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ELECTRONICS DESIGN OF THE INFRARED/ULTRASONIC SENSING FOR A ROBOT GRIPPER

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Abstract

The following paper is an overview of the electronic design of the Infrared/Ultrasonic Sensing Robot Gripper (Instrumented Gripper) designed, built and tested at the National Institute of Standards and Technology (NIST) in Gaithersburg, Maryland. The gripper is for use in the Automated Manufacturing Research Facilities (AMRF) Cleaning and Deburring Workstation (CDWS) at NIST.

The paper begins with a System Description, followed by the design of the Sensor Circuitry and Power. The Sensor Circuitry includes that of the sensor interface (to the sensor and the system), through the rectification and/or interpretation circuitry, and finally to the output circuitry. Continuing on, the paper explains the experiments performed and the results from these experiments in detail. Future considerations for the system follow, and some applications for the Instrumented Gripper and further sensing ideas are explained. A summary and conclusion close the paper with some of the authors remarks about the system.

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1. Introduction

The Automated Manufacturing Research Facility (AMRF) is a facility used for studying small-batch automation. The Cleaning and Deburring Workstation (CDWS) is one of six workstations that make up the AMRF at NIST. The CDWS is made up of a six-axis hydraulic robot and a six-axis electric robot; a washer/dryer system; buffing system; and tray station. This workstation is designed for use as a research tool to study the use of robotics in cleaning and deburring metal parts that were machined in the AMRF. The six-axis hydraulic robot is used to pick parts from a tray and place them on a rotary vise, located within the work volume of the two robots. The six-axis electric robot is used for deburring and part manipulation. After deburring the part, the hydraulic robot takes the part from the vise, places it in a washer/dryer system and/or buffs the part via the buffing-wheel system, and places it back onto a tray to be delivered to an inspection station, also within the AMRF.

The major research effort at the CDWS is to automate robot programming using computer-aided design (CAD) data. This CAD data includes part geometry that is used to generate accurate robot paths for both part handling and deburring. An operator selects the edges to be deburred and the deburring parameters, such as tool speed and feed rate, from a computer display showing the part. Also, the operator specifies how the hydraulic robot is to grip the part, how the part is be clamped in the vise, and how the part is to be placed in the washer/dryer. These instructions, called process plans, are translated into the proper format and sent to the robots.

Parts enter and exit the CDWS on parts trays placed at the roller tray stations. With slight vibrations or initial misalignment, the parts will possibly be moved from their taught points and will possibly not be “seen” by the robot without part sensing capabilities. Vision is the classic solution for part location, but can be very expensive. Another approach is to use sensors in the end of the robot gripper for part detection. Knowing the sensor locations and using a scanning algorithm incorporating the robot and gripper sensors, the part can be centered and retrieved. For part centering, both sides of the part must have the same reflective properties or the reflective properties must be known for the sides of the part to be grasped. In a factory turning out parts from bulk metal on milling machines, such as in the AMRF, this is not a problem since most sides of the part will have been machined by the time the part reaches the CDWS.

Along with the manufacturing processes incorporating part detection, the tedious and inefficient task of calibrating the robot must be addressed. Currently, the hydraulic robot is calibrated in software using an error map, which must be manually determined. The use of position sensors and a target block removes the need for manual calibration, resulting in a reduction of the time needed to prepare the robot for off-line programming.

This paper explains the electronic design of the Instrumented Gripper which has been constructed and is in use in the AMRF.

1.1. Objective

The objective of this project is to develop a state-of-the-art system to be used in a factory environment for locating known parts from a tray containing other known parts without the use of vision. The system will also use the sensing capabilities of the system for relative calibration of the robot, on request and as often as required, for consistent robotic results. The system must incorporate non-contact sensors so that parts are not misaligned while being detected. Also, the system must be versatile enough to be used as a robot gripper while the sensor system is not needed.

1.2. System Architecture

The Instrumented Gripper System is divided up into six parts: the gripper, infrared beam-break/proximity switching circuitry, ultrasonic control circuitry, power, quick change, and cabling.

The gripper is the sensor housing for the system. All infrared sensors are located on the inside (gripping face) of the fingers of the gripper. These are used for part detection and centering about the part. Also, ultrasonic sensors are located on the front and bottom faces of the fingers. These sensors are used for environment detection. Infrared sensors are used on the inside of the fingers because of their small size, rugged housing, high power, and low cost. Ultrasonic sensors are used for environmental detection because of their small size, small angular displacement, long range, and their signals are not absorbed by the part or object of interest. See figure 1 for the approximate sensor location in the fingers of the gripper.

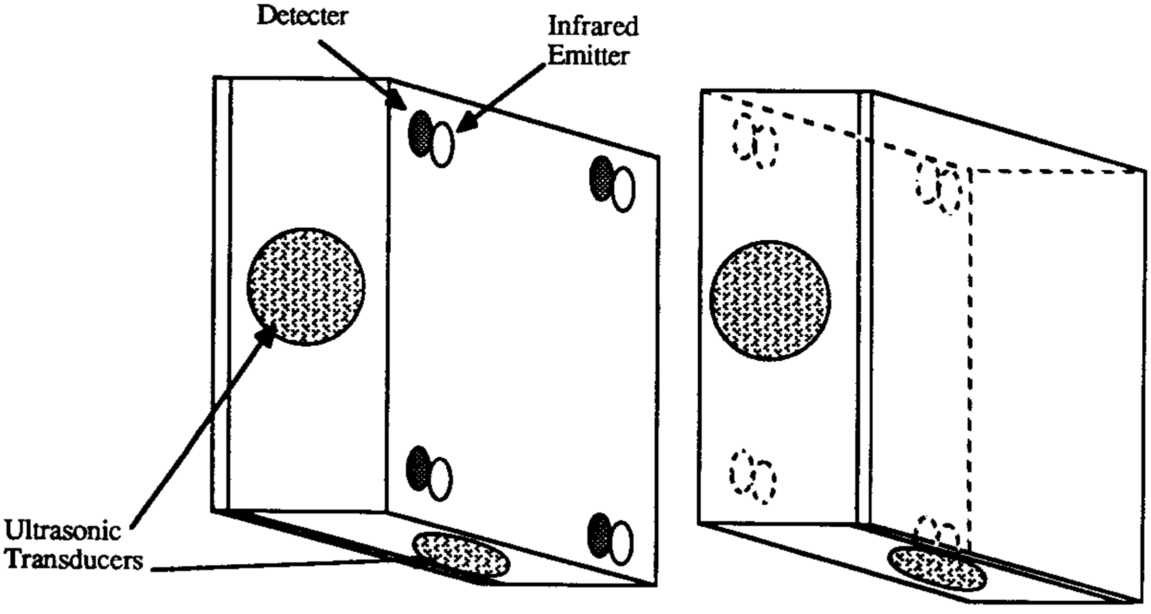

Figure 1. Isometric view of the fingers of the Instrumented Gripper

2. System Design

2.1. Sensors

2.1.1. Infrared

The emitter is a gallium arsenide infrared-emitting diode that emits non-coherent, infrared energy with a peak wavelength of 940 nanometers. The light emission is within ±10° with a 20% output or ±5° with an 80% output and thus is very focused . The maximum continuous forward current is 100 mA, and when pulsed for 1μs at 200 Hz, the maximum rated forward current is 10 A.

