



## Electronic Systems

### ✓ Robot Avoids Collisions With Obstacles

Infrared sensors detect nearby objects.

*John F. Kennedy Space Center, Florida*

A developmental robot is equipped with infrared sensors and with a control system that act in concert to enable the manipulator arm to move around obstacles. The robot can avoid collisions with other objects, even when they are moving in unpredictable ways. The control system of the robot requires no prior knowledge of the environment, unlike traditional robot controls, which rely on complete mathematical models of the environment and are at a loss when geometric relationships change or are even partly unknown.

The sensor subsystem includes standard 40-conductor ribbon cable. Forty-pin sockets are attached to the cable at intervals of about 50 mm. An infrared light-emitting diode and a positive/intrinsic/negative photodiode are inserted in each socket. The leads of these diodes are bent

so that each makes contact with a different set of conductors in the ribbon. The diodes can thus be addressed and turned on by energizing the appropriate conductors. The ribbon cable is flexible, and can be conformed to any shape object, and placed on the robot where required.

When a light-emitting diode illuminates an obstacle, the reflection is sensed by the collocated photodetector. The control algorithm for the sensor strives to attain two goals: to move the end effector of the manipulator to a target position and to avoid obstacles. The highest priority goes to avoiding collisions; moving the end effector toward the desired position is permitted only when the path is clear.

The algorithm operates in three modes,

- Mode 1. The arm moves the end effec-

tor toward the target, when no objects are in range, at a standard minimum velocity.

- Mode 2. When an obstacle comes within range, the redundant degree of freedom of the arm is used to avoid hitting the obstacle while continuing to move toward the target.
- Mode 3. If the obstacle comes even closer, all the joints of the arm are moved as necessary to avoid hitting the obstacle, even if this entails moving the end effector away from the target.

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