CHAPTER 11
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CONDITIONING TOOL FOR PERSONS WITH NERVOUS DISORDERS

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INTRODUCTION

Some persons who have nervous disorders, such as severe nail biting or hair pulling, engage in these behaviors so much that they are unable to function normally, due to having sore and/or bleeding fingers, hair loss, or other problems. To help condition these individuals to stop biting their nails or pulling their hair, a tool was desired to provide audible feedback when the compulsive behaviors took place, reminding the user to stop this behavior.

SUMMARY OF IMPACT

The device developed in this project is a proof-of-concept device, which allows researchers in the to record data pertaining to the number of compulsive behaviors that have taken place - with and without the audible feedback. It is hoped that these data will allow researchers to determine the effectiveness of this or other types of therapy - ultimately helping individuals to alleviate their behaviors.

TECHNICAL DESCRIPTION

The device consists of three separate parts:

- A transmitter,
- A receiver/micro-controller, and
- A liquid crystal display.

The transmitter is similar in size to a wristwatch and worn on the wrist. Each patient uses two transmitters, one for each wrist. The receiver is worn on a collar or lapel, or in some other location near the patient's head, and has a buzzer to indicate a "violation". The LCD is used only by the researcher for the purpose of retrieving the data collected, setting the buzzer and resetting the clock. Since there may be more than one patient being observed at any given time, the external LCD will provide overall cost reduction because only one display will be needed.

The transmitter is a lightweight, low-power, unobtrusive device and small enough to be comfortably worn on a Velcro wrist strap. The design is based on a Colpitts oscillator tuned to produce a 7V p-p sine wave at approximately 1 MHz (with some variation due to component tolerances). A radio frequency signal was selected since it is less affected by clothing or hair between

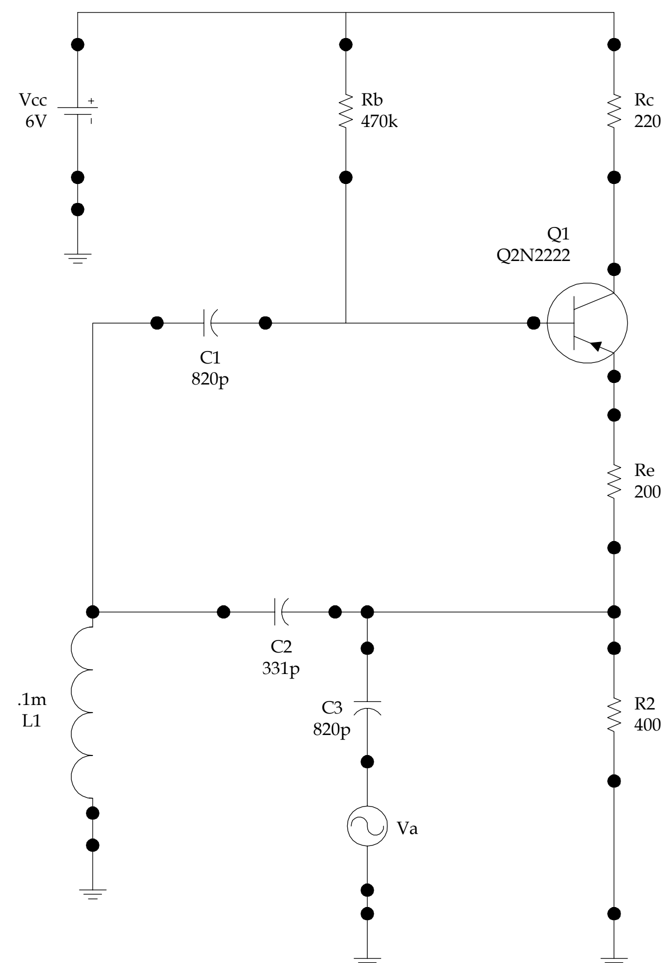

Figure 11.1. Transmitter Circuit.

the transmitter and receiver. Through experimentation, it was observed that having the transmitter strapped to a wrist improved signal range since the body acts as an antenna. Powering the transmitter are two lithium-ion coin batteries (23mm dia.). Each is rated at 3V and 250mAh, with typical drain current of 0.2mA and maximum drain current of 10mA. Each battery is fixed to the backside of the transmitter board by a 23mm battery clip.

The receiver detects the RF signal from the transmitter, amplifies it and determines if a violation has occurred. The receiver circuitry can be broken down into four subparts:

- An LC tank,
- A buffer/amplifier,
- A detector / comparator, and
- A PIC.

Separating the buffer from the BJT amplifier is an AC coupling capacitor. The BJT is configured as a common emitter amplifier. Biasing is set so that the BJT is near cutoff, allowing for maximum amplitude swing of the output, since only the peak value is of concern.

The receiver operates by detecting the relative strength of the transmitted signal. At determined amplitude, a violation is declared.

The first sub-circuit is the LC tank. It is made up of three components:

- An inductor,
- A capacitor, and
- A trimmer capacitor.

The LC tank is tuned to the transmitted signal frequency by adjusting the trimmer capacitor. The output of the Op Amp is a 0 to 300 mV p-p sine wave. The component chosen was a LT1211 single supply, low power, 14 MHz GBW precision operational amplifier. Since the Op Amp is operating in single supply mode the non-inverting terminal must be set to a voltage greater than 700 mV. This feature limits the amount of gain that can be achieved, since the DC bias is amplified along with the 1 MHz sine wave.

An envelope detector converts the clipped sine wave to a DC voltage that is then used by the comparator to determine if a violation has occurred. The comparator used is a MAX921 single supply, low power surface mount IC. Hysteresis is needed to prevent multiple violations triggered by noise or slight movements. It is accomplished by the feedback resistor and the two resistors connected to the non-inverting terminal of the comparator.

