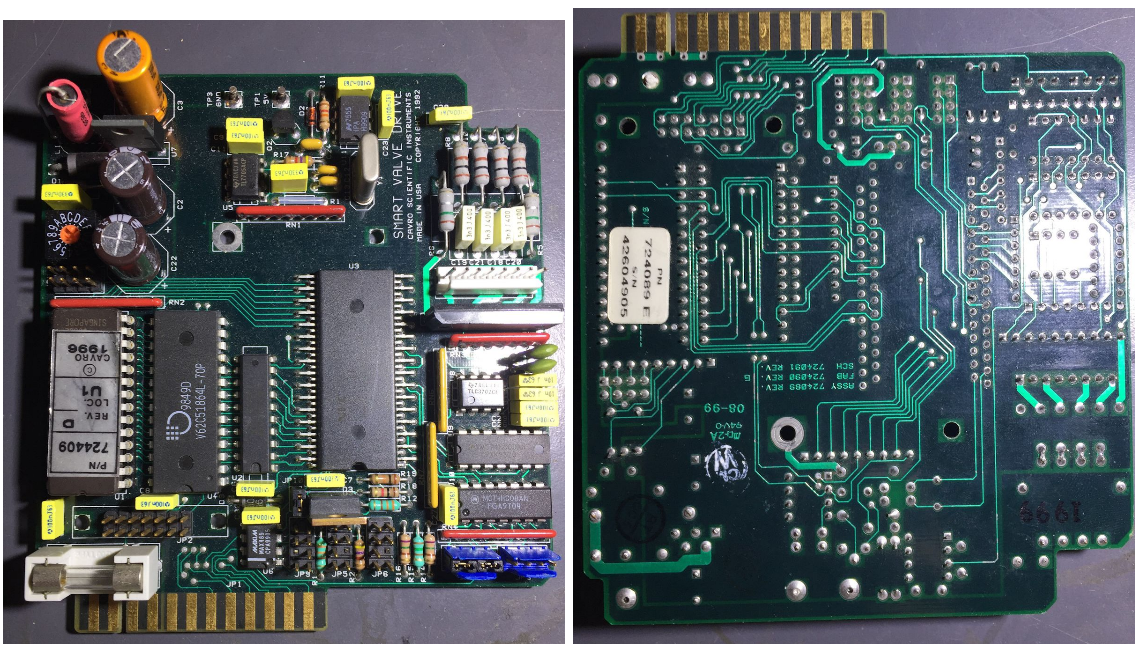
The microcomputer can output an address number, and store that number in the latch by pulling the Latch Enable pin to 5V. The Output Enable pin is tied to GND, which means the latch will always output to the SRAM and ROM. This allows the microcomputer to latch the address, select the SRAM or ROM chip using their respective Chip Select pins, and then read or write data on the next instruction.

The clock is a 14.74MHz crystal oscillator connected to the clock pins of the microcomputer. A 555 timer generates another signal that is used in the two 74HC chips of the motor driver. A Texas Instruments TL77005ACP Supply Voltage Supervisor monitors the voltage coming in from the power supply of the board and sends a RESET signal to the microcomputer when the voltage is stable. This is crucial in precise equipment when an inaccurate voltage could lead to unexpected behavior.

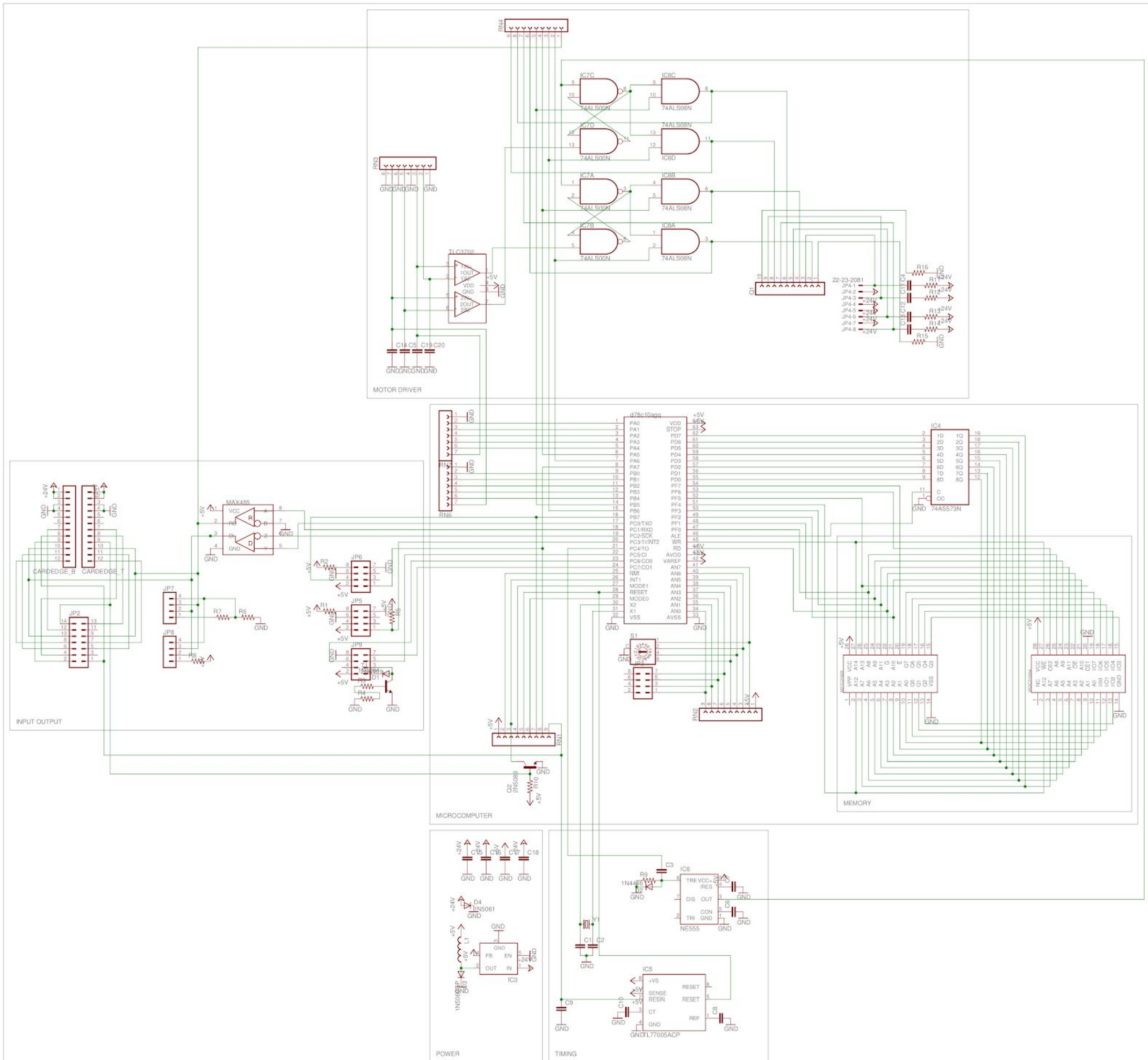
The microcomputer operates the motor control circuit via two basic DACs made with resistors. In the motor driver circuit, a Texas Instruments TLC3702 Voltage Comparator takes these two analog inputs and feeds them into two gate chips wired to generate patterns for the stepper motor. The 74HC00 NAND gate chip appears to be made into two SR latches and the 74HC08 AND gate combines those with another 4 bits from the microcomputer. These gates then drive a large transistor chip, which switches 24V power to the motor coils.