The detectors are supersensitive NPN planar silicon photodarlington amplifiers. In this case only the emitter and collector leads are used since no gain or sensitivity input is needed. The maximum rated light current for the device is 200mA and a collector to emitter voltage of 25V max.

2.1.2. Ultrasonic

The ultrasonic sensors used operate at 222 kHz and have detecting ranges of 3 in. to 14 in. The resolution of each sensor is stated to be 0.030" with a sensing repeatability of ±0.010 in. typical at 25 °C and a very directional cone of ±8°. The transducer head is sealed and, hence, is a good sensor for industrial applications where precise uses are a necessity. For example, the sensor can detect an object of 1/8 in. diameter perpendicular to the transducer head.

The power requirements of the sensor are 110 VAC, 15 to 24 VDC, or regulated 12 VDC, of which we chose to use a regulated 12 VDC supply. The transducer head is threaded on the outside and is easily mounted from the inside of the finger and flush with the outer surface of the finger.

2.2. Electronic Circuitry Design

2.2.1. Infrared (Beam-Break/Proximity Sensing on a Part)

A robot gripper, such as the one shown in figure 2, has two fingers that are simply blocks of a material like aluminum or plastic and may or may not have sensors mounted within its gripping path or exterior to this path. These sensors, infrared emitter/detector pairs in this case, are used to help locate a part of interest relative to the robot gripper. Four sensor pairs are mounted between the fingers to allow the gripper to "see" a part that is between the fingers. Each of the four pairs of sensors is located on a corner of the finger within the gripping area of the gripper. The sensor locations are shown in figure 1 for both fingers and the sensor numbering is shown in figures 3a and 3b for the left and right fingers, respectively.

Beginning with the interior sensor pairs, (numbers 1 through 8) the idea of beam-breaks is used since it is a definite way of detecting an intrusion of a part within the fingers. Emitters 1 through 4 emit infrared light to the detectors on the opposite finger (detectors 5 through 8). The emitter is capable of passing a continuous 100 mA of current through it or by pulsing the emitter it is able to pass up to 10 A of current. Hence, pulsing the emitter is most logical for producing a strong signal. Since many grippers are capable of opening to a maximum distance of about six inches, the emitters must produce a strong enough signal at

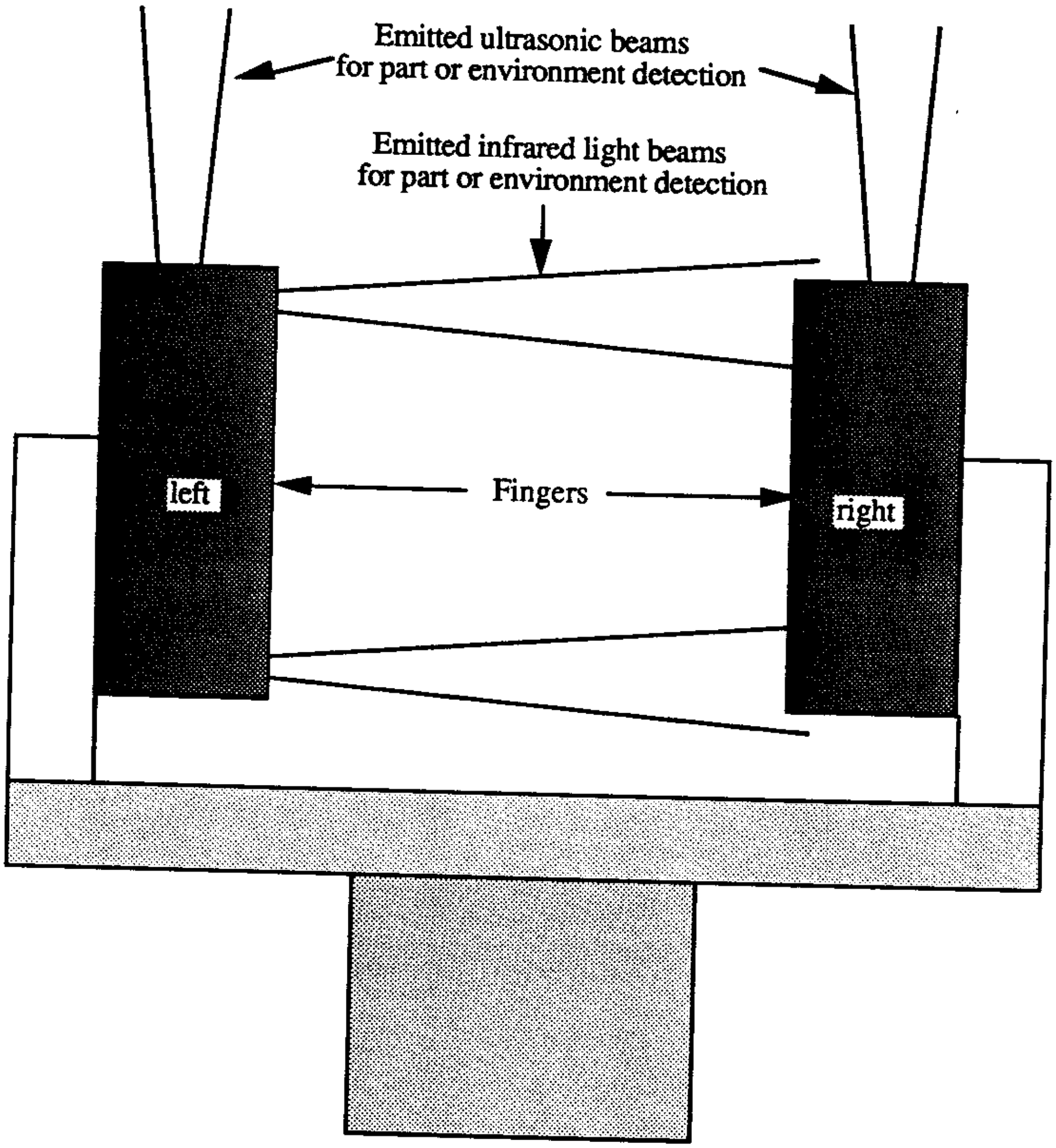

Figure 2. Top view of a typical robot gripper showing emitter beams

the detector for the detector to tell the difference between a pulse of light from the emitter or spurious light within its environment.

To be able to at least double the continuous forward current rating, a signal is used where half of the time the emitter is on and off the other half. This signal can easily be produced by any number of oscillators on the market today. TTL logic is desired, in this case, for easy integrated circuit availability. Therefore, a 5 V input signal is used and a 74124 voltage controlled oscillator is used since it can be enabled or disabled with a logic 0 or 1. Figure 4 shows an emitter E1 connected to a 60 ohm load resistor at the cathode and a 5 V supply voltage attached to the anode, providing 100 mA to pass through the diode continuously (since the diode characteristically has low forward resistance and therefore, doesn't compare with the load resistor.) Now, if instead of grounding the load resistor it is connected to the 74124 output so that the potential drop across the diode and resistor is 5 V for half of the time, a current of 2 x 100 mA or 200 mA can be obtained if a 25 ohm load resistor is used. Although this idea seems simple, it produces problems. The 200 mA is only available if the 74124 can sink all 200 mA of current when the oscillator is in its low state. Unfortunately, the 74124 can only sink about 10 mA. Hence, a current driver is needed. A ULN2003 hex current driver is used in this case and is able to sink about 500 mA of current while working with a supply voltage of 5 V. Since 30 ohm resistors are more standard, these will be used for the load resistors and are still small enough for the emitter to produce a strong signal at a detector six inches away (from 0 V to ~4 V for distances of 6 in. to 0 in., respectively). The L14F1 detector has a light current of 200 mA maximum, and therefore the 30 ohm resistance is fine for its load resistor also.