The receiver PIC software was written using the Microchip Assembly Language and is over 2,000 lines in length. The code functionality is broken into

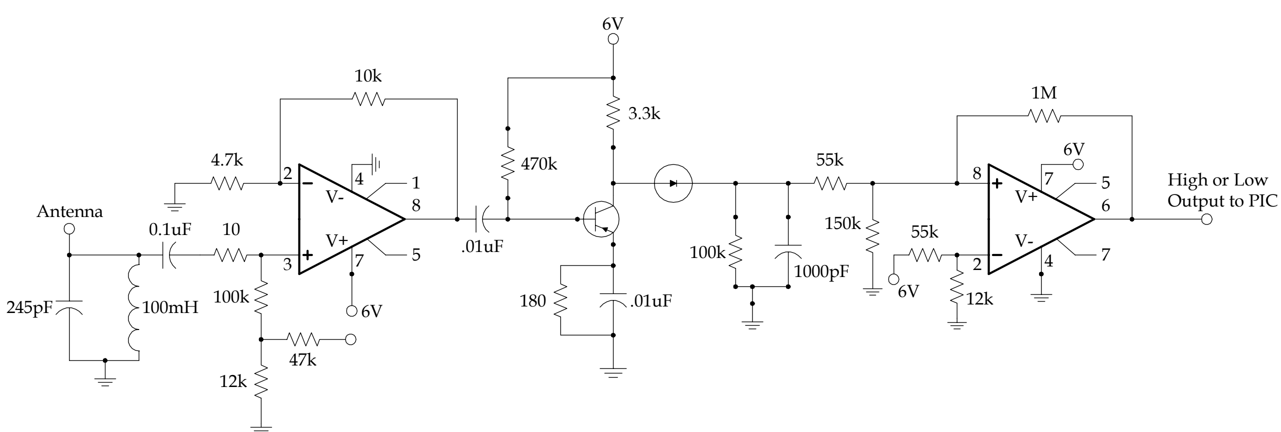

Figure 11.2. Receiver Circuit.

six individual software modules:

- Range,
- Timer,
- Data Collection Monitor,
- Analog to Digital,
- Buzzer, and
- Serial.

The Range module provides a software interface to the comparator hardware. When the comparator output swings from low-to-high or high-to-low an interrupt is fired in the PIC. The Range module then services the interrupt, calling related software routines to mark the start or end of a violation.

The Timer software module is driven by an external 32.768 kHz crystal and maintains an accurate time count at 3.9 ms resolution for up to 194 days. This code also provides a timestamp to the other software modules during a violation event (start violation or stop violation).

The Monitor software module accumulates all violation data. It is activated by the Range module when the comparator output transitions. When a violation begins, a call is made to the Timer module to capture the exact time of the event. That timestamp is then used to calculate the duration of the last non-violation. The shortest and longest non-violations are then updated with the last non-violation length if needed. When the Monitor is informed of the end of a violation, the Timer module is again used to capture the timestamp of the event. That data is then used to calculate the duration of the violation, and the longest, shortest, and total violation times are updated in memory.

The Analog to Digital (A/D) module provides a software interface for the on-chip A/D converter. The A/D input is attached to the analog input of the comparator to monitor the signal strength of the transmitter waveform. This information is never used to calculate violation data. It has been developed to drive a signal Strength Bar Graph on the Display unit, which has proved useful during Receiver hardware and software development.

The Buzzer module provides a software interface to the external piezoelectric horn. Routines are provided to activate, deactivate and mute the buzzer. When the buzzer is active and not muted, an additional on-chip timer is used to chirp the buzzer on and off. The piezo itself gives a steady tone, so the PIC output to the buzzer hardware is toggled at approximately 10 Hz. This high-pitched chirping has proven more noticeable to observers than a high-pitched, steady tone.

The final software module of the Receiver PIC is the Serial Module. It is responsible for all data communication between the Receiver and Data Display unit. Commands from the Display are analyzed for transmission errors using an 8-bit Hamming Code. This coding scheme allows 3-bit errors to be detected and avoids the execution of misunderstood commands. Once a valid command arrives on the serial line, the Serial Module makes appropriate calls to the corresponding software modules to mute/de-mute the buzzer, calculate an A/D sample, and begin data download or reset the receiver's violation data.

