A Homebrew Analog Computer

The author's reflections on his early-60's computer experiments

By Forrest M. Mims III

In the early 1960s, before the arrival of the integrated circuit and the microprocessor, do-it-yourself computer hobbyists were a rare breed. Some built primitive digital machines using stepping relays and indicator lamps, while others made analog models from potentiometers and meters.

While a student at North Junior High School in Colorado Springs in 1958, I was fascinated by articles about "electronic brains" in *Popular Electronics*, a magazine published for electronics hobbyists. Unable to afford the material to build a digital machine, I experimented with simple analog computers made from potentiometers and meters. I entered two of these machines, which solved simple arithmetic problems, in school science fairs.

Thanks to the inspiration of daydreams brought on by the daily task of memorizing long lists of vocabulary for a 10th grade Latin class, in the spring of 1960 I began designing an analog machine for translating languages. That fall I assembled a working version of the translator.

The translator worked poorly, but it placed third in the math division of a regional science fair. By the time I graduated from high school in the spring of 1962, the translator worked reliably. Its design was more complex, and it could be programmed to translate 20 words of one language into another.

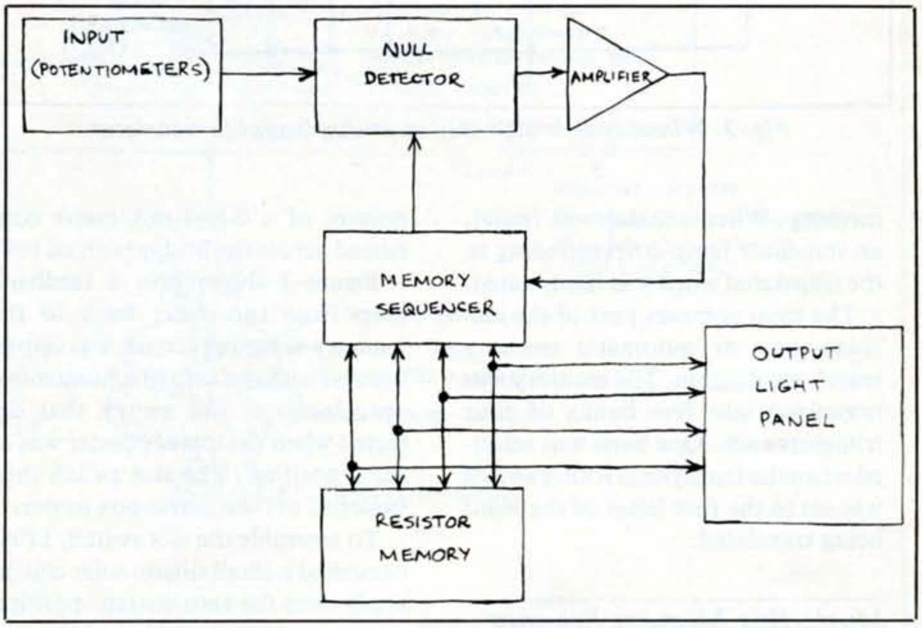


Fig. 1. Block diagram of analog computer language translator.

My translator, which required up to a second to match an input word with a word in its memory, was extremely slow by today's standards. It was also much bigger, heavier and had considerably less vocabulary capacity than a pocket phrase book, but it actually worked.

An Analog Memory

A unique feature of the translator was its use of an array of miniature screwdriver-adjustable trimmer resistors as programmable analog storage elements. Borrowing from today's terminology, the trimmer array could be considered an SPROM (Screwdriver-Programmable Read-Only Memory).

Twenty trimmers were provided, one for each word. Each word was manually set to a resistance corresponding to that of one of the words in the machine's vocabulary.

Figure 1 is a simplified block diagram of the machine. In operation, the first six letters of a word to be translated were dialed into an input panel containing six potentiometers connected in series. Each word provided a different resistance.

