Designing a Tiny Magnetic Card Reader

Here's how it was designed and how it works.

by Robert B. Taggart

ONE THING WE HAD WAS an abundance of ideas for tiny card readers. The HP-65 card reader project began in the electronic research laboratory of HP Laboratories before the introduction of the HP-35. The basic design goal for the card reader was to propel a magnetic card the size of a piece of chewing gum at a constant speed of 3¾ to 6½ cm/s. Of course, it also had to fit inside the HP-35 package.

Many schemes were tried, including music box mechanisms, hand feed, gravity feed, and dashpot systems. Motor-driven schemes didn't generate much enthusiasm at first. But one day while digging through a file on motors that was about to be discarded, I found a brochure describing a Swiss-made motor less than 1½ cm in diameter. Within a day we obtained two samples. They had ample torque and their unique construction provided very low brush noise. The motors had a tested lifetime of over one thousand hours.

These tiny motors turn at speeds in excess of 10,000 r/min. The problem of reducing this high speed down to 6 cm/s was solved by using a worm gear, which provides a large speed reduction in one stage. Other schemes were tried but the worm and wheel combination proved best.

Gripping of the card under all conditions was another problem that had to be solved. The card is very small and would be handled extensively. Even grease could not be allowed to stand between a card and good gripping. Plastics and rubbers of various kinds and textures were tried. We tried to put tire-like treads into the rubber and even put ridges in the card for better grip. But finally we found a polyurethane rubber with the right texture that grips even when the card is coated with oil.

The major problems we faced were caused by trying to squeeze so much information onto such a short card. If the card could have been longer the design would have been much easier. However, having a short card offers the user the convenience of labeling the top row of keys with the program card. This restricted the length of the card to less than the width of the calculator. All kinds of things become critical in trying to read and write on short magnetic cards in such a small machine at 300 or more bits per inch. Azimuth alignment of the magnetic head at 400 bits per inch must be accurate within ±¼ degree. The best way to align heads with this precision is under a microscope. But can you align a head to this kind of accuracy in a molded plastic part? Based on the HP Manufacturing Division's confidence in the plastic we decided to try. We succeeded, thereby achieving a significant cost saving over using a metal frame. Using such a short card required bunching the magnetic head very close to the drive roller and gear train. This unusual geometry combined with the tight tolerances of ±0.001 inch on some dimensions made the reader frame a complex challenge.

The short card and higher bit density created numerous problems related to keeping the vibration of the drive train to a minimum. Of all the problems we faced this proved to be the most difficult. Finding the right process for making the worm gear and refining that process to a high degree made it possible. A method was developed to couple the worm gear to the motor and all these ideas combined to provide the necessary precision and smoothness. The bit-to-bit speed variation was held to less than 10%.

Another challenging problem involved inventing the set of switches that turn on the motor when the card is inserted, then turn on the magnetic head when the card is over the head, and finally provide file protection when the card corner is cut off. Three switches are provided. Some of these serve double duty in that they help wrap the card over the magnetic head for better head contact. The geometry of the switches is unusual and many new ideas were required to fit three switches, a gear train, a drive roller, a backup roller, and magnetic head pole tips in a volume of 1¼ × 1¼ × 2½ cm. This very tight spacing was made necessary by the short card length and high bit density.

The short card and the fact that the recording rate is controlled by the clock in the calculator requires that the speed of the card be kept nearly constant under conditions of varying temperature and humidity. For instance, with a slow clock and a fast card reader it is conceivable that the card might go through the machine before all the program could be recorded on it. Conversely, if the clock were fast and the card slow the bit density could exceed the maximum permitted by the head alignment.

To solve this problem the voltage across the motor is regulated and each machine's card speed is set within ±2% by an external trimming resistor on the bipolar circuit that sets the voltage across the motor. We had decided at the outset to use as large a motor as would possibly fit to maximize the amount of available torque. The greater the available stall torque the less sensitive the card reader will be to changes in load. This eliminates the need for feedback speed control.

Speed control turned out to be a very nasty problem particularly at low temperature. It was discovered that at freezing temperatures the polyurethane rubber becomes hard as a rock. This increases the current drain on the motor enormously and reduces the card speed to almost zero. Numerous other types of rubber were tried, many of which remained softer at low temperature, but none of which gripped as well as one polyurethane composition. Eventually by increasing the thickness of the polyurethane we reduced the magnitude of the problem. It was at this point that we appreciated the unique gripping properties of this type of polyurethane.

How the Card Reader Works

Fig. 1 is a diagram of the card reader. As the card is inserted into the right side of the machine, it is forced against one edge of the card slot by one of two tiny leaf springs. This helps align the card with the magnetic head. Pushing the card farther into the machine causes it to activate the motor start switch when the card approaches the rubber drive roller. This turns the motor on.

Each of the three switches in the card reader is activated in the same way. The card displaces a nylon ball resting on the bottom of the card slot. Movement of the ball forces a tiny finger of copper to move upward. The end point of this copper switch finger makes contact with a contact pad on the underside of the keyboard printed-circuit board. The contact point of the switch moves a distance several times the thickness of the card to provide a reliable contact. Each switch is adjusted to the proper contact position during assembly.

When the bipolar motor circuit is turned on a precise voltage is fed to the motor terminals to establish the motor/card speed to within a few percent. The motor turns at a speed near 10,000 revolutions per minute. The motor is directly coupled by a tiny polyurethane sleeve to a miniature worm gear. The end of the worm gear rests against a thrust ball bearing and drives a helical gear. The helical gear is pressed onto the hub of the polyurethane rubber drive roller, which grips the card.