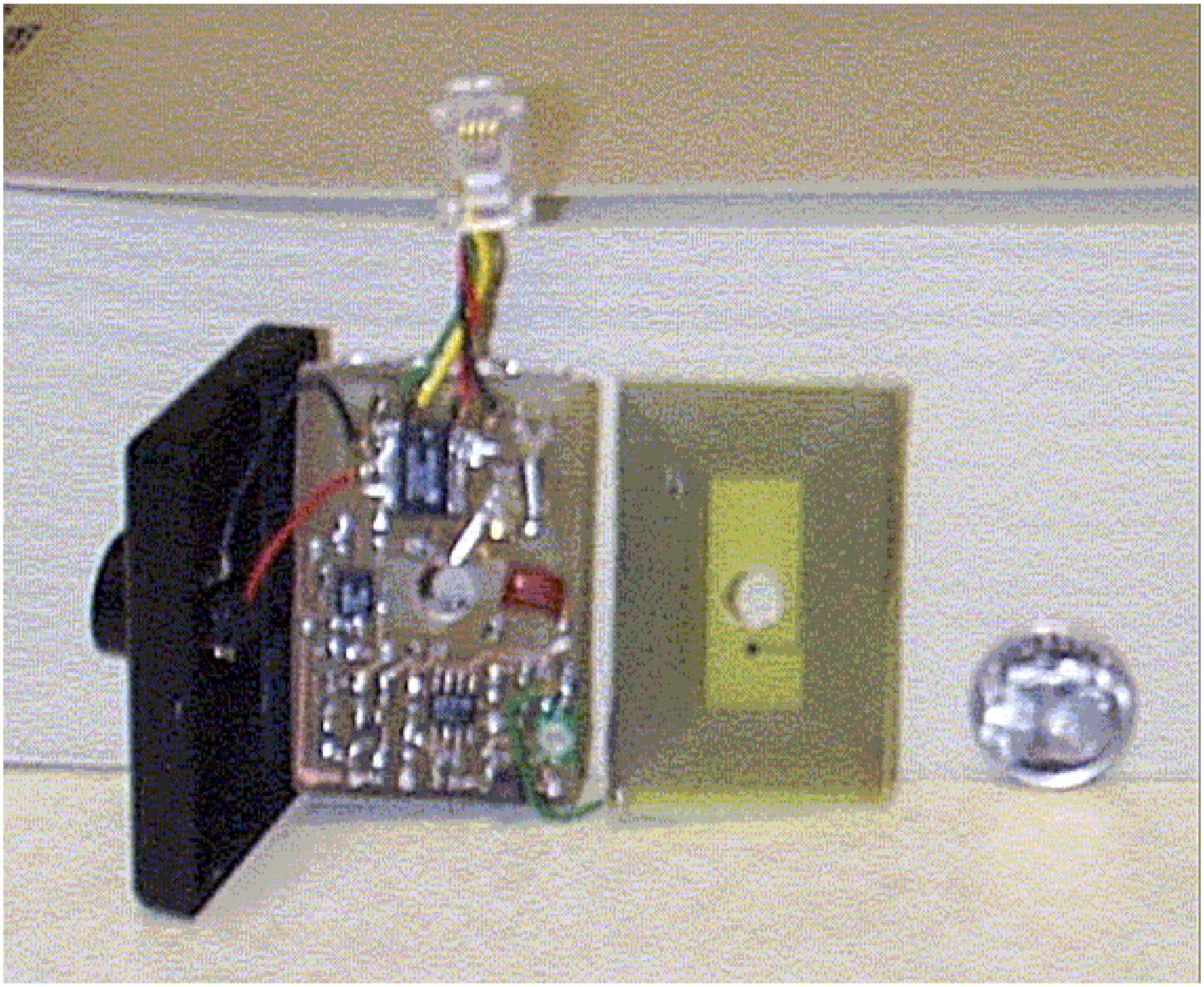

Figure 11.3. Receiver Unit for Uploading Data.

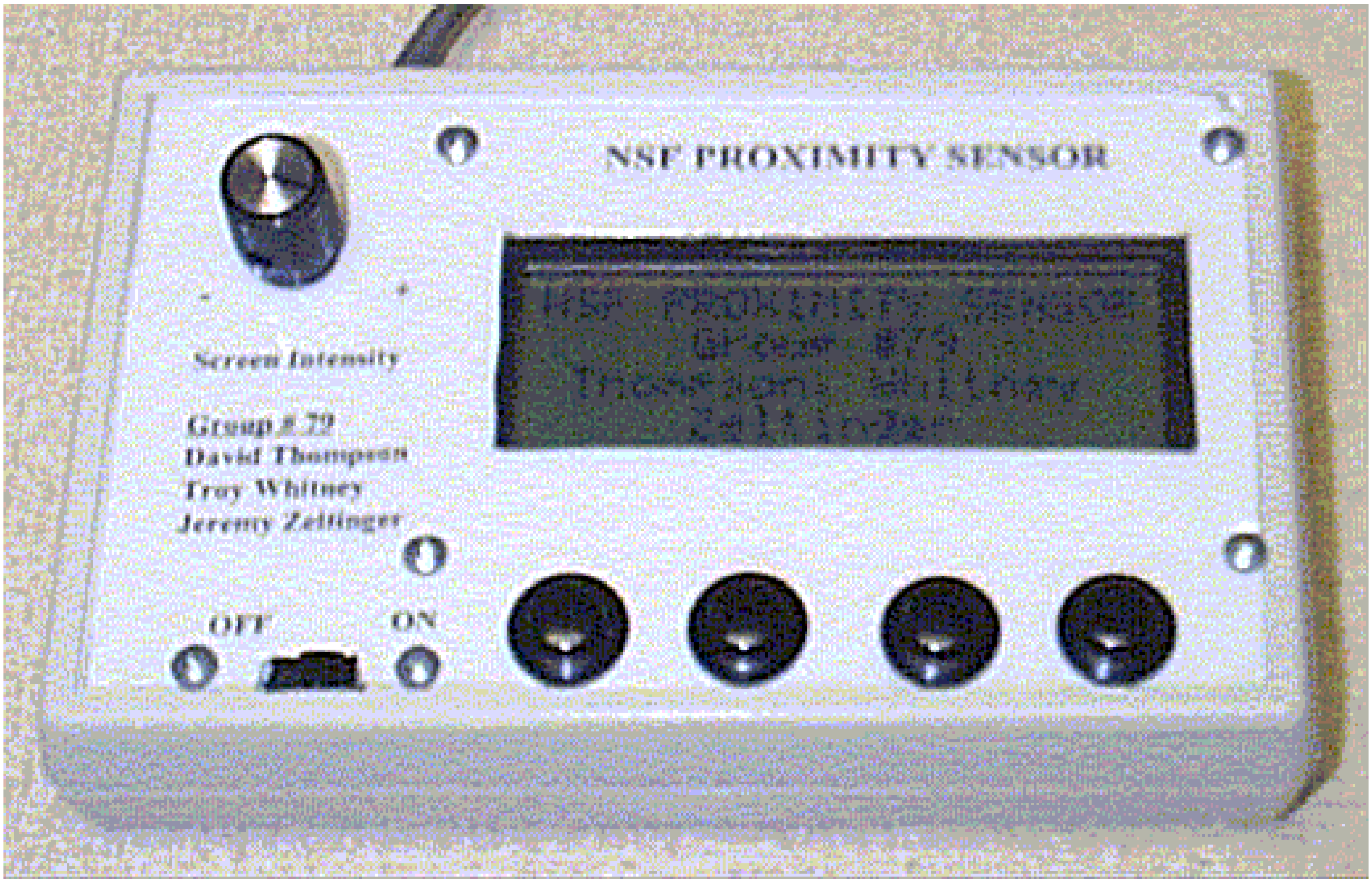

Figure 11.4. Base Unit for Uploading Data.

The following test parameters are shown on the Display:

- Total test time,
- Total violation time,
- Number of violations,
- Longest violation duration,
- Shortest violation duration,
- Average violation duration,
- Greatest time between violations,
- Shortest time between violations,
- Average time between violations, and
- Percentage of time spent in violation.

The Display unit is also used to pass commands to the Receiver to enable/disable the buzzer, monitor elapsed time or signal strength, and reset the Receiver. The Display is driven with a Microchip PIC16C66 micro-controller operating at 4 MHz. The entire Display device is powered with a 9-Volt battery.

The cost was approximately $30 for each transmitter and receiver unit while the LCD display unit costs approximately $70 each.

MOISTURE DETECTOR

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INTRODUCTION

Caretakers for people with severe learning disabilities check the beds of their patients several times each night for wetness. In order to allow these patients to sleep better, a device was requested to allow the caretakers to check for wetness in a less obtrusive way.