With only a signal voltage of less than a volt appearing at the output of the detector (emitter) D5, some amplification is required so that TTL levels are obtained. To accomplish this task an LM324 operational amplifier is used in the non-inverting state to provide the necessary gain for a TTL output signal. The gain is calculated as in (1) below where R2 is the feedback resistor
from

$$G = R2/R1 + 1 \qquad (1)$$

the output to the inverting input. With a signal of 1 V maximum appearing at the output with no amplification, a gain of 3 will provide a strong enough signal at the output for TTL logic. Hence, if R2 is 1k ohm and R1 is 510 ohm then (1) becomes:

$$G = (1000/510) + 1 = 2.96 \approx 3 \qquad (2)$$

With a supply voltage of 5 V, the LM324 op-amp can only provide a maximum output voltage of ~4V. (The LM324 is a monolithic op-amp and therefore, only needs a single ended power supply i.e., 0 V to +5 V.) Since a gain of 3 will assure an output voltage from the op-amp to be at a TTL logic level at the high range, the low range is also questionable and for this reason one way of "cleaning up" or regaining a square pulsed output is to feed the output into a 7414 Schmitt trigger. A complete schematic of the beam-break and proximity sensing circuitry is shown in figure 5.

Now that a "clean" pulse train is appearing at the detector D5, the beam-break technique can be used. This is accomplished by the use of a "missing pulse detector." A missing pulse detector detects when a pulse does not appear at its input. A 74123 multivibrator is used for this by feeding the output signal from the 7414 into the low input of the 74123. The 74123 timing is set up in such a way that the input pulses are sampled every 1 1/2 pulses and therefore, it always has the same stated input being sampled upon with the output always being high. This will continue as long as pulses continue to input the multivibrator. As soon as pulses stop, the 74123 detects a "missing pulse" and triggers a low output at Q. This is how a beam-break is detected. This signal output is then sent to a computer port so that the computer knows an object has broken the path of the beam-break.

The idea of beam-breaks was taken one step further by using this beam-break signal to trigger the proximity sensing. This is done by taking the output Q from the 74123 and inputting it into the set (preset) input of a 7474 flip-flop. With Q (74123) attached to the reset (clear) of the 7474, it always stays in the reset state until the polarity is reversed on the set and reset inputs. Therefore, as a beam-break occurs Q (7474) goes high and can be used to turn on another detector D1 for proximity sensing between E1 and D1. A unity gain op-amp is used at the input of the detector to make sure that the input signal is strong enough to drive the detector.

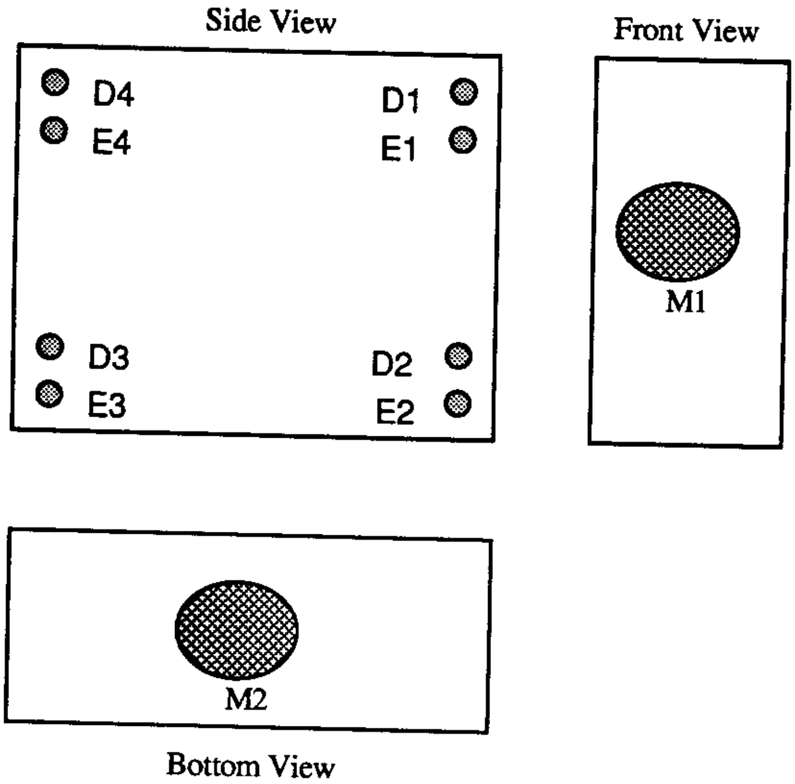

Figure 3a. Left finger showing positions of emitter/detector pairs and ultrasonic transducers

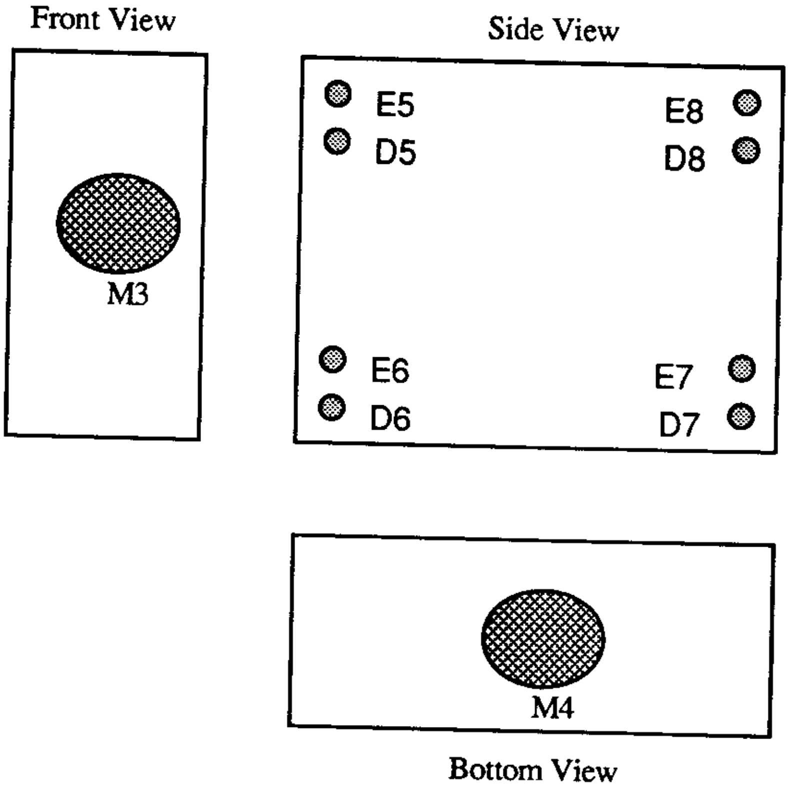

Figure 3b. Right finger showing positions of emitter/detector pairs and ultrasonic transducers

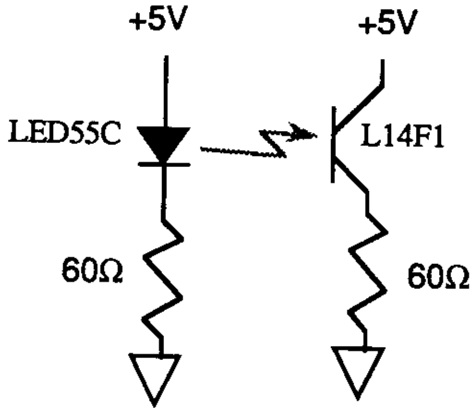

Figure 4. Emitter and detector schematic showing load resistors.

