

CHAPTER 4
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Battery Operated Capacitive Proximity Switch

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INTRODUCTION

A capacitive proximity switch has been developed which is battery operated. This type of switch is very useful as an input interface device for children with disabilities. This device is especially suitable for children whose most reliable activation site (part of the body that can be used to operate input devices) is the jaw or head. This is because severe motor deficiency of both upper and lower limbs limits direct access to computers and other electronic devices by these individuals. Since the device is a proximity switch, a true zero force input is obtained while still providing tactile feedback. Therefore, movement of the jaw or head can be used to operate or control other devices. Since the device uses an analog sensor, the sensitivity and range of the device are also adjustable. This adjustability allows for accommodating various sensor sizes and types, different children, and various mounting configurations. Small size and easy handling with little or no risk of damage or injury to the child is also required. Additional requirements are that the device must be portable and battery powered. No commercial devices were found that met all of the requirements, therefore, such devices were developed. This recent version incorporates a common battery checking circuit and an improved circuit for the capacitive proximity sensing.

SUMMARY OF IMPACT

A 4-year-old child with a high cervical spinal cord injury resulting from a motor vehicle accident has used this device. The occupational therapist was concerned about losing residual head and neck motion as well as psychological and behavior issues during therapy. The proximity switch was interfaced with a modified TV control unit so that the child could operate the television in her room. At present the device has been used for approximately one month and the therapist and child appear to be satisfied with the performance of the device. Some refinement and

further work is needed on the mounting system for the sensor, yet the zero-force nature of the sensor, the relatively thin sensor (<1cm in thickness) and large surface area of the sensor were advantageous. The portability and adjustability of the circuitry and physical sensor allow for adequate positioning and performance. Work is in progress to modify a remote control unit for operating a VCR utilizing the proximity device. Future work will include adapting other devices for use with the proximity device as well as other input devices.

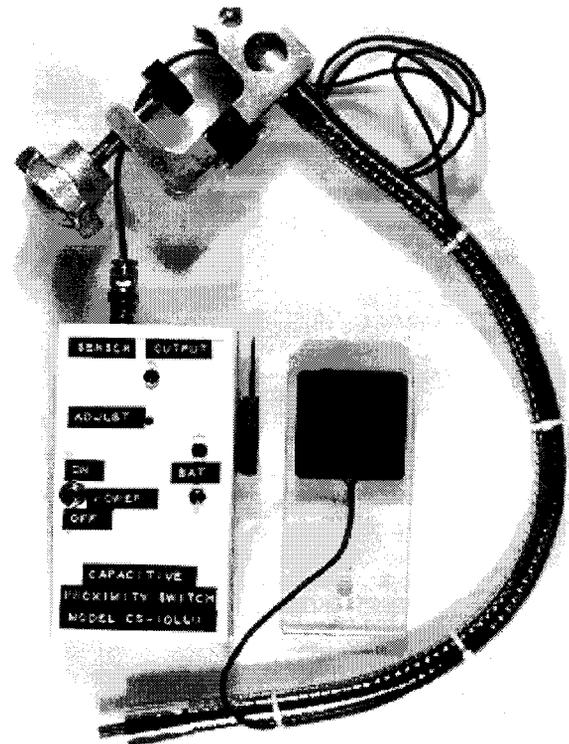


Figure 4.1. Picture of Capacitive Proximity Switch.

TECHNICAL DESCRIPTION

The physical device shown in Figure 4.1 consists of three components which are 1) the mounting system or site for the sensor, 2) the sensor probe and cable, and 3) the electronics unit. The sensor is based on the principle of the capacitive coupling between an insulated metal plate and a part of the human body such as the hand, foot, or head. As the hand, foot, or other area of the body moves closer or further from the insulated metal plate the apparent capacitance of the plate changes. Therefore, the sensor acts as a nonlinear variable capacitor. A graph of the relationship between the measured capacitance and the distance of a human hand from an insulated metal plate is shown in Figure 4.2. The schematic diagram of a circuit utilizing this phenomenon is shown in Figure 4.3. In Figure 4.3, it can be seen that the circuitry is comprised of three main IC's which are a quad comparator (LP339), a hex inverting Schmidt trigger (74C14), and a voltage reference and op-amp (LM611). One Schmidt trigger is utilized in an oscillator circuit while the remaining Schmidt triggers are used as buffers and drivers. The oscillator frequency is determined by the RC time constant of R1 and C1. Two of the comparators are used as a two-stage sensor circuit. The first stage is a differential amplifier. The signal from the oscillator is split through a variable resistor, R2, dividing the signal amplitude between two legs of a modified RC bridge. The capacitive probe is connected to the circuit via a BNC connector. The comparators output is given by