SUMMARY OF IMPACT

The device is a prototype used for evaluation by the clients. If it is found to be a comfortable and effective tool, several more copies will be made. Hopefully, the ability to let the patients sleep undisturbed will allow the patients to sleep better, thus improving their dispositions during the day. The ability to detect wetness by glancing at a set of lights will also make nightly rounds quicker and more convenient.

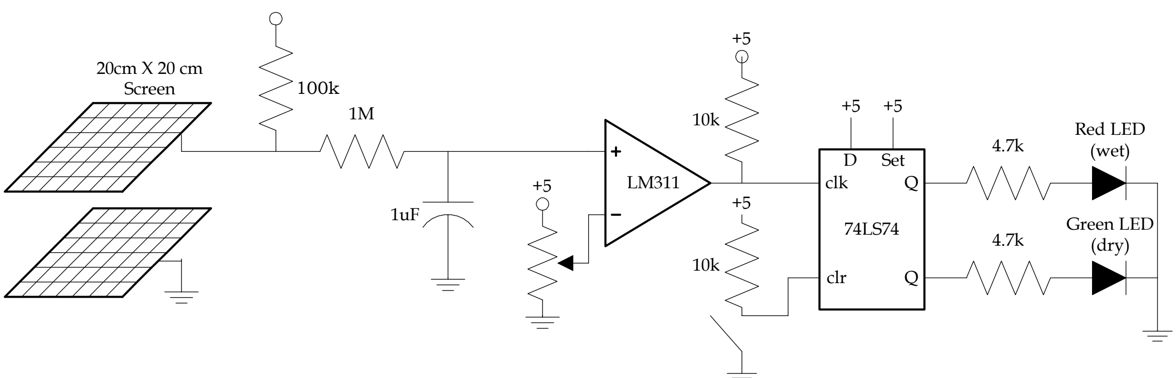

Figure 11.5. Moisture Detector Circuit.

TECHNICAL DESCRIPTION

The design of the moisture detector was broken down into four components:

- A sensor,
- A filter,
- A display, and
- A power supply.

The sensor consists of two 20cm x 20cm pieces of aluminum screen separated with a piece of cloth. A voltage divider powered by a 9V battery detects the presence of moisture between the screens. A LM311 comparator then converts the variable voltage on the screen to a 5V TTL signal. This signal then sets a flip-flop.

Once the flip-flop is set, a red LED is turned on, signaling that the bed is wet and the sheets need changing. A green LED indicates that the bed is dry and serves to let the operator know that the sensor is operating properly.

The overall design is packaged in a 5cm x 3cm x 8cm plastic box with an on/off switch and a reset switch. Once the bed is wet, the red LED remains on until the operator pushes the reset button. This feature allows the operator to know that the bed has been wet sometime during the night if, per chance, the bed dries out.

One problem with this design is that it will only work if the patient wets the sensor pad. To motivate the patient to target the pad, the cloth casing was made of Green Bay Packers materials.

A single 9V battery powers this device and should have a 6-month life under continuous use. The overall cost for the final design is approximately $30 each.

Figure 11.6. Package of the Final Design.

Figure 11.7. Sensor Pad Designed to Encourage Hitting the Pad.

FORCE SENSOR FOR AN INDIVIDUAL WITH A PROSTHETIC LEG

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INTRODUCTION

Difficulty in learning to walk on a new artificial limb lies with figuring out whether or not one has weight on the involved limb, and similarly, if one is ready to lift the prosthetic leg. Biofeedback pertaining to the weight applied to the limb may help patients make such judgments more quickly and effectively. A device was designed to provide audible feedback regarding force for use by patients with prostheses working on walking skills with physical therapists.

SUMMARY OF IMPACT

The device was designed for evaluation by physical therapists. They will assess the effectiveness of the sensor used to measure the weight applied to a limb, and the use of a pitch associated with that force. If these aspects of the design prove helpful, a useful tool may be developed to help people with an artificial limb learn to walk.

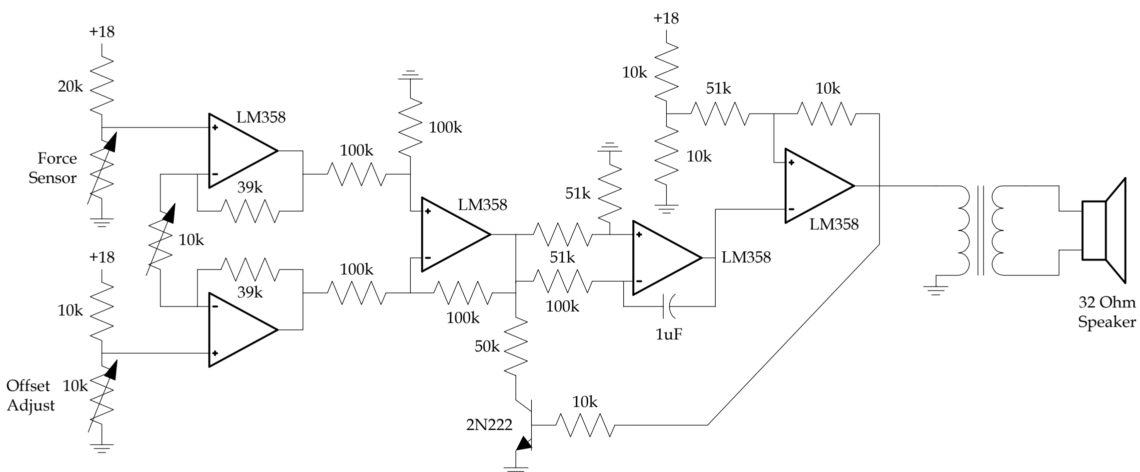

Figure 10.8. Circuit for Converting Force to an Audible Tone.

TECHNICAL DESCRIPTION

The Force Sensor consists of three main components:

- The sensor,
- The amplifier, and
- The power supply.

For a sensor, a Flex Sensor strain resistor was used. This sensor is a 5cm long strain gage, measuring from 10k Ohms to about 30k when bent. This sensor is placed on top of an Air 2 insole shoe insert, on which the patient stands. Resistance for this sensor placed on the shoe insert results in a reading of 10.36k Ohms with no weight applied to 16.1k with one Schleiper on the shoe (about 80kg).

The resistance of the strain resistor is converted to a voltage using a voltage divider circuit. This signal is then amplified 10x by LM358 amplifiers connected as an instrumentation amplifier as shown in Figure 11.9. The voltage at the output of the instrumentation amplifier varies by about 0.575V for a force varying from 0kg to 80kg.

