NBSIR 82-2590

A Guide for the Construction and Operation of Drill-Up

U.S. DEPARTMENT OF COMMERCE
National Bureau of Standards
National Engineering Laboratory
Center for Manufacturing Engineering
Washington, DC 20234

October 1982

U.S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

NBSIR 82-2590

A GUIDE FOR THE CONSTRUCTION AND OPERATION OF DRILL-UP

Kenneth W. Yee

U.S. DEPARTMENT OF COMMERCE
National Bureau of Standards
National Engineering Laboratory
Center for Manufacturing Engineering
Washington, DC 20234

October 1982

U.S. DEPARTMENT OF COMMERCE, Malcolm Baldrige, ***Secretary***
NATIONAL BUREAU OF STANDARDS, Ernest Ambler, ***Director***

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

A GUIDE FOR THE CONSTRUCTION AND OPERATION OF DRILL-UP

Kenneth W. Yee

ABSTRACT

This guide provides detailed information for the construction of a single-speed version of Drill-Up and instructions for its installation and operation. Drill-Up is an instrument designed to prevent breakage of small-diameter drills used on automatic-feed drilling machines with a spindle retract ability. The method and applications have been previously described in the references given. The hardware and software necessary to construct an instrument for use at a single selected drilling speed are described. The circuit diagram and source program are included. The description is of a preliminary design implemented at the National Bureau of Standards (NBS) and in use in the NBS central machine shop. Sufficient details are included for those equipped to use the common 8048 family of microcomputers to build a "cookbook" instrument. The information is also adequate to implement the instrument on any existing microcomputer or microprocessor.

A GUIDE FOR THE CONSTRUCTION AND OPERATION OF DRILL-UP

1. INTRODUCTION

Drill-Up is an instrument designed to prevent breakage of small-diameter drills used on automatic-feed drilling machines with a spindle retract ability. The method and application have been previously described.[1,2] This system will predict failure of small drills on constant-feed-type drilling machines. It is presently optimized for drill sizes of about 1/8 inch (3 mm) or smaller, where the expected failure is breakage. It may not work on machines that use constant force, such as manual drill presses or special air-over-hydraulic feed machines. The reason for this is that the detection method depends on deflection of a long slender column with one rigid support on the end opposite an axial load; that is, a drill held in a chuck. When the drilling is improper, due to factors such as a dull or worn tip or a hard spot in the work piece, the material cannot be removed as fast as the drill is being fed. When this occurs, the drill deflects as a column and induces a vibration signal as it scrapes on the side or bottom of the hole. If this is allowed to continue, the column will totally collapse, resulting in drill failure. The detection method recognizes that the scraping in the hole will be synchronous with the rotation of the spindle. Of course, as the drill goes further into the workpiece, the material provides an instantaneous stabilizing transverse-load which, in effect, shortens the column and increases the load required for failure. In this case, the drill failure may be caused by seizing, due to material caught between the drill and the side of the hole. This may also result in a synchronous vibration.

Drill-Up is not perfect, but can prevent a large number of failures; more than 90 percent of the potential failures have been prevented. The system has been used most frequently with drills about 0.04-0.05 inch (1.0-1.2 mm) in diameter. The system was tested drilling 0.04-inch (1-mm) holes in a 1/4-inch (6.4-mm)-thick mild steel (C1015-C1020) cold-rolled plate. Failure was encouraged by removing the coolant. In 47 out of 50 cases, the system retracted the drill before failure occured. Additional details are given in references 1 and 2.

The present paper describes the hardware and software necessary to construct an instrument for use at a single selected drilling speed. The testing, operation, alterations required for other speeds, and some pitfalls are included. A preliminary design is described, shown in Figure 1, which was implemented at the National Bureau of Standards (NBS) and is in use in the NBS central machine shop. This design has been found suitable for a wide variety of applications, but changes, such as amplifier gain, may be required for an unusual setup (e.g., a very rigid workpiece). No effort has been made to optimize the circuit described in terms of component count or cost. The components used were those at hand and are by no means unique. The instrument uses a low-cost, single-chip microcomputer to implement its function. Sufficient details are included, for those equipped to program and construct devices using the common 8048 family of microcomputers, to build a "cook-book" instrument. This information is also adaquate to implement the instrument on any existing microcomputer or microprocessor. The instrument described is covered by an application for patent with rights assigned to the U.S.

Department of Commerce. Those desiring information on licensing should contact the Office of Government Inventions and Patents.[3]

2. BLOCK DIAGRAM DESCRIPTION

When Drill-Up determines that drill breakage is imminent, it outputs a command to the drilling machine to retract the drill. The input sensor is a piezoelectric accelerometer which is mechanically coupled to the workpiece as indicated in the block diagram in Figure 2. Potential drill breakage is determined by time-domain analysis of the accelerometer signal. A calibration routine in the microcomputer automatically adjusts Drill-Up to the normal amplitude of the signal. The system to be described operates at one programed drilling speed (4800 rpm for this example) and relies on the machine to be within the allowable tolerance, ±5 percent of the nominal speed. The circuit detects large-amplitude accelerations, caused by vibration of the workpiece, which are synchronous with the drill rotation.