This was the first time I have ever simply found a piece of something and been able to figure out exactly what it is in enough detail to replicate it. The experience taught me how to do this and gave me the confidence to try again in the future. It also gave me insight into the design process of the product, and how engineers think when designing a reliable piece of laboratory equipment.

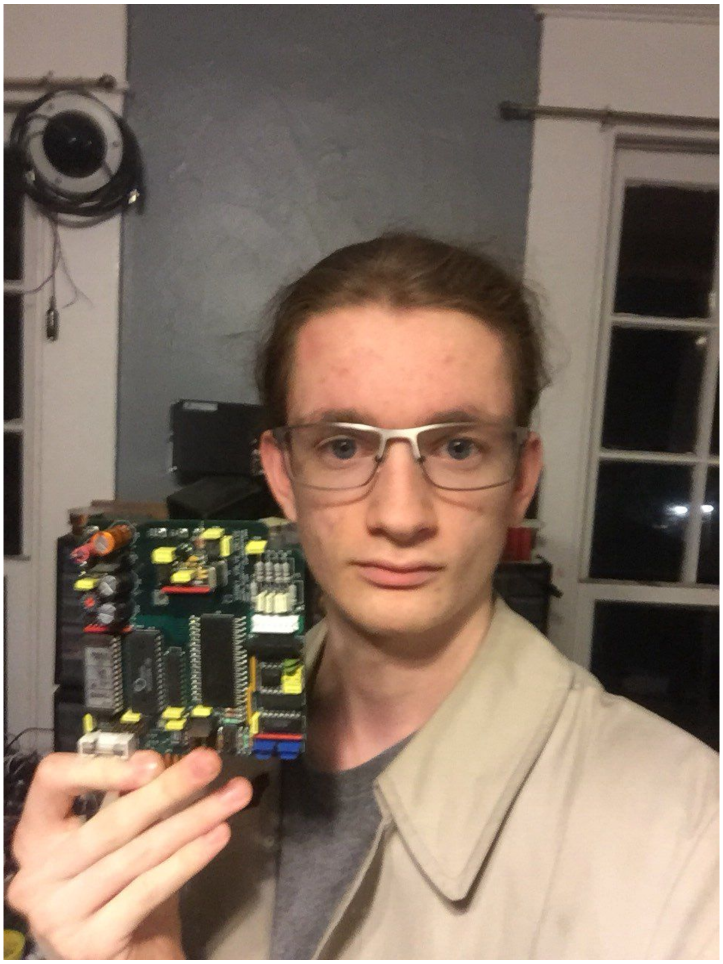
Photos



The front and back of the 4-layer board.
This device still works and I can see activity on the memory buses.



I carefully mapped out the traces on the board over several days. It was far more interesting than it sounds.



Components list:
ROM: m27c256b 256k EEPROM
RAM: v62c51864 8k x8 SRAM
Micro: d78c10agq 8-bit microcontroller with ADC, 44 I/O lines, and no ROM
MAX485: RS-485 transceiver
555: 555 timer
TL7705ACP: Voltage monitoring and reset pin
TLC3702CP: Voltage comparator
74HC00: Quad input NAND gate
74HC08: Quad input AND gate
74HC573: 3-state Octal latch
Capacitors: Nichicon
1A fuse