One way to not be constrained to using the reflective properties of the part material in proximity sensing is to compare two proximity output signals at known locations opposite to one another. To use this approach in this project another emitter and detector pair is needed for the comparison to take place. By using an emitter E5 and a detector D5 located opposite to E1 and D1, the control circuitry for E5 and D5 can now begin.

By taking the output Q from the 7474 and inputting this into the enable of another 74124 oscillator, the same idea of pulsing an emitter used earlier on E1 can be used for E5 but in this case a controlling signal is being used to turn the 74124 on. Also, as used on E1, a ULN2003 current driver is needed to sink more current than the 74124 is capable of doing. If E5 is used to emit a beam, then a detector D5 (used earlier for beam-breaks) is needed for detection of the beam. This now produces a problem: as E5 turns on, pulses now begin to appear again at the detector D5 as if there was no part blocking the beam-break.

Until now, no timing constraints have been mentioned. To address the problem of communication, control of timing is now necessary. Using the given equation from the 74124 data sheet, an external capacitor is used to set the timing. According to (3):

$$f0 = (5 \times 10^{-4})/Cext \qquad (3)$$

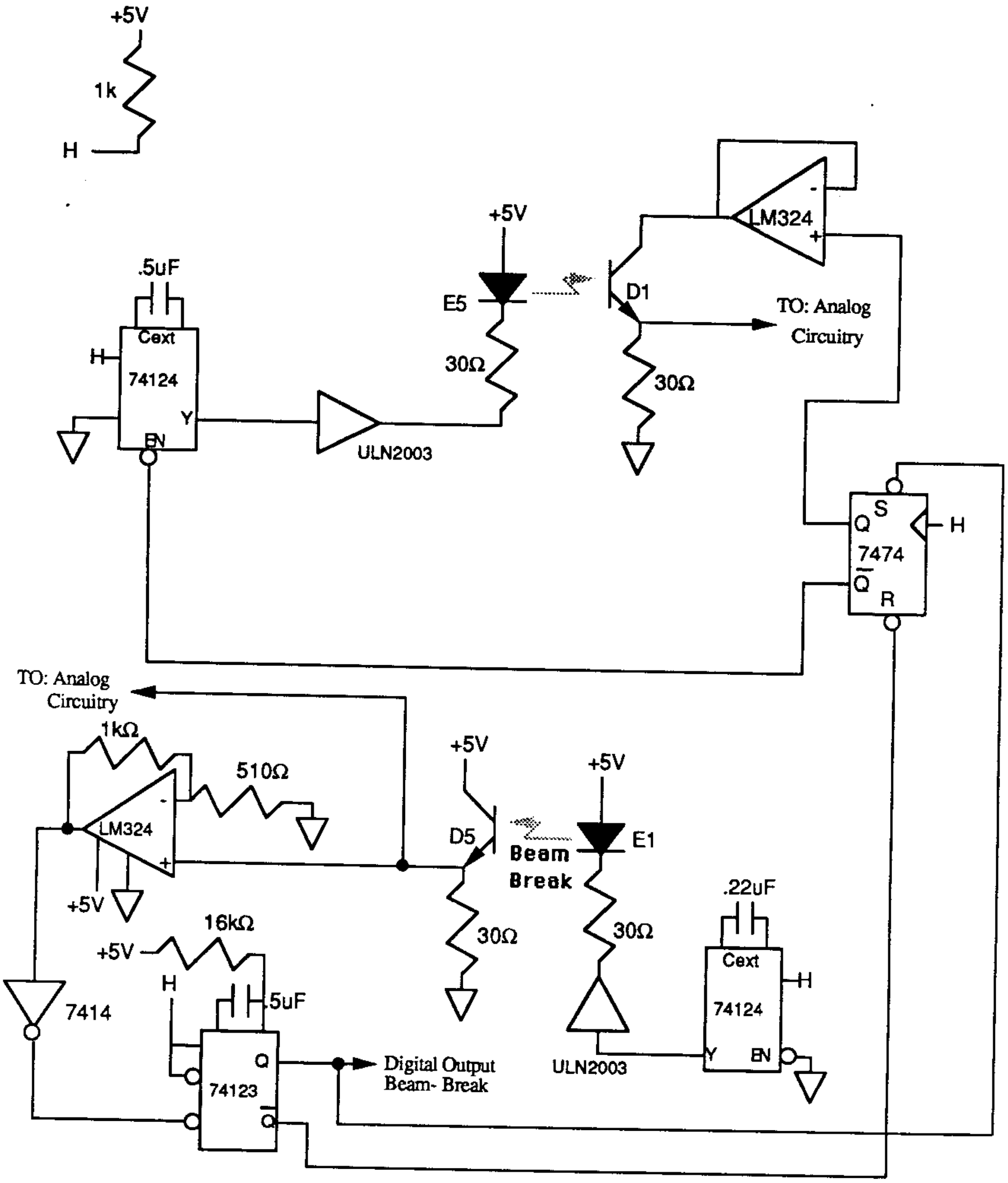

Figure 5. Schematic diagram showing one channel (of four) of the beam-break and proximity sensing circuitry.