Once amplified, the voltage drives a voltage-to-frequency circuit. The output for this amplifier is a 0-18V square wave. A 32-Ohm speaker converts this square wave to an audible tone thorough a 1:1 transformer to remove any DC offset.

The final device is shown in Figure 11.9 where the insole is shown along with the case containing the amplifier, oscillator and transducers.

The device runs on two 9V batteries with a life of about 20 hours continuous use. This life should be sufficient for the physical therapists to evaluate this device, for the patient to learn sufficient skills for walking on the prosthetic limb. The overall cost of this device was about $70. Several such devices could be built at low cost should the sensor and audible feedback prove useful to the therapists.

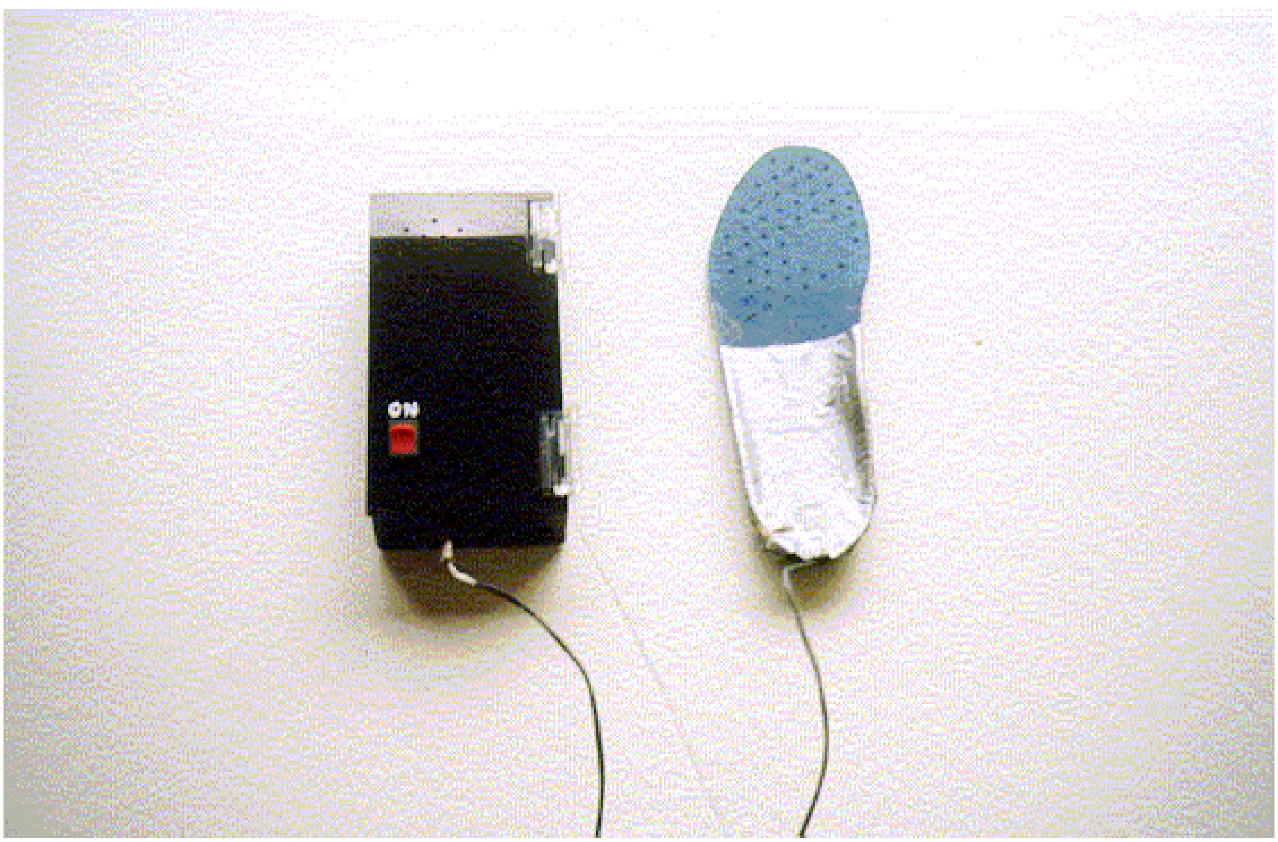

Figure 11.9. Device Showing the Shoe Insert with the Sensor Attached and the Amplifier/Oscillator Circuit in a Case.

CAMERA FOR PERSONS WITH VISUAL IMPAIRMENTS

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INTRODUCTION

The aim of this design is to enable a person with a visual impairment to take snapshot pictures. By way of a digital image sensor, the device will take in data corresponding to light intensity. After the device processes this data, an image of the object will appear on a tactile display with numerous variable pins, in a 'bed-of-nails' fashion. For added functionality, the device will have a real-time update feature.

As this tactile device is currently impractical to implement, in this iteration of the Camera for Persons with Visual Impairments the focus was primarily on the image sensor and data processing portions of the project. A 1x4 grid of pins will be implemented until such a tactile device is realized.

A schematic for the Camera for Persons with Visual Impairments can be seen in the diagram in Figure 11.10.

SUMMARY OF IMPACT

Ultimately, the Camera for Persons with Visual Impairments may prove to be a valuable tool, allowing people with visual impairments to gather some idea about what images look like. It may be use in art galleries, with televisions, and overlooking panoramas.

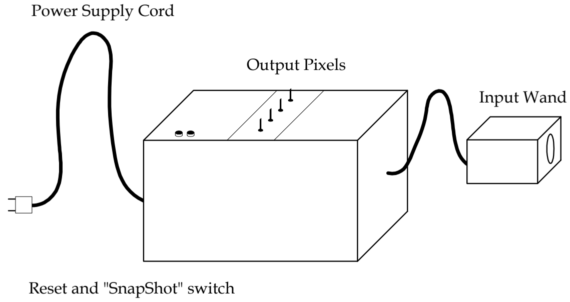

Figure 11.10. Casing for the Camera for Persons with Visual Impairments. A Portable Hand Unit allows the Operator to Point the Sensor Around While Feeling the Light Intensity via Four Pixels Placed on a Larger, Less Portable Unit.