As shown in Figure 2, the accelerometer signal is amplified by a high-input-impedance voltage amplifier with a selectable gain of one or five. A remotely-selectable adjustable attenuator has been included to accomodate a second tool (e.g., a center drill) operating at the same drilling speed, which causes significantly larger normal vibrations. The attenuator is switched into the circuit by a signal from the machine controller, indicating that the second tool is in use. The signal is amplified further by a variable-gain amplifier which can be adjusted from about 4 to 24. The signal is ac-coupled to one input of an analog voltage comparator. The reference "threshold" is supplied by a digital-to-analog (D-A) converter which is driven by the microcomputer calibration routine and will be described later. Signal peaks which exceed the threshold trigger a monostable multivibrator (one-shot) which generates a pulse with a width 40 percent of the drill-rotation period (5 ms for the present 4800 rpm). Two pulses per revolution are possible if both of the drill bit cutting edges hit the workpiece. These pulses are applied to an input of the microcomputer (an 8748 has been used), called test input zero (T0). This input is used because the 8748 has software branching based on the signal level of this input. The microcomputer continuously monitors this input until a pulse is found. It then delays for half a pulse width (2.5 ms) and resamples the input at time intervals equal to the period of rotation (12.5 ms). If pulses (caused by successive accelerometer signals greater than the threshold) are found, the input is repetitively sampled at rotation period intervals until four pulses are found. If, at any sample, a pulse is not found, the system resets. When four pulses in a row have been found, the system outputs a signal called Up-Z on port one, bit zero (P10). This signal triggers another one-shot which generates a pulse approximately one-second long. This time was selected to ensure easy perception of a front panel light, indicating "retract," which is operated from the same signal. The Up-Z signal activates a relay which can be connected to the emergency "retract" circuit of a machine controller. For the controller in use, this relay is normally closed and is opened when Up-Z occurs. When this is detected, the machining center in use retracts the spindle and interrupts the N/C machine program. In most cases this will occur before the drill breaks, but delay in the retract mechanism may result in occasional breakage during the retract. The drilling process may be continued at any time without adjustment to Drill-Up.

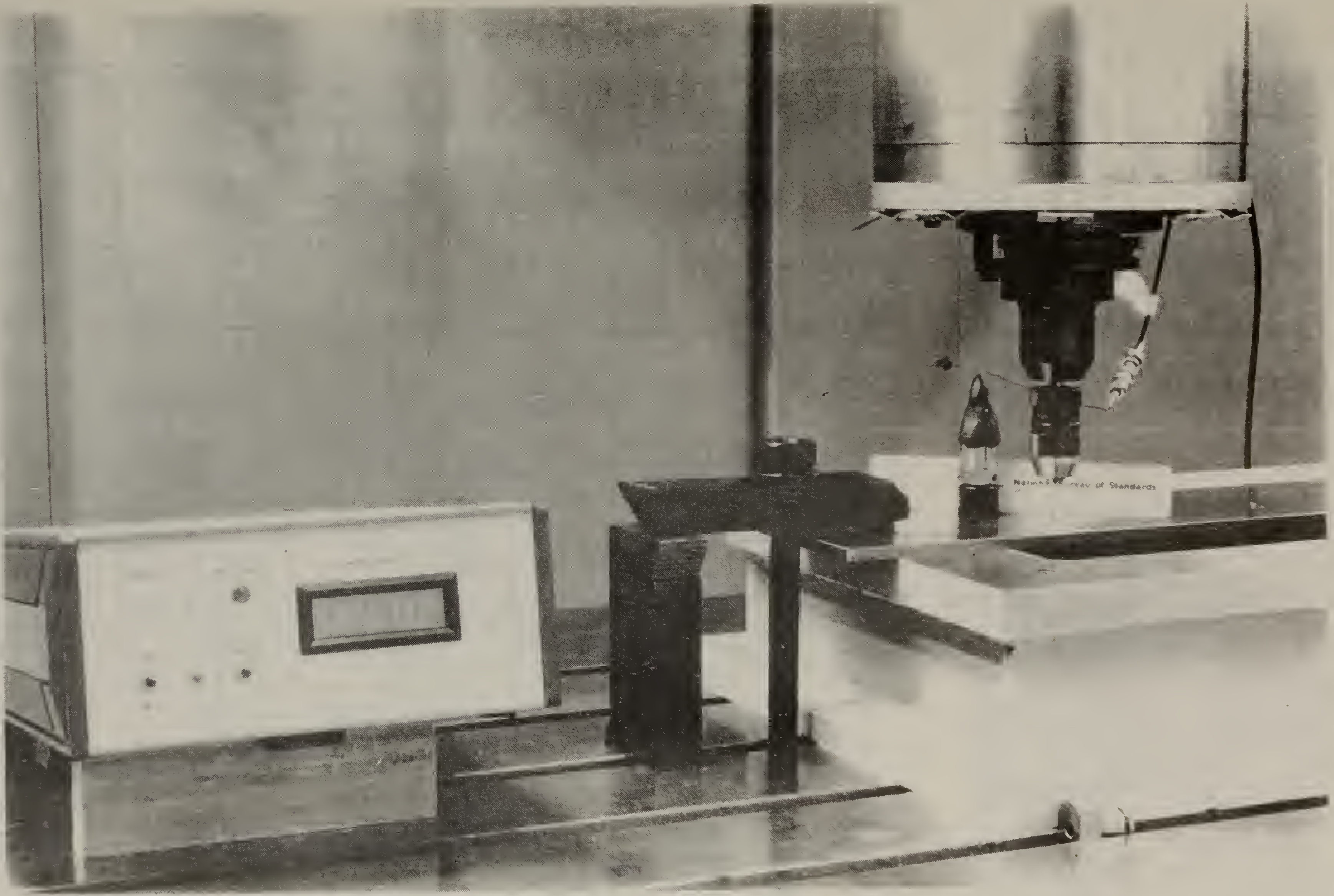


Figure 1. Drill-Up.