The first letter of the word was then dialed into a rotary switch on the machine's main control panel, and then the power was switched on. The machine then automatically compared the input resistance with each of the trimmer resistors in its

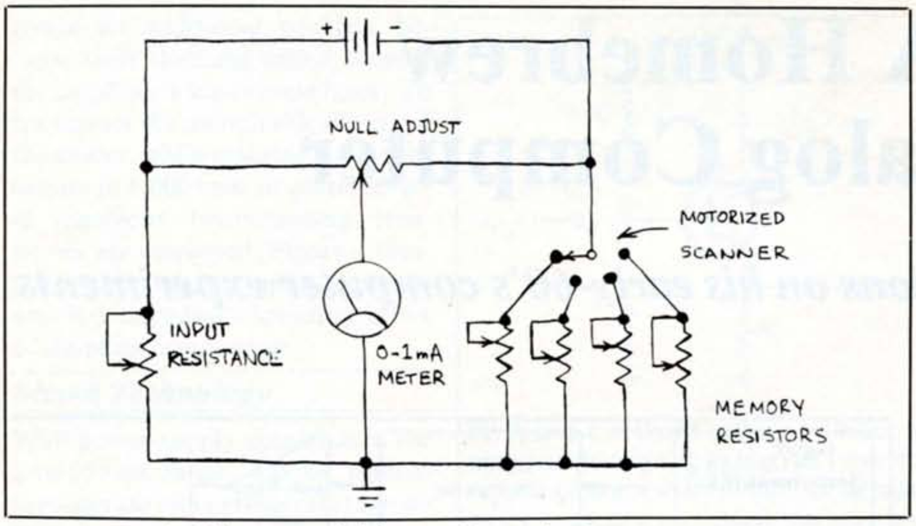


Fig. 2. Wheatstone bridge used in analog language translator.

memory. When a match was found, an indicator lamp corresponding to the translated word was illuminated.

The most complex part of the machine was its automatic memory search mechanism. The memory was organized into five banks of four trimmers each. One bank was selected when the front panel rotary switch was set to the first letter of the word being translated.

Music-Box Memory Scanner

In those days, I couldn't afford a stepping relay. Therefore, I modified a battery-powered music-box mechanism to sequentially scan each of the four trimmer resistors in the preselected bank.

The most difficult part of the design was devising a method to determine when the resistance of the word dialed into the input panel matched that of one of the trimmer resistors in the machine's memory. The obvious solution was to make each resistance one leg in a Wheatstone bridge, as shown in Fig. 2.

A potentiometer connected across the two resistors permitted the bridge to be balanced so that the current flow through each side of the bridge was equal when a match was made. A match was indicated when the pointer of a 0-to-1-mA meter connected across the bridge pointed to 0.