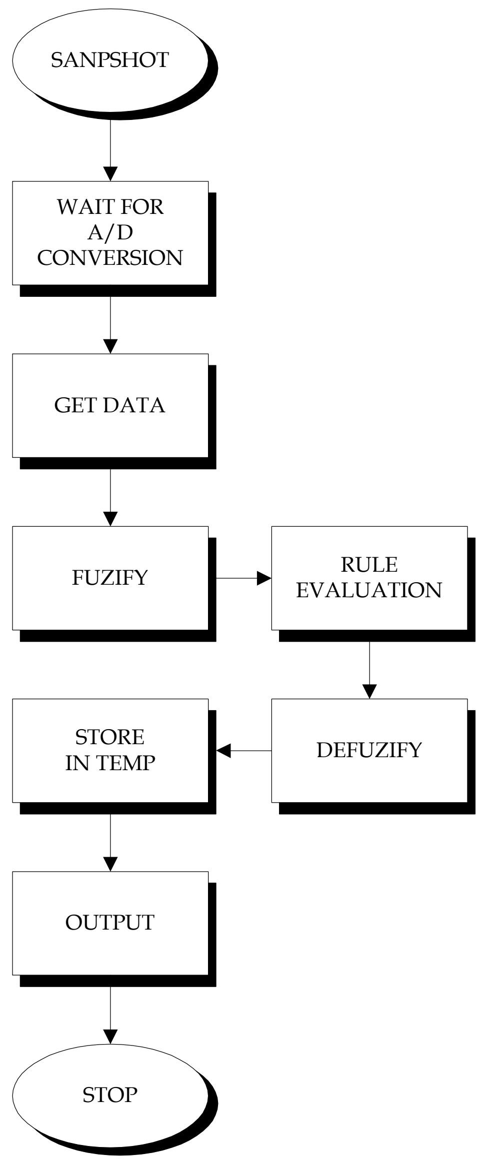

Figure 11.11. Flow Chart for Fuzzy Algorithm.

This is the second iteration of the Camera for Persons with Visual Impairments (formerly Camera for the Visually Impaired). In this iteration, a simple and effective input device was developed, fuzzy logic was implemented for interpreting the data, and stepper motors were used to drive the pixel outputs. The first two developments were simple and effective in this iteration and are suggested for future designs. The stepper motors, however, required considerable power (> 30W) and were too large for expansion o to larger arrays. It s recommended that a third iteration be implemented, therefore, before increasing the resolution of this device.

TECHNICAL DESCRIPTION

The camera for the Visually Impaired was divided into four sections:

- A sensor,
- A processor,
- Actuators, and
- A power supply.

The sensor consists of four photovoltaic cells placed in a pinhole camera providing a resolution of four pixels. The output of the sensors drives four AD626 instrumentation amplifiers, which generate a 0-5V output. A 6812-evaluation board reads this analog signal.

Once the pixel intensity is read by the 6812, a fuzzy algorithm, shown below, determines the proper pixel height.

Sixteen outputs from the 6812 then drives four stepper motors so that the height of each pixel is proportional to the light shining on the corresponding sensor.

While this device works fairly well, a third iteration is warranted before delivery to a person with sight disabilities. First, the overall cost is high, at $725. Half of this cost was due to using a 6812-evaluation board; cost could be significantly reduced by using a different processor. Second, the device consumed 37 Watts, primarily due to using a transistor switch. An H-bridge amplifier is recommended for future designs. Finally, a CCD camera would be preferable to a bank of photovoltaic cells and recommended. With these changes, the design presented here may result in a user friendly and useful tool for persons with visual impairments.

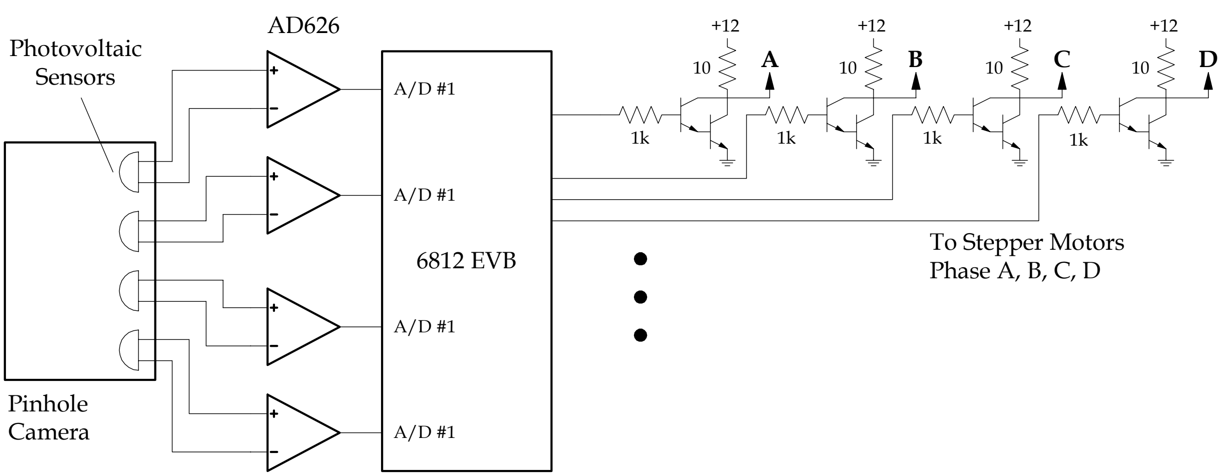

Figure 11.12. Circuit for the Camera for Persons with Visual Impairments.

ULTRASONIC CANE

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INTRODUCTION

People who are visually impaired typically have difficulty detecting the presence of obstacles while walking. Typically, a cane is used, which has several disadvantages. First, the cane only detects the presence of obstacles about 1 meter away from the operator, i.e., the length of the cane. Further, some individuals wish to avoid their obvious marking as being visually impaired associated with the use of white canes.

In order to alleviate these two problems, a device was designed to:

- Allow the operator to detect the range of obstacles ahead from 0.1 to 10m away,
- Signal to the operator the range to these obstacles, and
- Be inconspicuous during use.

SUMMARY OF IMPACT

The device built is the ninth iteration of the Ultrasonic Cane. Ideas incorporated in this iteration include:

- The housing of the sensor in a flashlight casing (see Figure 11.14) rather than on a cane,
- The use of a relay to chatter at different frequencies to report the range of an obstacle to the operator,
- The buzzing of the relay felt by the operator's hand while holding the device

With feedback from a user with a visual impairment, the practicality of each of these innovations can be assessed. If they are effective, reliable, easy to use, and represent improvements on previous designs, a more useful device may be developed.

