HYBRID CIRCUIT MODULES FOR MOTOR COMMUTATION AND CONTROL

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Since the advent of space flight, we have been involved in the development of electromechanical torque systems for the space environment. We felt that three major areas required additional development to assure proper and long-life operation of hardware. These areas are (1) bearings, (2) torque multipliers, and (3) motors (Figure 1).

(1) Since standard contacting bearings present lubrication problems in a hard vacuum, we have developed magnetic bearings which eliminate physical contact between members.

(2) Although direct drive systems are feasible in certain applications, gear reducers have weight and size advantages when used as torque multipliers. We now have developed a rotary actuator which greatly reduces the windup and backlash normally encountered in gear reducers; in addition, the device has an integral motor.

(3) The two motors most widely used with torque-producing devices in space missions are the synchronous hysteresis motor and the permanent-magnet dc motor. The commutator for brushless dc motors will be discussed in this paper.

Since permanent-magnet dc motors normally incorporate brushes and brushes generate electrical noise and have limited life, we developed techniques which eliminate these problems. Although we have made contributions to flight programs in the past in an advisory capacity, we are now prepared to support this advice with space-qualified designs. Brushless motors and torquers have been used in existing programs. Various techniques have been developed on an application-by-application basis. No standard approach or hardware exists and every new application demanded its own development program and flight qualification process.

This past year we have developed circuitry, covering a wide power range, which can be easily qualified to a particular flight specification. We have done this by packaging circuitry, successfully employed in the laboratory, using "thick film" hybrid techniques. It was decided to use a modular approach. The modules developed will be tested in a set of environmental conditions to establish the reliability of the approach.

Figure 2 shows the basic building blocks required for a brushless motor. The power commutator contains the driving circuit for the motor armature and an amplifier that controls the armature current. The position decoder contains digital integrated circuits which receive the signals from the armature position sensors and generate the driving signals for the power commutator in the proper sequence. V_{in} is the input voltage, which controls the motor current, and the CW and CCW commands determine the rotational direction of the motor. These two blocks are each packaged in a square package, 2.5 cm on a side. Photographs of the units are shown in the upper portion of Figure 2. This is all the hardware required to drive motors with stall currents up to approximately 400 mA, which represents at least a 4:1 weight and volume advantage over previous methods.

To extend the range to about 2.5 A, only two more similar units need to be added. To extend the range to 20 A, these four units should be employed, and the analog mode of current control used in the 2.5 A configuration should be changed to a switching mode of current control. To control the motor in a feedback configuration, one more unit of the same dimensions should be added, and full bidirectional control is obtained.

This approach has resulted in a total system efficiency of 70 percent from 45 mA to 20 A, representing a current ratio of 450:1. Figure 3 shows the three current regions covered. It indicates the load-dependent and the load-independent losses encountered and shows that through the proper choice of system configuration 70 percent efficiency can be maintained.

Again it should be emphasized that we are now prepared to support the advice we have provided in the past with space-flight-qualified designs. This has been accomplished by packaging standard electronic circuitry in hybrid form which can be readily qualified to any required space-flight specification.

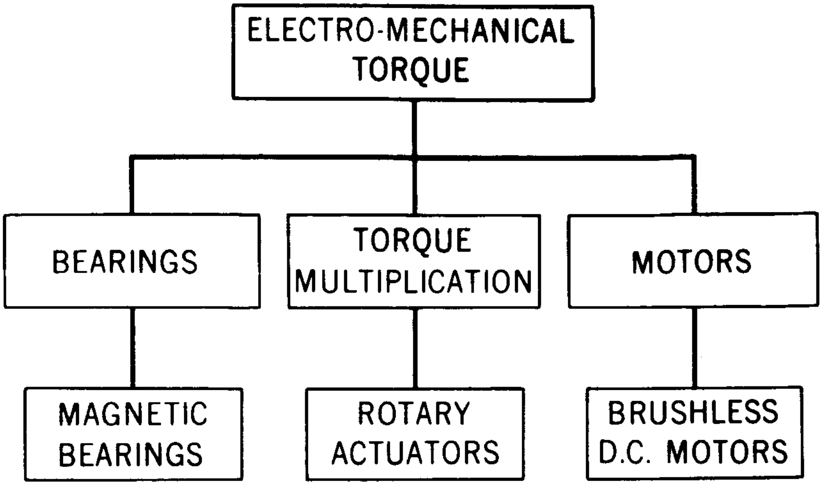

Figure 1—Systems under development.