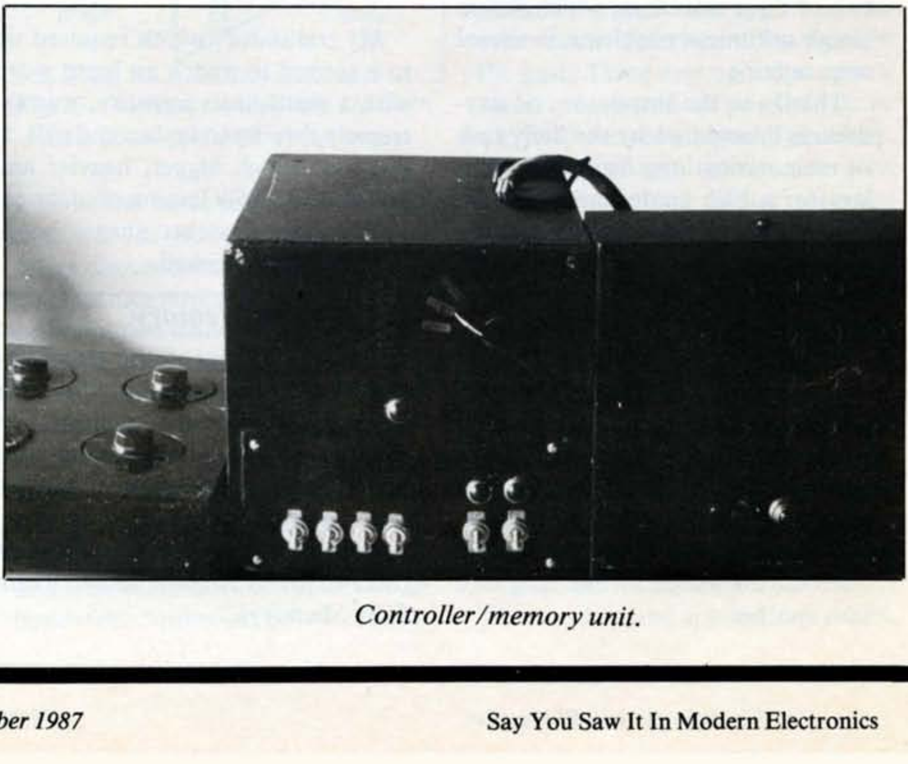
Figure 3 shows how a feedback loop from the meter back to the memory scanning circuit was implemented with the help of a homemade optoelectronic slot switch that detected when the meter pointer was at the 0 position. The slot switch then switched off the music-box motor.

To assemble the slot switch, I first cemented a small silicon solar cell directly over the zero-current position marked on the faceplate of the meter. Then I carefully cemented an aluminum-foil flag to the meter's pointer. Finally, I replaced the meter's glass faceplate with a sheet of black plastic. A slot cut into the opaque cover allowed light from a small lamp to strike the solar cell's sensitive surface when current flowed through the meter.

The solar cell was connected to a single-transistor amplifier whose output struck the cell. The relay's contacts were connected as a switch between the electromechanical memory scanning mechanism and its battery. Therefore, when the meter indicated a current, the solar cell was illuminated and the memory scanner continued to operate.

If the pointer moved to the zero position, thereby indicating a match in the resistance of the input and the sampled memory trimmer, the foil flag shaded the solar cell. This caused the relay contacts to switch off the motor-driven scanner while simultaneously applying power to a panel of incandescent indicator lamps. A single lamp glowed to indicate the translated word.

Though my analog language translator was a bit clumsy, it did work. Recently, I recovered it from



Controller/memory unit.