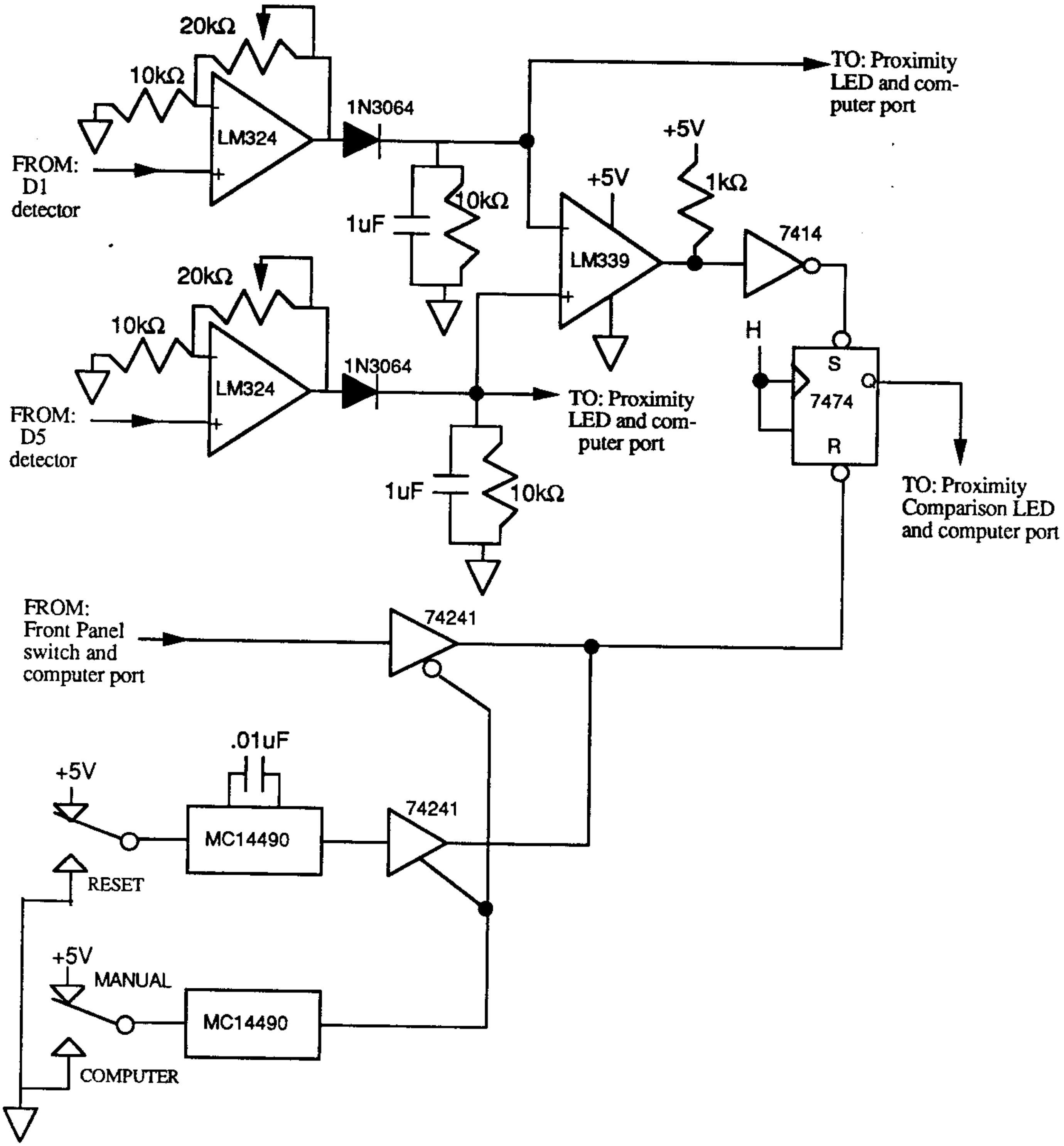

Figure 6. Schematic diagram (1 of 4) showing analogcircuitry outputed from detectors D1 and D5 (Switches are mounted on the front panel)

If this frequency is used for E1 and E5, the pulses will look the same at detector D5 and the above problem will occur. But if E5 uses a higher frequency, then a high-pass filter can be used at the output of D5 to pass only high frequencies to the beam-break circuitry. The low frequency pulses will then be directed toward the analog circuitry needed for proximity sensing. With this in mind, a 0.5uF capacitor is used so that a frequency of 1 kHz is output from the 74124 feeding E5 as shown in (4):

$$f0 = (5 \times 10^{-4})/(.5\ uF) = 1k\ Hz \qquad (4)$$

Since the strength of signals is proportional to the distance of the reflecting surface, the relative output of the sensors gives a measure of distance. Given the constraints of the signal, for example 1 V to 5 V, an analog signal can now tell the approximate location of the sensor relative to the detected object. The outputs from detectors D1 and D5 are inputs to op-amps set to unity gain (see figure 6). The op-amps provide a strong signal to drive the circuitry that follows. The pulsed signal is no longer necessary, so to switch to a purely analog signal, a diode and resistor/capacitor combination is used. The resistor and capacitor are used to smooth out the pulsed signal by using a large capacitor with a resistor of moderate value in comparison. A diagram of this resistor/capacitor smoothing is shown in figure 7.

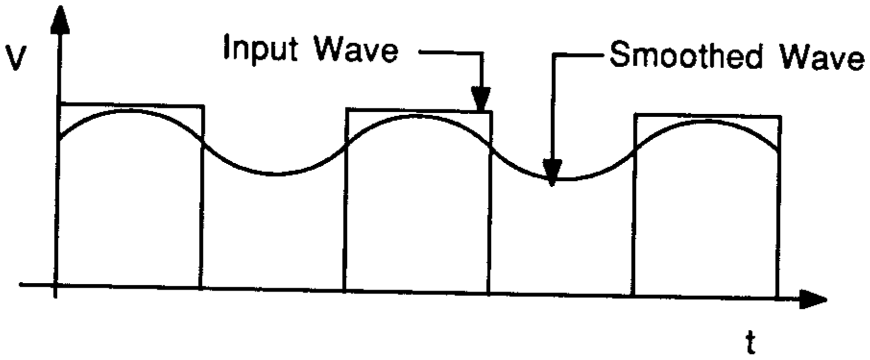

Fig. 7 - Amplified detector signal and analog signal produced by smoothing with a resistor/capacitor circuit

The diode is used to pass only the forward signal through the op-amp, and not for draining the capacitor, thus completing the smoothing process. Both signals can now be compared using an LM339 voltage comparator. When the two inputted signals are not equal, the comparator output is low. Only when the two inputted signals are the same will the output signal change to the high state. This is then fed into a 7414 Schmitt trigger for inversion (since one was used earlier, this will work fine as a simple inverter) to be inputted to 7474 flip-flop. The flip-flop is used because as the two detector signals become very close in value to one another, the output of the comparator will trigger every time the two signals are equal. In this application, approximate location information suffices for part detection. When the two detector signals become equal, the comparator output jumps high, is inverted, and sets a flip-flop waiting in the reset state. The Q output from the 7474 goes high and is then sent to the computer to let it know that the part is centered between the fingers of the gripper. The outputs from the op-amps (attached to the outputs of the detectors) are also sent to the computer, for the purpose of assuring the robot controller that the robot gripper is moving in the correct direction and not for actual proximity sensing.

Also shown in figure 6 are two switches and tristated drivers. These are used so that an operator can switch between a manual reset or computer reset of the 7474. This is often useful for debugging a piece of equipment that is being built. Both the flip-flop and the computer need a low to reset. The computer/manual switch is attached to the 74241 tristated drivers, and will allow only the signal coming from the computer or the manual reset switch to pass through, but not both. An MC14490 debounce I.C. is used on all switches to prevent oscillations from switches to trigger an unwanted signal from the switch. They pass the same stated signal from input to output.

Along with part detection and centering of the gripper on the part for pick-up, external detection sensors are used to assure the computer that the gripper is in the general area that the gripper is "looking" for. The sensor pairs located on the front and bottom of the fingers are also compared exactly as they were for proximity sensing.

To allow the reader to see the computer inputs and outputs necessary for beam-breaks and proximity sensor comparison, a drawing has been included in the appendices showing the pinout for the computer ports J1 and J2.

2.2.2. Ultrasonic (Proximity Sensing on a Part/ Environment)

Ultrasonic sensors are chosen for use in proximity sensing upon the part/environment because they reflect sound from objects that would normally absorb light. If infrared sensors were used on the front and bottom of the fingers, they may not sense the presence of an object, tray, etc. whereas ultrasonic sensors will. With the use of an ultrasonic sensor that has a small cone of reflectivity, signals transmitted from a sensor, bounced off of an object, and reflected back to another sensor are kept to a minimum.

The purpose of using sensors on the front and bottom of the fingers is to ensure that, when the robot is sent to a general location for part pick-up, it can tell if the gripper is aligned parallel to the table (or parts tray). Therefore, by comparing two proximity signals coming from the bottom two sensor pairs, the gripper and computer can work together to complete this alignment. Sometimes the robot needs to pick-up parts from a perpendicular alignment to a parts tray and for this reason front proximity sensing is needed to complete this task. When the detected signals from M1 and M4 are equal, the computer knows the gripper is aligned properly. The basic operation of the control circuitry for the ultrasonic proximity sensing of the Instrumented Gripper the following: transmit a pulse from the ultrasonic transducer, detect the pulse from the same transducer, and represent the detected signal as a number corresponding to a distance.