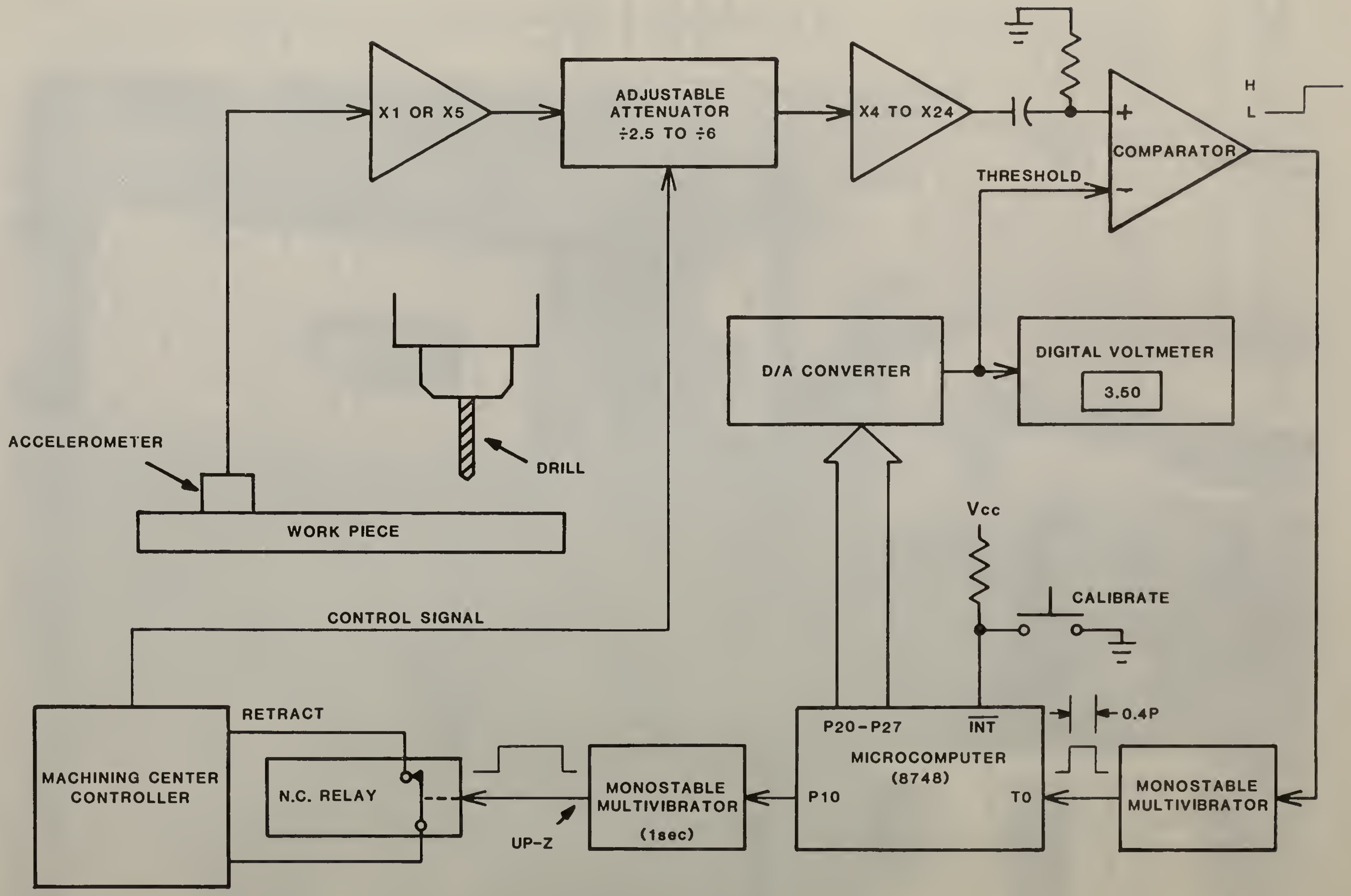


Figure 2. Block diagram of Drill-Up.

The calibration routine in the microcomputer, which allows the instrument to automatically adapt to the signal during normal operation, is activated by a front panel switch that provides a hardware interrupt signal to the computer. The routine reduces the threshold from approximately 1/5 of full scale (10 V) in increments at fixed time intervals. For the present application, the steps are 0.4 V at 1.5-second intervals. This continues until the peaks of the signal begin to exceed the threshold. The microcomputer determines that the threshold has been exceeded by counting the pulses appearing on the input terminal. When a predetermined number (160 for 4800 rpm) have occurred, the level of normal drilling has been found. The system then outputs a value, on port 2, to the D-A converter which sets the threshold to five times the level found for normal drilling. This threshold, in volts, is displayed on a digital voltmeter. The system is operating to detect potential breakage immediately upon termination of the calibration cycle.

3. FLOW CHART

The flow chart of the main computer program is shown in Figure 3. The complete listing of the program "DRLLUP" is given in Appendix A. The microprocessor, after power-up, immediately jumps to an initialization procedure which sets the D-A converter (threshold) to about 1/3 full scale (an arbitrary initial value) and enables the hardware interrupt which starts the calibration routine (described below). The "start" sequence then occurs. The Up-Z signal is cleared, the hardware timer is stopped, and the "count" which is the number of pulses to be found after the first is loaded with N (3). The input T0 is then continuously tested for a "1" indicating that the signal has exceeded the threshold. When the first pulse is found, the timer is loaded with "delay" (20 percent of the period of rotation) and started, and the timer flag is tested until it indicates that the time is up. The timer is then loaded with "wait," which is equal to the period of rotation, and started. When time is up, the input is again tested for a "1." If no input is found, the program returns to "start" and looks for a new first pulse. If a second pulse is found, the "count" is decremented, and, if not zero, the timer is reloaded with "wait". The process is repeated until "count" reaches zero (four pulses in a row at one-period intervals have occurred). If the third or fourth pulse is not present, the program returns to "start". When "count" is zero, the Up-Z signal is output and the timer loaded with "tzup". At the end of this time, which is the maximum timer cycle (20 ms), the program returns to "start," where Up-Z is reset and the program begins to look for a new pulse.