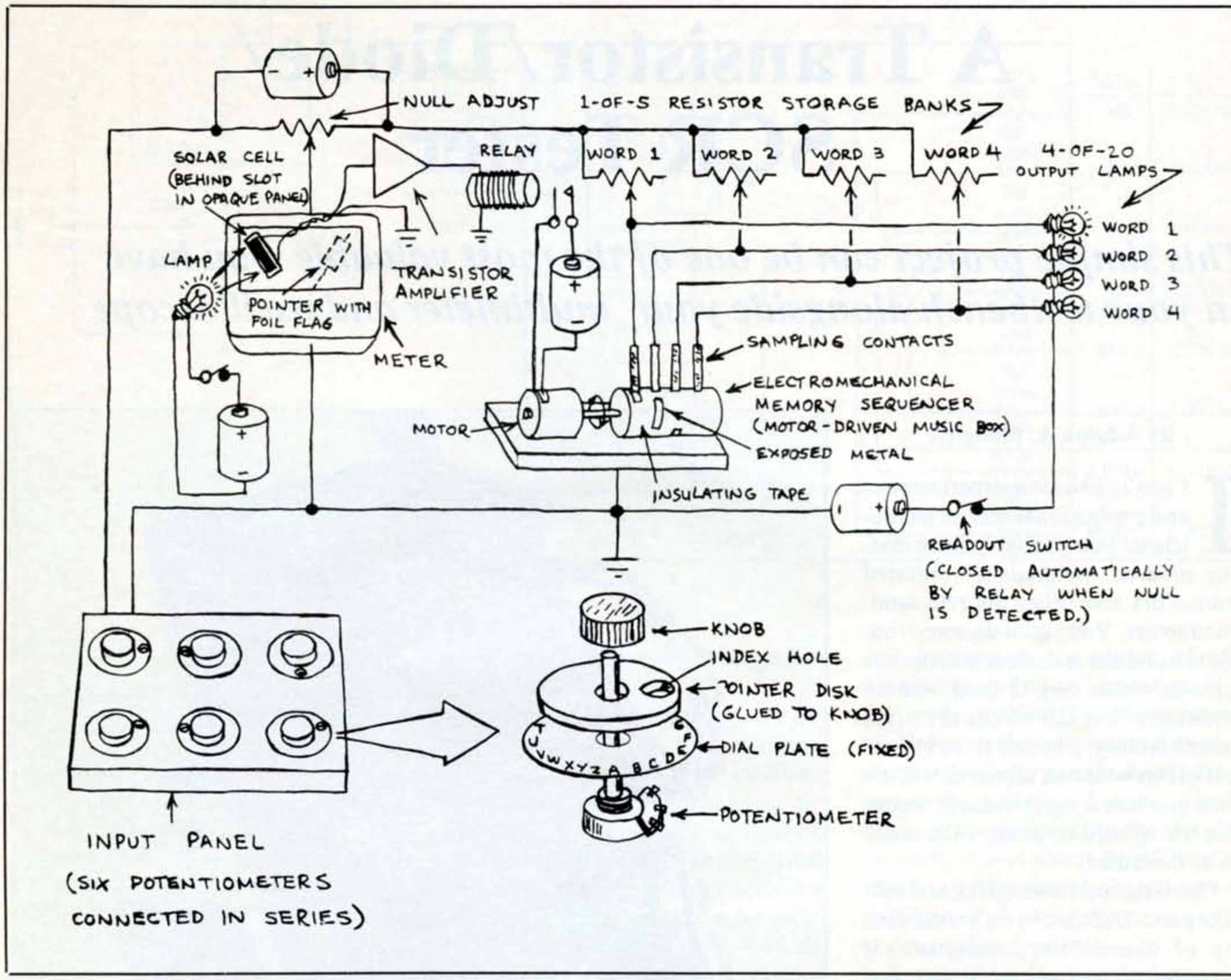


Fig. 3. Circuit and mechanical details of analog computer language translator.

the attic, wiped off the dust and inspected some of its hundreds of solder connections. Only two of the knobs on its input panel were missing. Everything else, from the meter pointer flag and the solar cell to the music-box scanner and trimmer-resistor memory board, is still in place.

Though more than 20 years old, the batteries have not leaked. When time permits, I'll replace them with a new set and find out if the translator still translates.

Lessons From the Past

Tinkering with this antique analog machine has made me acutely aware of the sophistication of today's computers. Nevertheless, I'm still attracted to that primitive but still viable method of using trimmer resistors as storage elements. Assuming a 100-ohm space between settings, a 1,000,000-ohm (1-megohm) trimmer can be "programmed" with a screwdriver to any of 1,000 different resistances. This is nearly the storage capacity of an 11-bit binary register.

Moreover, the music-box mechanism, meter, slot switch and relay of my old translator can now be replaced with several integrated circuits. A solid-state version could be designed around a comparator, some analog switches, a clock circuit and a decoder counter.

However, I wouldn't use an updated version of the translator for translation; that task is handled much more efficiently by digital processors. Instead, I would use it for controller applications that can best exploit the simplicity of a screwdriver-programmable read-only memory.

Imagine a miniature analog-digital machine that operates sequentially, has a programmable memory and responds directly to analog input signals. Perhaps I'll build a breadboard version and see how it works. **ME**