The four ultrasonic sensors are composed of the ultrasonic transducer and the electronic control board per sensor. The control board requires +12 VDC power and a transmit pulse to receive a detected signal from the sensor. Figure 8 shows a timing diagram for the ultrasonic transmit and detect signals. The timing between transmit pulses cannot be less than 8ms for the sensor to function as the manufacturer specifies and to allow enough time for the detected signal to be received.

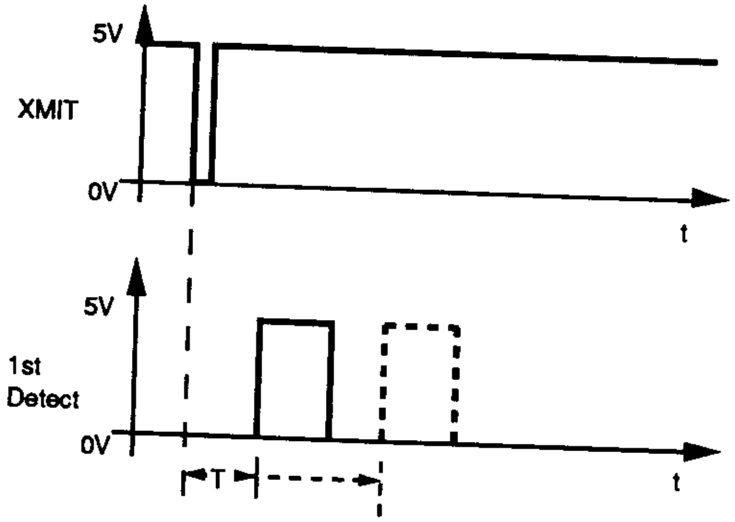

Figure 8. Timing diagram for the ultrasonic transmit and detect signals

To allow the computer to control the operation of the ultrasonic sensors, four optically-isolated switches are used to enable/disable power to each control board (see Migatron Control Circuitry and Boards, page 1 of the Appendix). For manual operation, a second switch is provided on the front panel of the System Interface chassis (ENABLE) which overrides the computer operating mode and turns all four control boards on. Once power to the control board is enabled, a transmit pulse is needed to make the transducer send a transmit signal. The transmit pulse (XMIT), also under computer or manual operating modes, is timed via a 74123 'one-shot A' set with a resistor-capacitor combination of 0.001 seconds. This allows a pulse width of 1 ms to be sent to all four control boards.

Computer control of the transmit pulse is provided through a voltage-controlled oscillator and then through a 'one-shot B' set at 1 ms output pulse. This is sent through a 7411 three-input AND gate along with a COMPUTER XMIT and a ONE-SHOT XMIT (single pulses from the computer and from a manual push-button switch, respectively). The output from the AND gate is then sent through the 'one-shot A' described above.

The next stage of the ultrasonic controller is the detection circuitry. When a detect signal is received from the transducer, a pull-up is needed on the first detect output of the control board to make the signal 0 - 12 VDC. In turn, this signal needs to be brought to TTL levels to be compatible with the rest of the circuit (see Counter Circuitry, page 2 of the Appendix). A ULN2003 open-collector driver is used for this purpose. The output is sent to a pull-up resistor to +5 VDC, and the signal is now at a TTL level. The signal is then sent through a 7414 Schmitt trigger to 'clean up' the signal, and then to a 7474 flip-flop.

Now that the signal has been sent and received, the distance between the transmitted and received signals are needed to let the computer/user know how far the Gripper is from an object. The distance from the transducer is given by the following equation:

$$T \text{ (in ms)} \times 17.22 = \text{Distance from transducer (in cm)} \qquad (5)$$

Therefore, the transmit and received signals are sent to a 7474 flip-flop which is the switch for the counter circuitry that follows. When the transmit signal is sent to the control board, it is also sent to the flip-flop. The output is gated through a 7400 NAND gate along with an oscillator and then to a counter. The NAND gate starts output with a transmit and stops output when a detect signal is received, since the flip-flop output is brought low again. The NAND output looks like a 'packet' of pulses between transmit and detect signals (see figure 9) and is counted via the 74393 counter. Each counter is reset when a transmit pulse is sent to allow the latest information to be counted.

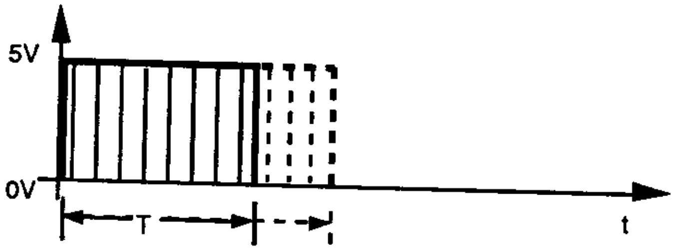

Figure 9. Transmit/receive signals prior to counting.

Once the counter has counted the pulse packet, it is sent to a 74373 shift register for storage until the computer or user shifts the data to the output. The input enable of the shift register is connected to the detect signal to time the shift operation synchronously with the timing of the detected signal. Hence, the pulse packet is delivered to the shift register as soon as possible for the most accurate result. The manual push-button SHIFT/M1 (M1-M4) overrides the computer mode and allows the user to shift out data from the shift register manually.

The outputs, Q0 - Q7, of all four shift registers (one per channel or sensor) are tied together and allow the computer to read them one channel at a time. Taking this one step further, these 8 output lines are brought to two more shift registers (74295) and now provide four output lines per shift-register to be sent to the computer or front panel of the System Interface chassis as on/off LED's. Manual operation of the high and low byte data is provided via the LED's on the front panel. This provides four bits of information, whether by manual or computer control, as a HIGH BYTE for coarse and four bits as a LOW BYTE for fine data representation of a distance between the ultrasonic transducer and the object, respectively. A complete circuit diagram of the ultrasonic system is shown in the appendices.

2.3. Power

The power needed for the Instrumented Gripper System is +5 VDC and +12 VDC. All digital and analog circuitry runs on +5 VDC and only the Migatron Ultrasonic Electronic Control Boards need +12 VDC to operate.

Two 3A power supplies make-up the +5 VDC power and one +12 VDC @ 1 A power supply is needed to run the ultrasonics. The total power used by the +5 VDC supply is 19.5 watts and 2.30 watts for the +12 VDC supply. Capacitors are placed across the power and ground on each circuit board (5 in all) for decoupling purposes.

3. Experiments Performed

3.1. Test Procedures

3.1.1. Infrared

Upon receiving the emitters and detectors, one of each was placed onto a breadboard in order to determine the strength of the output signal would be for various load resistors and for various distances between the emitter and detector. A function generator was used to produce the desired square-wave for input to the emitter, and a variable power supply was used to achieve the desired +5 V source voltage.

In order to help design the beam-break and proximity circuitry, one channel of the beambreak/proximity sensing circuit, shown in figures 4 and 5, was implemented on a breadboard. The two emitter/detector pairs were mounted into two pieces of angle-aluminum for the purposes of alignment and distance. Also, the model served well to test the design theory of the circuitry.