A flow chart of the calibration subroutine is shown in Figure 4. When interrupted, the microcomputer automatically goes to address 3 where it is instructed to jump to the calibration subroutine labeled "level". The initialization steps load the memory location "fulbmp" with the number "levful" which is the number of pulses to be counted before the normal level is assumed to have been found. Memory location "dancnt," which holds the D-A converter normal-level count, is initialized at the number 50 which is less than the full-scale (255 for 8 bits) count divided by 5. This ensures that the threshold cannot exceed full-scale after the 5-times multiplication which will occur later. A flag is set on bit 7 of port 1 to indicate that a calibration is in progress. This bit operates a front panel indicator light. The "dancnt" value is output on port 2 to the D-A converter. The timer is then started for the time period between level changes, which has been

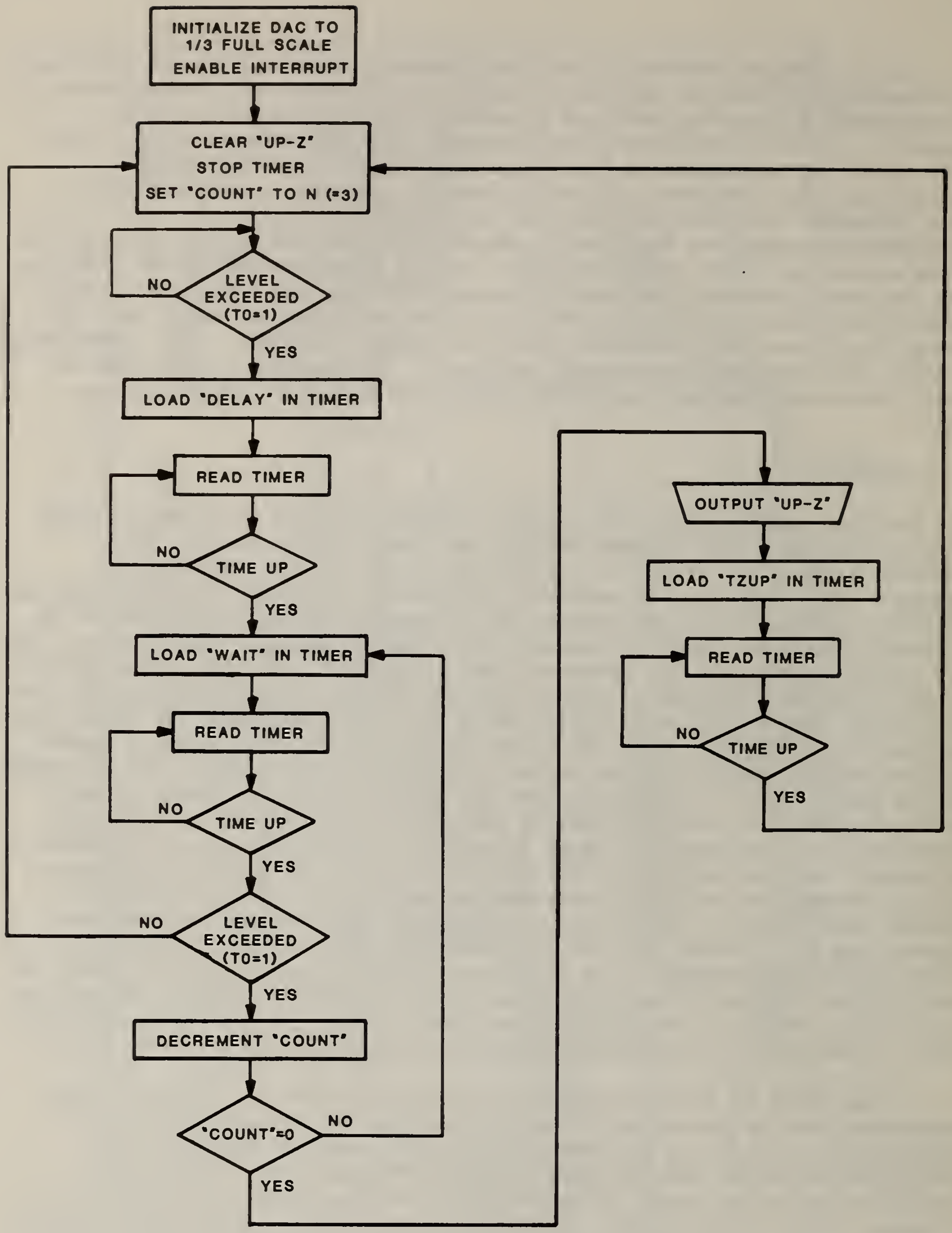


Figure 3. Flow chart of main program.