$$V_o = V_{i^+} - V_{i^-} \quad \text{for } V_{i^+} < V_{i^-}$$

and

$$V_o = 0 \quad \text{for } V_{i^+} \leq V_{i^-}$$

where V_o is the output voltage, and V_{i^+} and V_{i^-} are the two input voltages to the positive (+) and negative (-) inputs of the comparator. The input signals are from the two capacitors, C2 and the probe, which is an insulated metal plate. The RC low-pass circuit (R4 and C2) with the contribution of R2 balances out the residue and parasitic capacitance of the probe. As a part of the child's body such as the hand is moved closer to the probe, the capacitance at the probe increases. The change in capacitance results in a change in the signal amplitude of V_{i^+} . The second stage is a basic comparator with the output given by

$$V_o \approx V^+ \quad \text{for } V_{i^+} < V_{i^-}$$

and

$$V_o = 0 \quad \text{for } V_{i^+} \leq V_{i^-}$$

The resistors R6, R7, and R8 provide reference voltage V_{i^+} of the second comparator. This output from the second stage is inverted by a Schmidt trigger which drives a MOSFET (Q1) which in turn controls a relay activating the relay when the switch is activated. This switch output of the relay is accessed via a 2.5 or 3.5mm phono jack allowing for operation of a toy, tape recorder, or other device which can be turned on or off with the proximity device. The output of the second stage is also sent to another Schmidt trigger driving an LED so when the relay is activated, the LED is on indicating an on state for the relay. The adjustment of the two variable resistors, R2 and R7 allow for precise setting of the bridge and threshold for activating the relay.

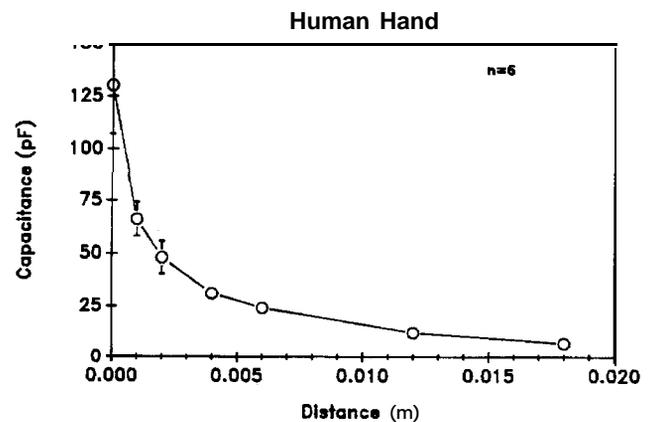


Figure 4.2. Relationship between the measured capacitance and distance of a human hand from an insulated metal plate.

A push button switch, SW2, operates the battery check circuit. The battery check circuit only draws supply current when on, thereby conserving battery power, yet allowing for testing of the battery to see if it needs to be replaced. When the battery is good, the LED, D2, is on with SW2 is depressed, else if D2 is not on with SW2 depressed, then the battery needs to be replaced.

The total cost of the device including the cable and probe(s) is approximately \$40 to \$60 or less depending on selection of enclosure, probe, connectors, and cable.