When the circuit boards were completely checked for mistakes, the rest of the wiring was checked in the same way as above. After all wiring of circuit boards, chassis, and cables were checked for mistakes and fixed, the power was turned on. This test procedure is mandatory for any system being built. With the power turned on, each circuit from beginning to end was checked for mistakes while following the schematics whether the circuit seemed to work or not. A good idea is to save as many mistakes as possible to be fixed, since taking the circuit apart and putting it back together again causes mistakes itself with broken wires, pins, etc. The system was checked until all schematics had been "debugged" for mistakes. With the system working as expected, the schematics were updated to match the working system and, hence, the system was complete.

3.1.2. Ultrasonic

Upon the fabrication of the Migatron Ultrasonics portion of the Instrumented Gripper, the system was taken to the CDWS to be interfaced to the robot controller via a digital I/O board. Minor wiring errors were resolved, as well as some software changes made for testing purposes. Also, the timing capacitor on the counting circuit 74124 oscillator was adjusted.

3.2. Test Results

3.2.1. Infrared

After having built a a similar gripper system equipped with the same infrared sensors and circuitry, the testing of the system was found to be the same as well. Parts were centered upon and the threshold potentiometers on the comparison circuitry were adjusted accordingly.

3.2.2. Ultrasonic

While setting the number of pulses within a pulse-packet, a problem occurred whereby 'holes' (data started at zero as if beginning at the transducer again) were seen in the output data. This is due to the low 8-bit resolution of the counter. For example, the data counted up to 1023 at approximately 7 in. Just past this point, the data began at zero again and started counting up again. By changing the timing capacitor on the timing oscillator (74124) the result was overcome and the entire distance from 3 in. to 15 in. was within 1023 counts. Unfortunately, the increase in range incurred a loss of resolution. This trade-off can be improved with larger counters, or by reducing the sensing range required. For our application, we have chosen to work in a more confined area, for a resolution of 0.0045 in., which is similar to the fundamental resolution of the ultrasonic transducer.

4. Future Considerations

4.1. Applications

As noted in the objective of this paper, two applications were stated: part/environment detection and known-point calibration of the robot to which it is attached. These two are of interest to the NIST Automated Manufacturing Research Facility (AMRF). At present, a plexiglass template is used to locate the part so that the robot 'knows' where to find it for retrieval (see figure 10). If the part is moved, the robot cannot 'see' where it is and possibly cannot find it. With the help of this gripper, the part is sensed with a scanning routine and retrieved by the robot.

The other problem is that of calibration of the robot. The Instrumented Gripper allows the robot to measure its positional errors automatically at a variety of locations in the workcell, a process that is currently done by hand. This scenario is now becoming a reality at the NIST AMRF/CDWS, and will be used as part of the Off-Line Programming Project at NIST.

Another application, not mentioned previously, is the use of the gripper with an imprecise robot so that the gripper uses its sensors for fine maneuverability of the robot. Since the robot becomes more precise with less gear backlash (among other things), the cost of the robot also increases. With the use of a precise gripper on a cheaper, less precise robot, the gripper could possibly take the place of such backlash problems and, in turn, such costs.

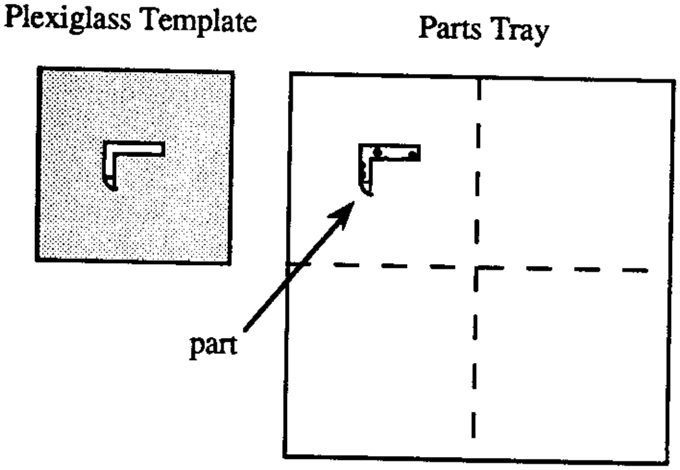

Figure 10. Plexiglass Template and Parts Tray used in the CDWS/AMRF

4.2. "Between-Front" Object Detection

The areas between, in front of, or below the fingers is sensed either by infrared or by ultrasonic sensors. The area between the fingers and in front of the fingers is not sensed by any of the sensors. In the Handbook of Industrial Robotics [1], a gripper is shown with an ultrasonic sensor placed at the back of the gripper to alleviate this problem. Another approach is to use wide-angle field of view inductive (for metal parts) sensors on the front-inside corner of the fingers, pointing them toward this area that is not detected.

5. Summary and Conclusions

Upon testing of the Instrumented Gripper System, the ultrasonic sensor package reflected well from a flat surface, such as a parts tray, and can tell when a part (object) is below the field-of-view of the ultrasonic sensor. Therefore, with a scanning routine and some knowledge of the part to be retrieved, the part can be retrieved without the use of vision and with only the use of a beginning taught location and knowledge of the part's size.

The infrared sensor package has proven itself again to be reliable. When a calibrated part (with known reflective properties) is brought between the fingers of the gripper, the beam from emitter to detector - right finger to left finger - is broken. The circuitry automatically switches to proximity comparison, and the part is now ready for centering upon by the robot. Once the part has reached a center point (signals from right and left fingers are equal), the proximity comparison signal shows a change in state and the task of finding a part and centering the gripper is complete.

Future work with the Instrumented Gripper System is to implement it into the AMRF/CDWS where the gripper will actually be connected to a robot and used for part locating and centering while periodically calibrating the robot via a calibration routine and calibration set-up within the work volume of the robot. This work has already begun and currently has a November 1989 completion date set for the calibration application.

6. Acknowledgements

This project was designed for the National Institutes of Standards and Technology, Robot Systems Division with the consent of Mr. Roger Kilmer and Dr. Ronald Lumia. I would like to personally thank Robert Russell and Wendell Wallace for their help in fabrication of the system after design, Wendell Combs for all machine work on the fingers, Chuck Giauque for help with cabling and software testing, and Nicholas Tarnoff for software development upon completion of the system.

The project is in its second phase upon completion of the hardware/software and testing of the hardware/software. This second phase is the actual use of the Instrumented Gripper in the AMRF/CDWS where parts will be maneuvered using the gripper. Also, the Unimate 2000 Robot will be calibrated without the use of a human to reteach path points to the CDWS system.

7. References

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[4] Migatron Corporation, Migatron Corporation Specification Sheet for the "RPS-300 Ultrasonic Transducer and Electronic Control Board", 1986.