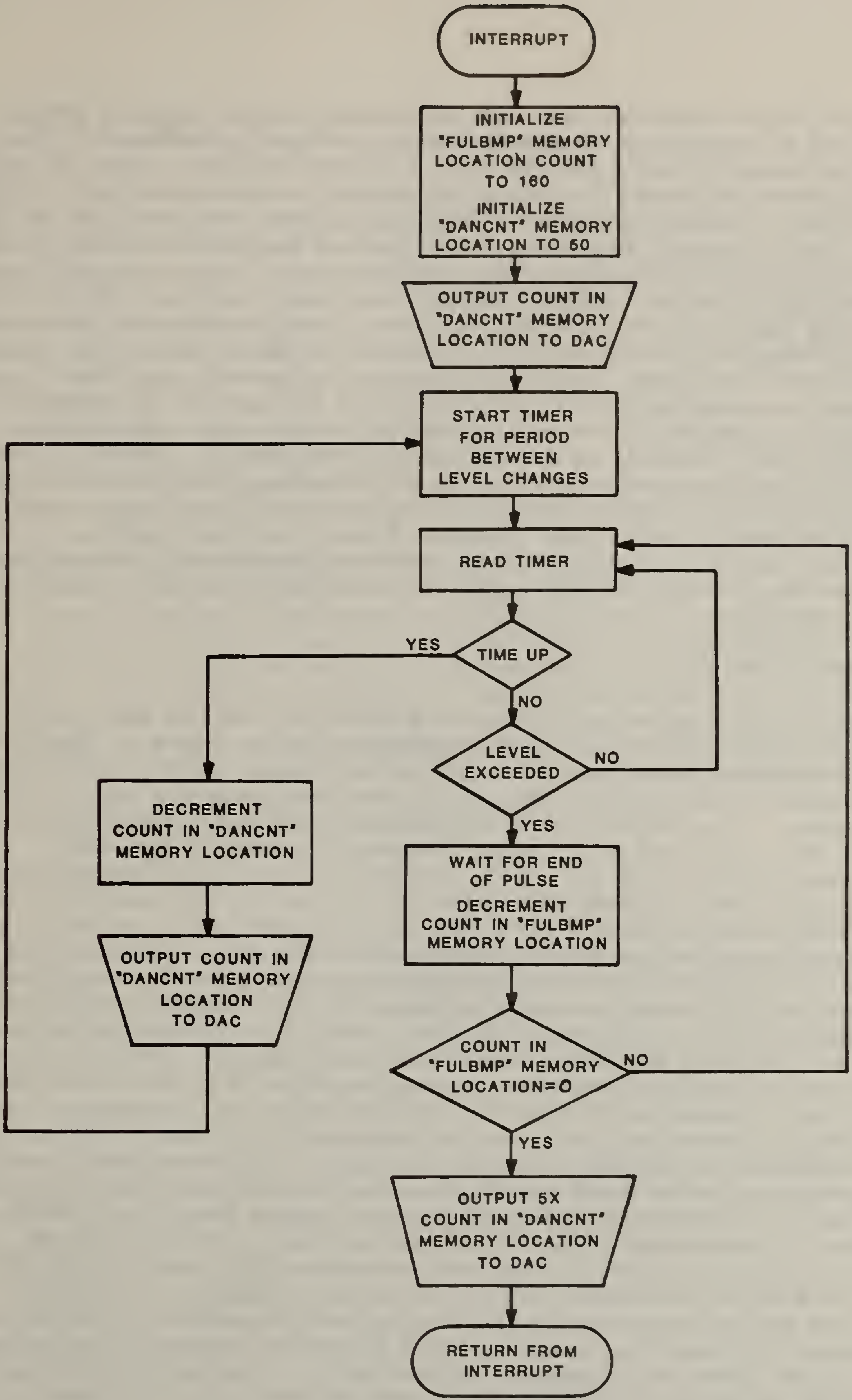


Figure 4. Flow chart of calibration subroutine.

selected to be 1.5 seconds; this time is a number (xt) of maximum timer periods (20 ms) as counted in memory location "xtimer" (see Appendix A). The program sequentially tests for the timer flag and then for a pulse on input T0. Whenever time is up, the value in "dancnt" is decremented and the new value output to the D-A converter. The timer is then restarted for the time between level changes. Whenever a pulse is found on T0, the program waits until the end of the pulse (to avoid counting it more than once) and then decrements the count in "fulbmp," checks for a zero count, and, if zero is not found, goes back to test the timer and input. The D-A converter continues to reduce the threshold level every 1.5 seconds. As the threshold approaches the peak values of the normal signal, an occasional pulse will be found. Eventually, a significant fraction of the peaks will exceed the threshold and the count in "fulbmp" will be rapidly reduced to zero. At that time the existing value in "dancnt" is multiplied by five (actually, added to itself repeatedly), and the resulting value is output to the D-A converter to set the operating threshold. This completes the calibration. The flag is reset and control is returned to the main program. Normal operation resumes immediately, and a retract could occur immediately following the calibration. During the calibration, drill breakage is a possibility since the main program is not operating.

4. CIRCUIT DIAGRAM

The circuit diagram is included in Appendix B, but does not show the 5-V and ±15-V power supplies. For the instrument shown in Figure 1, the majority of the components, other than the controls and indicators, are located on the printed-circuit board shown in Figure 5. The input sensor is an accelerometer. The piezoelectric accelerometer used has a sensitivity of about 90 mV/g, an unmounted resonant frequency of about 25 kHz, and a capacitance of about 1200 pF. It is connected to the input connector J1, shown in the circuit diagram, by 10 feet of 50-ohm coaxial cable which has a total capacitance of about 300 pF. The input amplifier U7 is a FET operational amplifier operating in the noninverting mode. The input impedance is essentially determined by the 10-megaohm resistor R20. The amplifier has a voltage gain of X1 or X5, selected by switch S3. The remotely-selectable adjustable attenuator consists of R12, R13, and R15. The attenuator is selected by relay K2 which is connected for operation by a 24-V dc control signal from the machine controller through connector J6. Shorting resistor R19 will allow operation from 5-V dc. If the relay is not activated, the attenuation is essentially zero. It will divide by a factor of about 2.5 to 6, as determined by R12 when the relay is closed. The second amplifier U6 is the same type of operational amplifier as that used in the first stage. It is connected in the noninverting mode with an adjustable gain from 4 to 24, as determined by potentiometer R8. The signal is then ac coupled through capacitor C12 to one input of the analog comparator U3. When switch S4 is in automatic mode, the reference voltage to the other comparator input is determined by the D-A converter U2. The current into the D-A converter output pin causes a voltage drop across resistor R5, which subtracts from the voltage across zener diode CR1, which is a nominal +10 V. The resulting reference voltage is the threshold voltage and is read by the digital voltmeter. The threshold voltage is zero for a zero output from the microcomputer U1 and a nominal +10 V for a 255 (FF hex) output. When switch S4 is in manual mode, the threshold voltage is determined by variable resistor R21 and is not affected by the D-A converter or, therefore, the calibration routine. This manual setting is useful when a calibration has been run for a specific setup and material. If set manually, it will be retained even if power is lost.