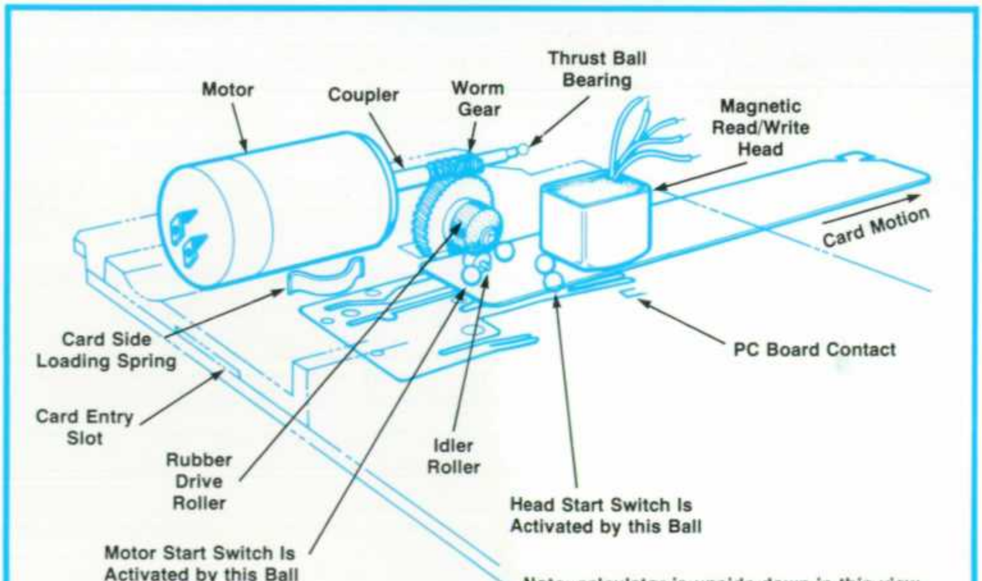

Fig. 1. *The HP-65 card reader.*

Once the motor is turned on by the motor start switch the user must push the card another small fraction of a centimeter so the rubber roller will grip the card. The card is then pinched and driven between the rubber roller and a fixed tiny idler roller made of nylon. The card proceeds through the machine toward the magnetic read/write head. Little bumps in the plastic support plate combine with the switch balls to wrap the card over the gap of the head.

As the card passes the magnetic gap of the head the leading edge of the card activates a second switch. This switch starts the write or read circuitry, depending on the position of the W/PRGM-RUN switch. Activation of this second switch lets the circuits know that the card is over the head and is assumed to be moving at the proper speed.

At nearly the same time that the second switch is activated, a third switch may or may not be activated depending on whether the corner of the card is cut off. This is the file protect scheme, which prevents the user from writing over a previous program. When the second switch is activated the third switch is interrogated. If the third switch is not activated (the corner being cut off) the machine will not write over that card when the calculator is in the W/PRGM mode. The data is written/read by a two-track recording scheme which is described elsewhere. As the card proceeds out the left side of the calculator it is held against the side of the card guide by a second side-loading leaf spring. When the trailing edge of the card passes the motor start switch the motor and read/write circuits are shut off. The card may then be removed from the machine.

Fig. 2 shows the card-reader parts disassembled.

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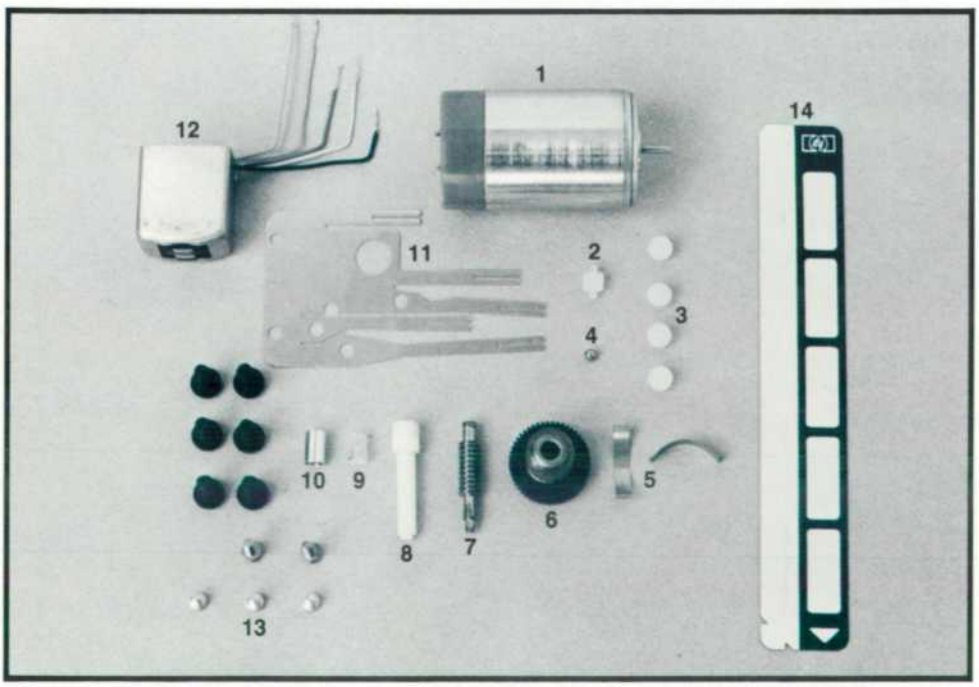

Fig. 2. *HP-65 card reader parts: 1. Motor 2. Idler roller 3. Switch activation balls 4. Thrust ball bearing 5. Card side loading springs 6. Rubber drive roller and helical gear 7. Worm gear 8. Drive pin 9. Coupler 10. Coupler sleeve 11. Switch contacts 12. Read/write head 13. Self-tapping switch adjustment screws 14. Magnetic card, 7.1 cm by 1 cm.*