TECHNICAL DESCRIPTION

The ultrasonic cane consists of four main components:

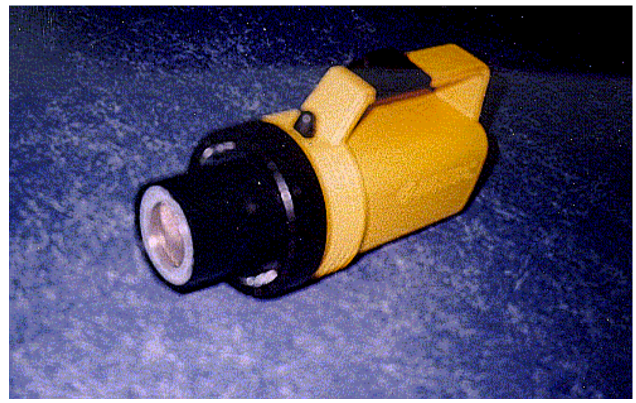

Figure 11.13. Flashlight Casing to Make the Ultrasonic Cane Less Conspicuous.

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- A sensor,
- A voltage-to-frequency converter,
- An actuator, and
- A power supply.

The sensor consists of a Senix Ultra U ultrasonic range sensor. This sensor is programmable to output 0-5V for obstacles ranging in distance from 0 to 2m through 0 to 30m. For this application, the sensor was programmed for 5V output at 3m.

Once the range information is converted to a voltage, an LM331 voltage-to-frequency converter turns the signal into a 1Hz to 30Hz square wave using the circuit shown in Figure 11.14.

The LM331 has an open-collector output, allowing a 15V relay to be connected directly to the output as shown. A mechanical relay was used so that the 1Hz to 300Hz square wave produced a "click" the operator could feel, the electrical properties of the relay being purely incidental for this application. This relay is externally mounted so that the operator can place his/her thumb directly on the relay to feel the vibration. This also helps facility replacement of the relay, which, with a rated life of 10 million cycles, should only last for about 60 hours of continuous use.

Powering the unit are four 9V batteries connected to a 5V regulator and a 15V DC-to-DC regulator. All tolled, the unit draws about 1.7W, giving the unit a battery life of about 3 hours of continuous use.

Several new concepts were incorporated into this iteration of the ultrasonic cane. The main advantages of this design were the placement of the unit in a small hand-held case and the use of a digital output. Its shortcomings however, are power consumption at 1.7W and high cost at about $500 per unit. If these features prove to be useful to the operator, designers may address these two shortcomings in future iterations.

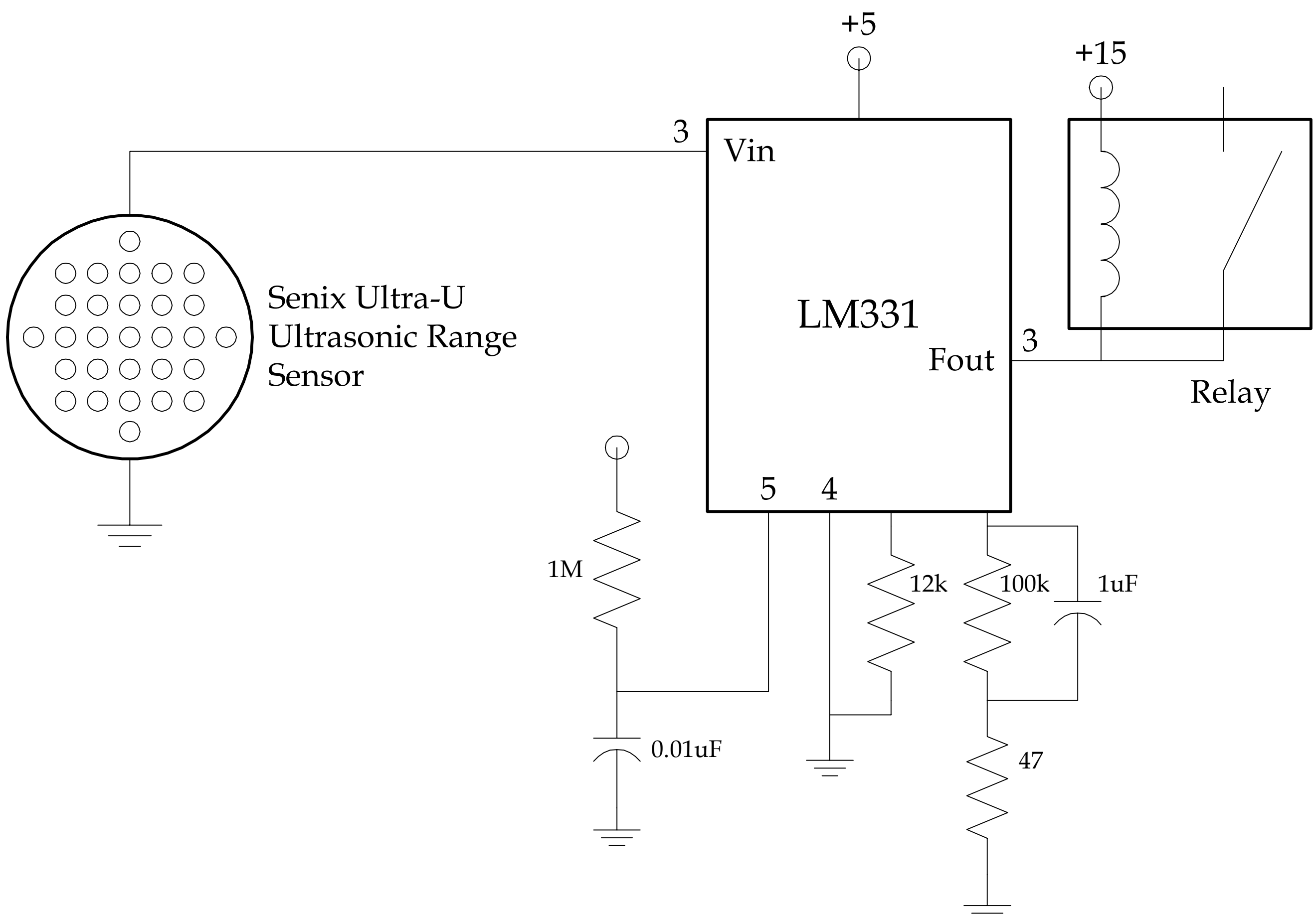

Figure 11.14. Circuit for the Ultrasonic Cane.