When the peak signal exceeds the threshold, the comparator output triggers the one-shot U4. Timing components R1 and C8 are selected for a pulse width that is 40 percent of the drilling period of rotation. This pulse is applied to the T0 input of the microcomputer and is available at a test point J4. The Up-Z output signal from the microcomputer on port 1, bit zero, triggers one-shot U5 which generates a pulse about one second long. This pulse opens the retract relay (K1) contact through a driver transistor Q1. A front-panel red light-emitting-diode (LED) indicates a retract. A positive going Up-Z pulse is available at test point J5. Switch S1 which is across the retract relay contact will disable the retract function when desired. Recall that, for the controller used, the retract circuit is normally closed. The retract circuit connects to connector J2. The calibration routine is initiated by switch S2 which produces an interrupt signal to the microcomputer. The calibration flag lights a yellow front-panel LED through driver transistor Q2. The computer clock frequency is determined by crystal Y1 which is presently 6 MHz. The power supply requirements are 5 V at less than 200 mA, ± 15 V at less than 50 mA. This does not include any power used by the digital voltmeter, should it operate from these supplies. The commons of the 5-V and 15-V supplies (digital and analog grounds) must be connected together at one point. If an 8748 microcomputer, programmed as shown in the listing in Appendix A, is used for U1 along with the component values as given on the circuit diagram, a Drill-Up system for use with a drilling speed of 4800 rpm will result. The tolerance on the drilling speed is about ± 5 percent from the nominal speed. Software and hardware changes, to be described later, are required for operation at any other speed.

5. TESTING AND SETUP

The test setup shown in Figure 6 is suggested for testing the circuit and adjusting the variable controls. This type of method must be used to generate a variable number of pulses that occur at time intervals corresponding to the period of drill rotation. A gated square-wave or pulse generator is required along with another pulse generator to produce the gate pulse. The output signal level must be variable from about 10 mV to 1 V peak-to-peak for a square wave (peak, if a pulse). The gated generator should first be adjusted for a frequency equal to the rpm/60, if a square wave, or a time between pulses of 60/rpm. For 4800 rpm, this is 80 Hz or 12.5 ms. The gate pulse must be adjustable in width from one to four or more periods of rotation (up to 50 ms for 4800 rpm). The repetition rate should produce a perceptible pattern on the oscilloscope (about 5-10 Hz). Connect the generators and oscilloscope to Drill-Up, as shown in the figure, and apply power. If 3 oscilloscope inputs are not available, a voltmeter may be used to monitor Up-Z since it is a one-second-long pulse. Set the gain switch S3 to low and set the threshold selector-switch S4 to automatic. Operate the gated generator in the continuous mode and adjust its output level to about 0.1-V peak. Adjust the gain by varying R8, until the signal at the amplifier output is 15 to 20 times the input level. Reduce the level as necessary to less than 2 V at the amplifier output and set the gain switch to high. Verify that the level increases by a factor of five. At power-up, the threshold should have been set to about 3.3 V (1/3 full scale). With the continuous input still applied, reduce the level at the amplifier output to about 1 V. Push the calibrate