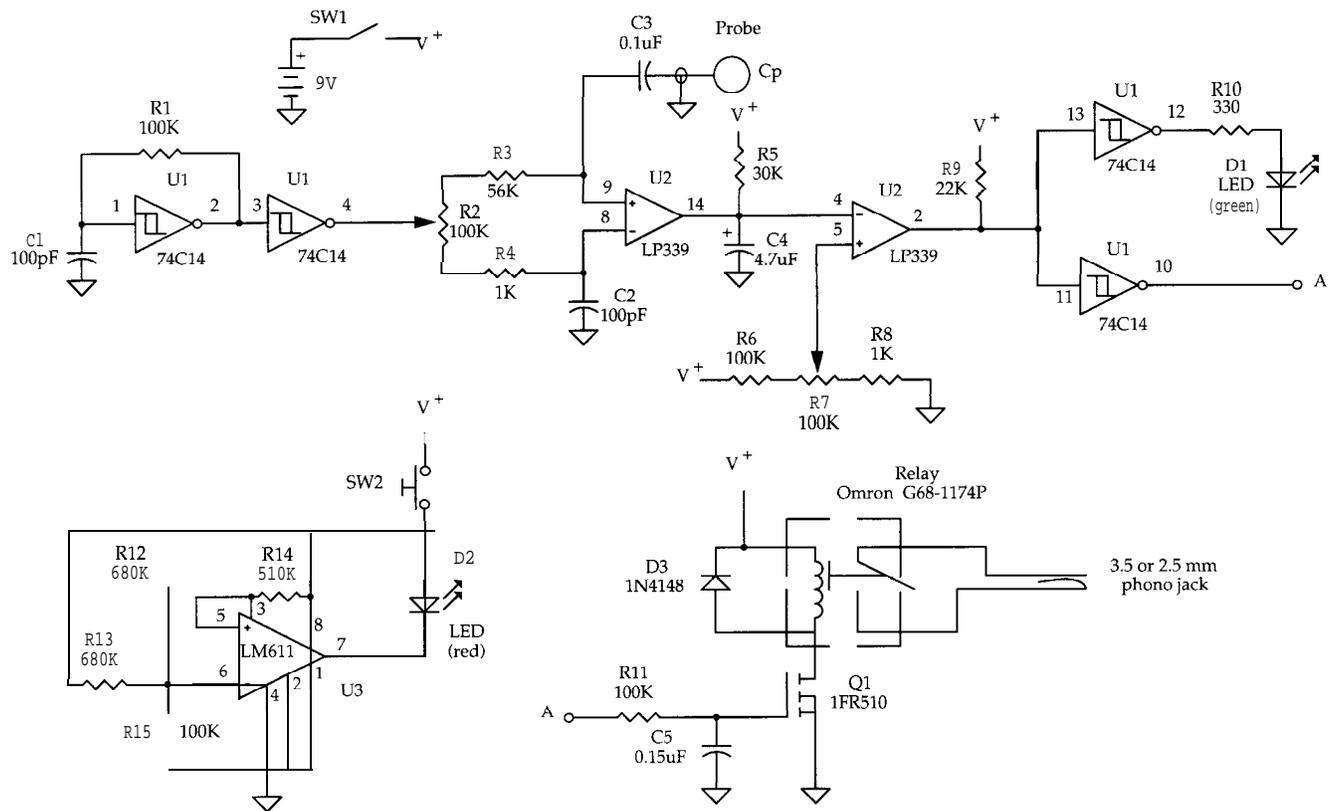


Figure 4.3. Schematic Diagram of Capacitive Proximity Device Circuitry.

A Head-Mounted Jaw Movement Transduction System for Measurement of Range of Motion of TMJ Patients

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INTRODUCTION

In an effort to quantify the effectiveness of physical therapy treatment for patients with temporomandibular joint (TMJ) pain, a device to measure the range of motion of the jaw in three dimensions was needed. Clinical observations suggest that the range of motion of the jaw of TMJ patients is limited and improves after treatment. Other investigators have shown that the range of motion of the jaw is an important indicator of the severity of TMJ symptoms. Therefore, by measuring and recording the range of motion of the jaw before and after treatment, the effectiveness of various treatment modalities can be assessed. Since no suitable commercially available device was available for this purpose, a device for measuring range of motion of the jaw was designed.

SUMMARY OF IMPACT

Although the device has not been fully evaluated yet, an examination of the device suggests that it will provide valuable data on the change of the range of motion of the jaw resulting from various treatment modalities. The data will enable the therapist to assess the success of a treatment for a patient with TMJ syndrome. In addition, the relative effectiveness of different treatment modalities can also be measured so that their relative effectiveness can be compared. By combining this data with other measures such as pain scales, electromyography data, and bite force data, a more complete understanding of TMJ problems and its treatment can be obtained. This data should aid in quantifying TMJ problems and the factors affecting them as well as the role of various treatment modalities in treating TMJ patients.

TECHNICAL DESCRIPTION

The device uses a uniform tapered cantilever beam system that can measure jaw motion in 2 dimensions. A commercially available headmount device makes it possible to measure the jaw range of motion relative to the head while allowing the TMJ patient to be comfortable during the measurement. The headmount structure consists of an ultra-low tubular aluminum superframe assembly, which can be adjusted, in three dimensions, to accommodate variations as well as asymmetries of the skull. The tubular aluminum has a 6.35-mm outside diameter and a wall thickness of 0.875-mm. The headmount weight is 160-grams, with slightly greater mass on the right side to counterbalance the transducer unit. The transducers to measure jaw motion consist of individual strain gauged cantilever modules. One cantilever module consists of two flexible metal strips to measure superior-inferior (S-I) and anterior-posterior (A-P) motion with a rigid wire piece for connection to the patient. The second cantilever module consists of one flexible metal strip to measure medial-lateral (L-M) movements and a rigid wire piece to connect to the patient. Two strain gauged are attached to each thin flexible metal piece of the cantilever beam increasing sensitivity and providing temperature compensation. Each cantilever is held by a support stand attached to an L-shaped spindle clamped to the headmount. A miniature plastic bead will be glued to a small disk that will be attached to the subject's chin with double-backed adhesive tape. A hole in the bead somewhat larger than the wire diameter will prevent artifacts resulting from small lateral-medial movements and slight rotations in the midsagittal plane about the axis of the cantilever measuring the SI and A-P motions.