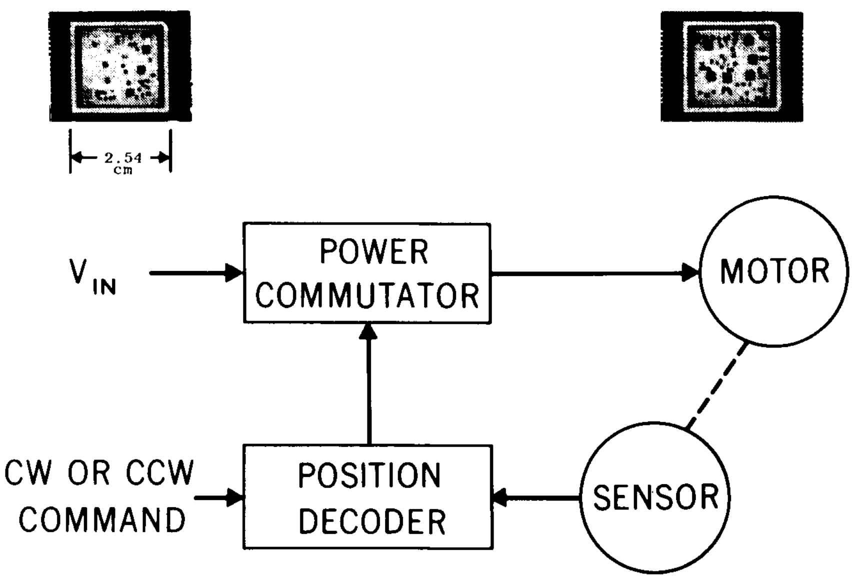

Figure 2—Hybrid circuit commutator.

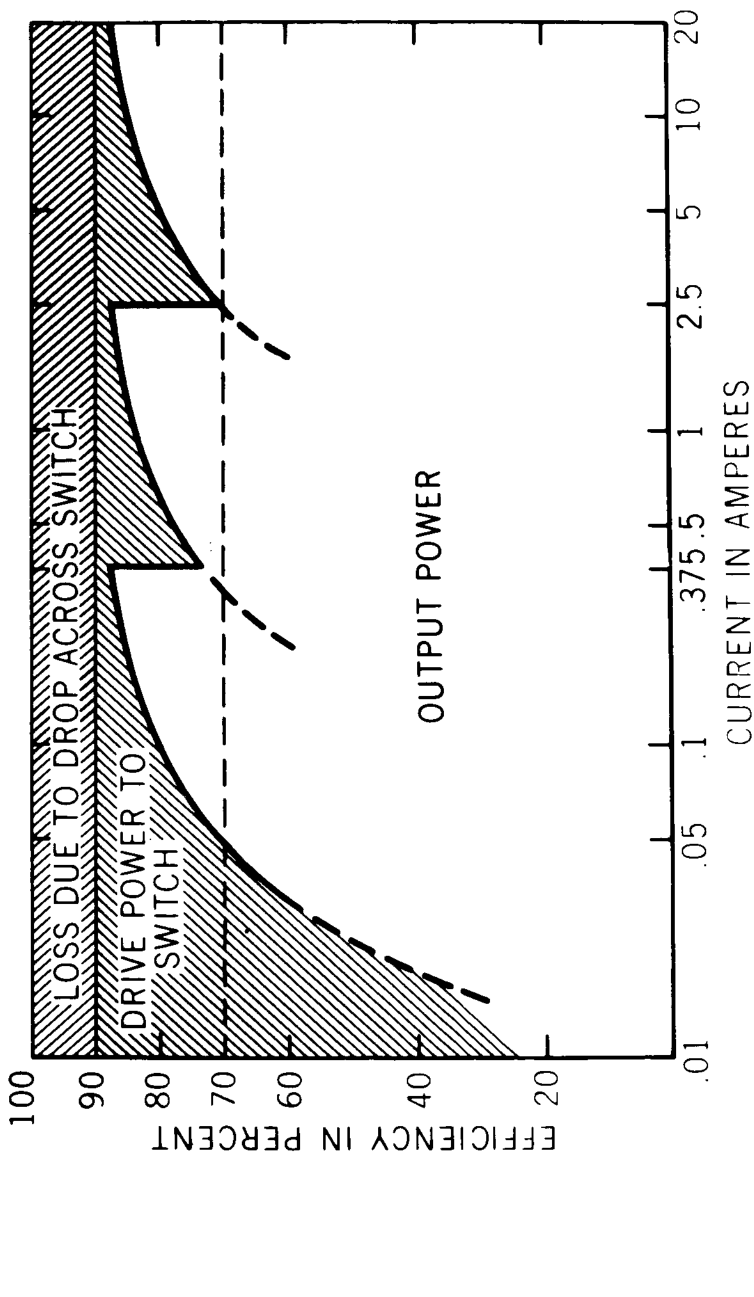

Figure 3–Efficiency versus load current.