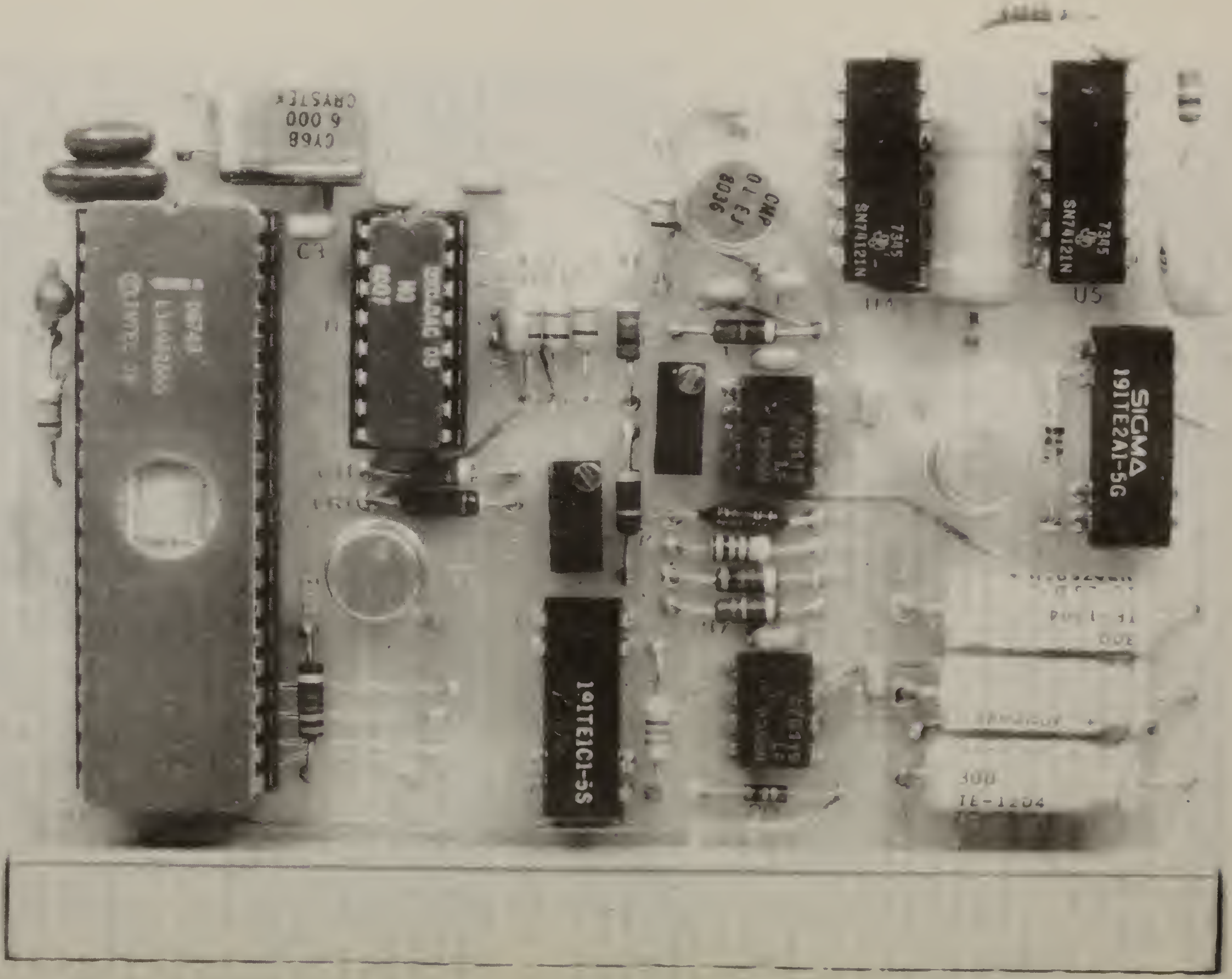


Figure 5. Circuit board.

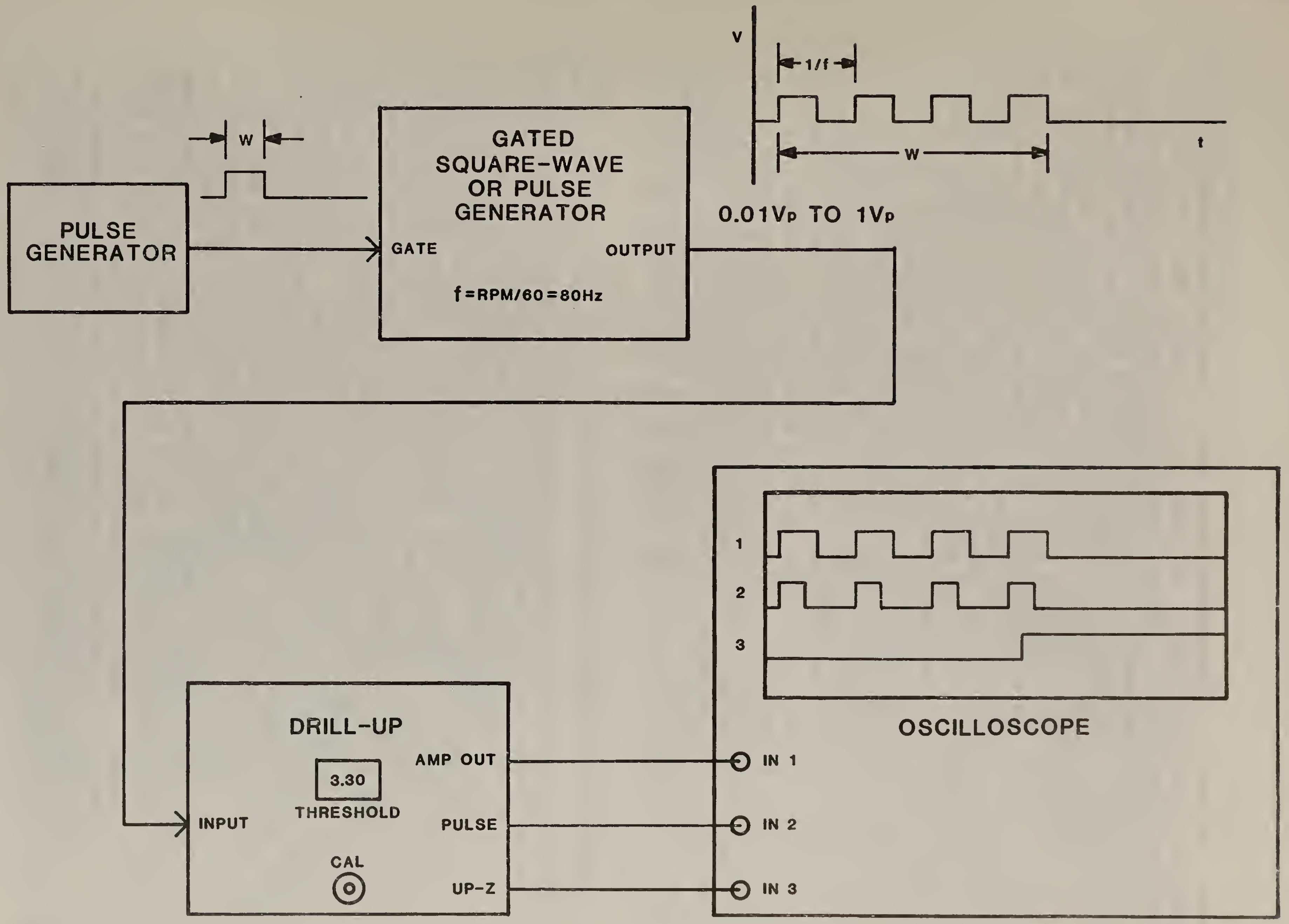


Figure 6. Test setup.