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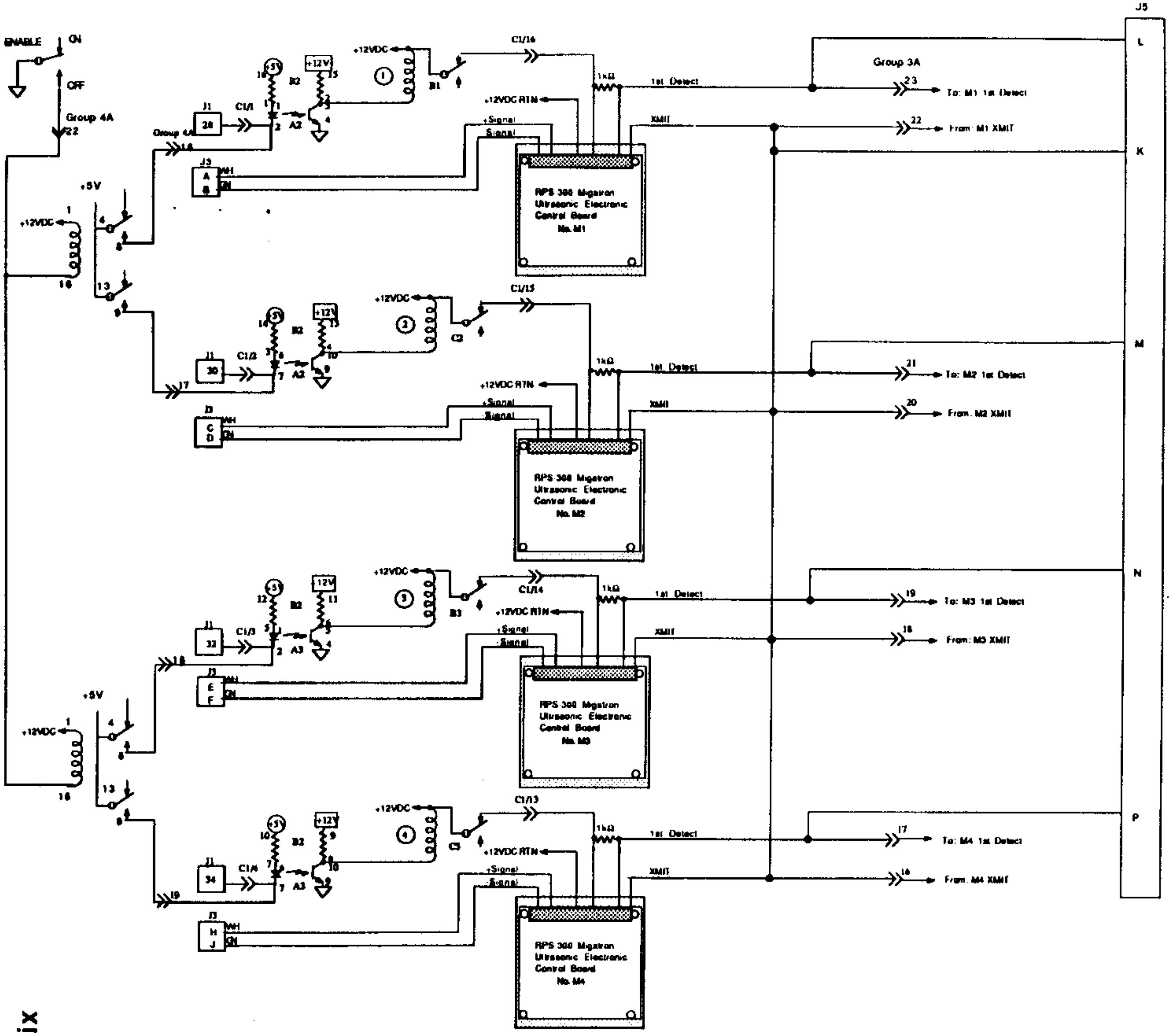
8. Appendix - Schematics of the Ultrasonic Control and Counter Circuitry

1. Migatron Control Circuitry and Boards
2. Counter Circuitry

Appendix



MIGATRON CONTROL CIRCUITRY AND BOARDS
for: Ultrasonic Ranging System
Instrumented Gripper (CDWS/AMRF)

Roger Bostelman
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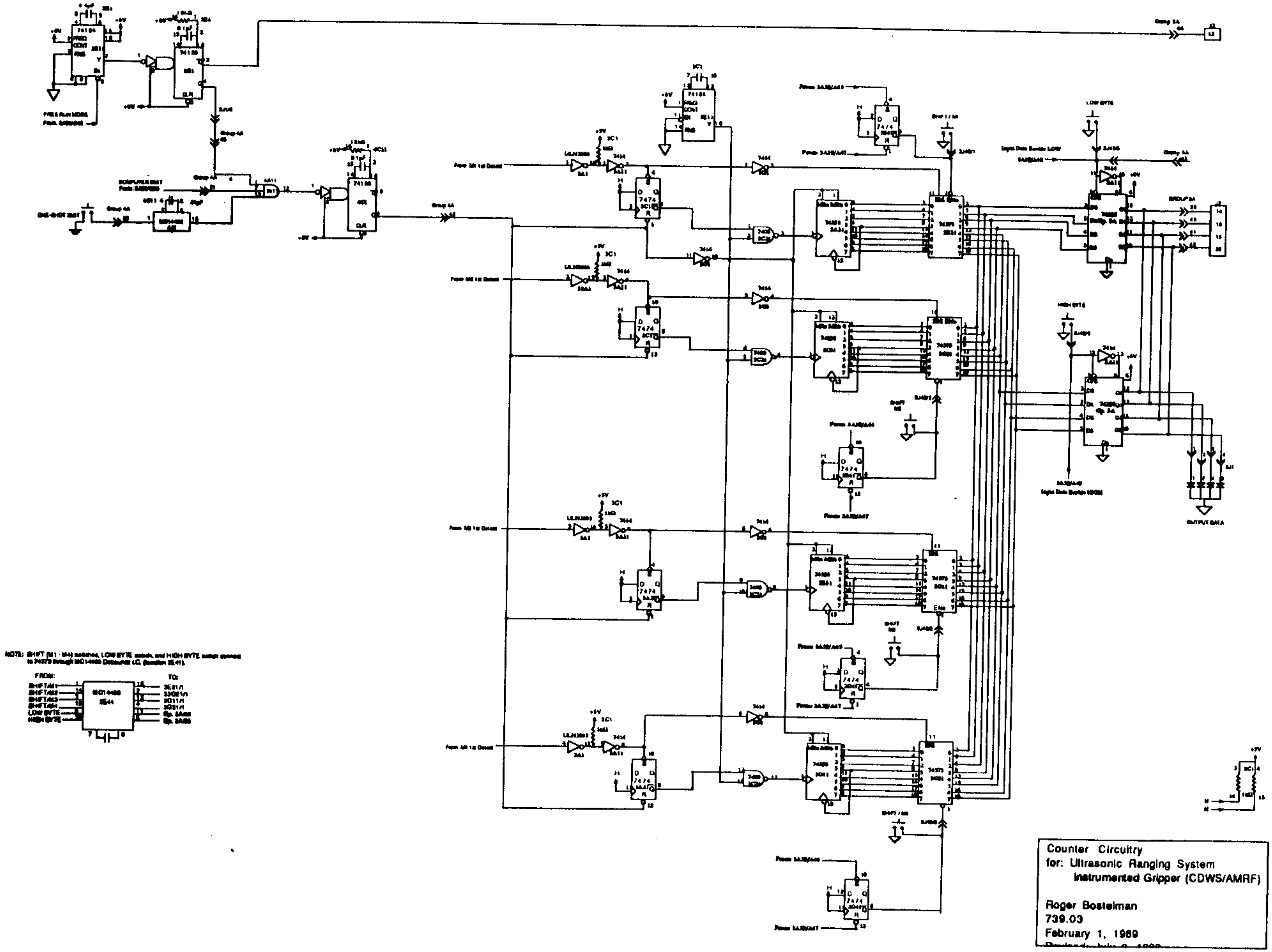

Counter Circuitry
for: Ultrasonic Ranging System
Instrumented Gripper (CDWS/AMRF)

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