EMG TELEMETRY

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INTRODUCTION

One of the more difficult things for persons with severe physical and learning disabilities to learn is how to control their arms and hands for functional tasks such as turning on a light switch or holding a glass.

In this project, a device that provides biofeedback to the operator, reporting whether a certain muscle is firing or not, was designed. The aims of the design are to:

- Measure muscle EMG activity,
- Produce some form of feedback (light or sound) according to the muscle activity,
- Be small and non-intrusive,
- Be easy to operate, and
- Use radio telemetry to avoid the possibility of tangling the operator in the attached wires.

SUMMARY OF IMPACT

It is unclear at present whether a light or a speaker will be more effective in signaling to the operator that a certain muscle group is firing. Using this device, therapists working with people who have motor skill problems may be better able to assess the merits of using biofeedback in this way.

Since biofeedback has proven to be a valuable tool in many areas, it is hoped that it will also prove to be a valuable tool here as well.

TECHNICAL DESCRIPTION

The EMG Wireless Transmitter can be divided into six parts:

- A sensor,
- An amplifier,
- A transmitter,
- A receiver,
- An output display, and
- A power supply.

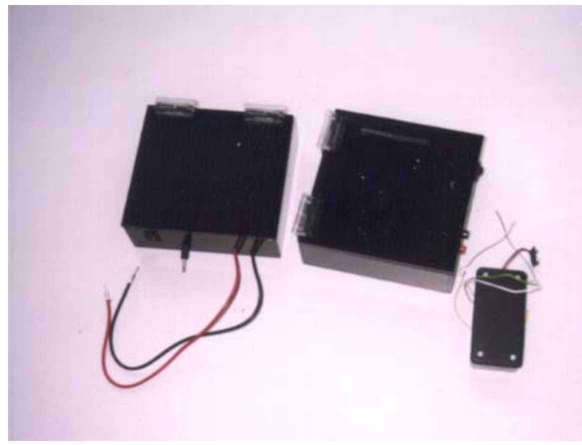

Figure 11.15. Receiver Circuit for the EMG Sensor.

For the sensor, EMG patches are used. These patches are placed on the patient's skin directly over the muscle to be monitored. If attached well, these sensors will typically output 1 to 3mV AC signals corresponding to the EMG signals produced by the muscles.

Once muscle activity is detected, a pair of AD626 instrumentation amplifiers is activated. These amplifiers amplify the signal by 1000, low-pass filter the data to remove noise, and half-wave rectify the EMG signals. An envelope detector and low-pass filter then converts the EMG activity to a 0 to 5V signal that is nearly constant for constant muscle activity.

To transmit this data, AN modulation on top of a 1MHz carrier is used. An LM331 converts the 0-5V signal from the amplifier to a 1kHz to 3kHz square wave. This square wave modulates a 1MHz square wave using a transistor as shown in Figure 11.16. The collector of the transistor is then attached to a 10cm wire, which acts as the antenna.

The receiver circuit uses a commercial portable MA radio tuned to 1MHz. If audible biofeedback is desired, the frequency heard on the radio corresponds to the amount of muscle activity. If visual feedback is desired, however, the circuit is connected to the earphone jack of the radio. This circuit uses the zero-crossings of the radio to power a LM331 chip configured in a frequency-to-voltage mode. The output voltage ranges from 0V to 5V. This voltage then drives a voltmeter with an LED bar chart display.

While conceptually this project has promise, another iteration may be required before it is ready to deliver to the customer. First, the overall cost of each sensor/transmitter/receiver circuit is rather high, at about $250 per unit. Second, the transmitter has a range of less than 3m. While this keeps the device within legal limits from an FCC standpoint, an improved transmitter with a range of 10m would be more useful and still meet FCC requirements.

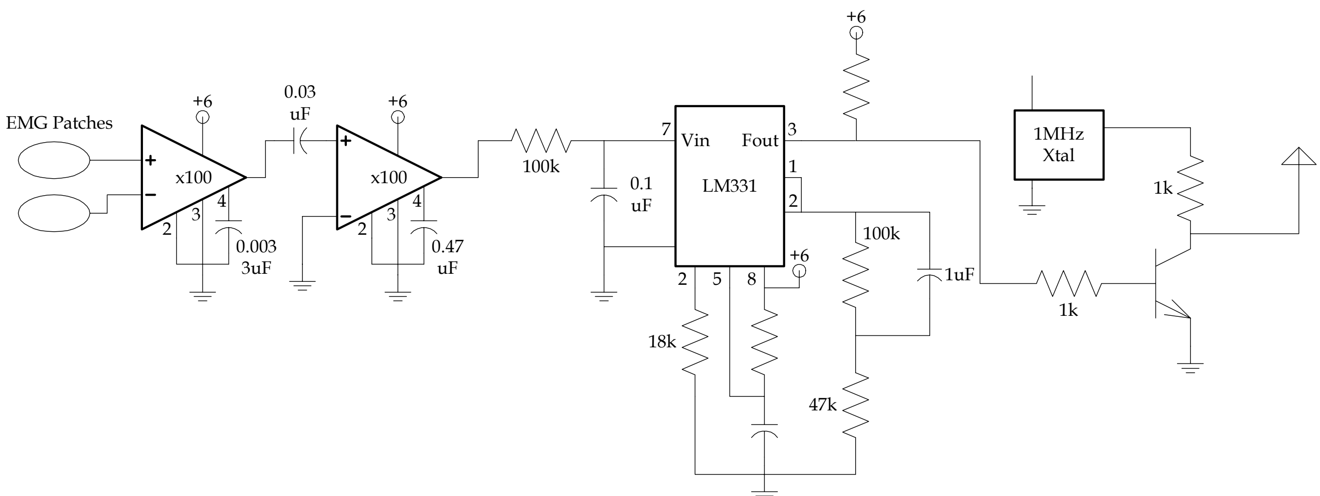

Figure 11.16. Transmitter Circuit for the EMG Sensor.