button. The yellow calibration-indicator should light and the threshold should jump to a value slightly less than 2 V (1/5 scale). The threshold will decrease in steps every 1.5 seconds. When the threshold reaches the level equal to the positive peaks of the amplifier signal, pulses will appear at the pulse output J4. They should be present for about 2 seconds. When they stop, the threshold will jump to a value equal to about five times the peak of the signal. The calibration indicator will turn to off. The attenuator may be tested and adjusted by applying 24-V dc to connector J6 and observing the change in level at the amplifier output. The attenuation factor is varied by changing R12. The gated generator should now be switched to the gated mode and the gate-pulse width set to produce 1 to 3 pulses. Increase the level from the gated generator until the peak exceeds the threshold. Pulses corresponding to the signal peaks should appear on the pulse output. Increase the gate-pulse width to allow 4 pulses and the Up-Z signal should appear during the 4th-pulse. The red retract-indicator should light. Verify that the circuit detects 4 or more pulses in a row, but not less than 4. An ohmmeter connected across connector J2 may be used to verify that the retract relay contacts open when Up-Z is generated. The enable switch S1 must be at the "on" position (contacts open). Now, vary the gated-generator frequency or period between pulses while ensuring that the gate still allows 4 pulses. The Up-Z should continue to be present until the frequency or period is changed by approximately ± 6 percent. If the tolerance is not symmetrical about the nominal value, the programmed rpm (4800) and the speed simulated by the gated generator do not coincide. If the total tolerance does not equal about 12-14 percent, the width of the pulse from one-shot U4 is not 40 percent of the period.

6. CHANGING THE PROGRAMMED DRILLING SPEED

As previously stated, the microcomputer program and circuit diagram given are for use at 4800 rpm. Several constants in the program and one or two hardware component values must be changed for any other operating speed. With the present 6-MHz crystal frequency, use of the program given is limited to a drilling speed range of 3000 to 10,000 rpm. This limit is due to the range of the internal timer. The limitation is primarily at the low speed end, where the timer count used is near the maximum. The low range can be extended, of course, by rewriting the program to run the timer more than once in order to obtain the longer time period. However, the present program can be used down to 500 rpm by changing to a lower frequency crystal, since the length of one timer count is related to the microcomputer clock frequency. The corresponding slower execution time for any program step is inconsequential. Values of the constants and components which must be changed are given in Table 1 for a number of other drilling speeds. Crystal frequencies of 6, 3, and 1 MHz are used to cover the range. If the computation of these values is not obvious from the data given, scaling will provide useful values for intermediate speeds. Note that a choice of crystal frequencies is available for some speed values. The symbols TDY, TPD, LEVFUL, and XT are constants that appear in the equates at the top of the program listing given in Appendix A. Note that TDY and TPD are negative numbers. All numbers given are in decimal. The number base is converted to hexadecimal by the assembler. The values for components R1 and C8 determine the pulse width of one-shot U4 which must be 40 percent of the period of the drilling speed. These component values are not unique for the required pulse width.

7. OPERATING INSTRUCTIONS

Attach the accelerometer to the workpiece using a threaded stud, quick-setting adhesive, or magnetic mount (if the workpiece is ferromagnetic). The sensor should be located so as not to interfere with the drilling operation, but be as close as practical while equalizing the distance from the sensor to the drilling location throughout the area to be worked. Depending on the particular setup, distances from a few inches to about ten inches are usually suitable. Attach the cable between the sensor and the input connector J1 on Drill-Up. Route the cable out of the way of the spindle. Set the threshold switch to "automatic" and set the gain switch to "low." Electrical insulation between the sensor body and the workpiece may be required to eliminate noise from ground loops. Such insulation should be provided if the peak noise-level, with no vibration of the workpiece, at the amplifier output test point J3 is greater than 50 mV at the amplifier gain settings used. Any insulating material must be nonresilient; if not, the high-frequency response of the accelerometer will be limited. With the retract "enable" switch S1 off, connect the cable to the machine-controller retract circuit to the retract connector J2.

The circuit should now be calibrated. Install a good drill bit and begin drilling at the nominal speed (4800 rpm for the design given). Ensure that the material, coolant, and drilling process appear normal. The drilling operation must be continuous during the calibration cycle or an invalid threshold will result. The system has been designed to accomodate continuous or "peck" drilling. The threshold should have been set to about 3.3 V at Drill-Up power application. Push the calibrate switch S2. The calibration indicator should light and the threshold jump to about 1.9 V and begin to decrease in 0.04-V steps every 1.5 seconds. When the level of normal drilling is found, the threshold will increase to five times the lowest value displayed during the cycle and remain at that value. The calibration indicator will turn off. The time required to complete the calibration depends on the threshold level to be found, but should be less than one minute. The resulting threshold level should be between 2.0 V and 8.0 V. If not, try another calibration cycle. If the values are consistently high or low, an adjustment of the amplifier gain is required. If too low, the gain switch may be changed to high. If too high, in either switch position, the internal gain adjustment potentiometer R8 must be varied to reduce the gain. Observing the signal, on an oscilloscope, at the amplifier output test point will facilitate these adjustments. The signal observed is the same signal that is compared with the threshold. If the pulse output from J4 is simultaneously observed, a pulse will occur whenever the positive peak of the analog signal exceeds the threshold level. These signals will be similar to those shown in Figure 7, where the top trace is the amplifier output and the bottom trace is the pulse output. Figure 7a, is a new drill operating normally. In Figures 7b and 7c, the coolant has been removed to promote breakage. In Figure 7b, only two pulses exceed the threshold and will not cause a retract, while, in Figure 7c, there are four pulses in a row which will cause an Up-Z and a subsequent retract.

If permitted by the machining process, it is recommended that the calibration cycle be repeated several times or until a similar threshold value is found two or three times in a row. An identical value should not be expected on successive cycles but values differing by 10 to 15 percent, or

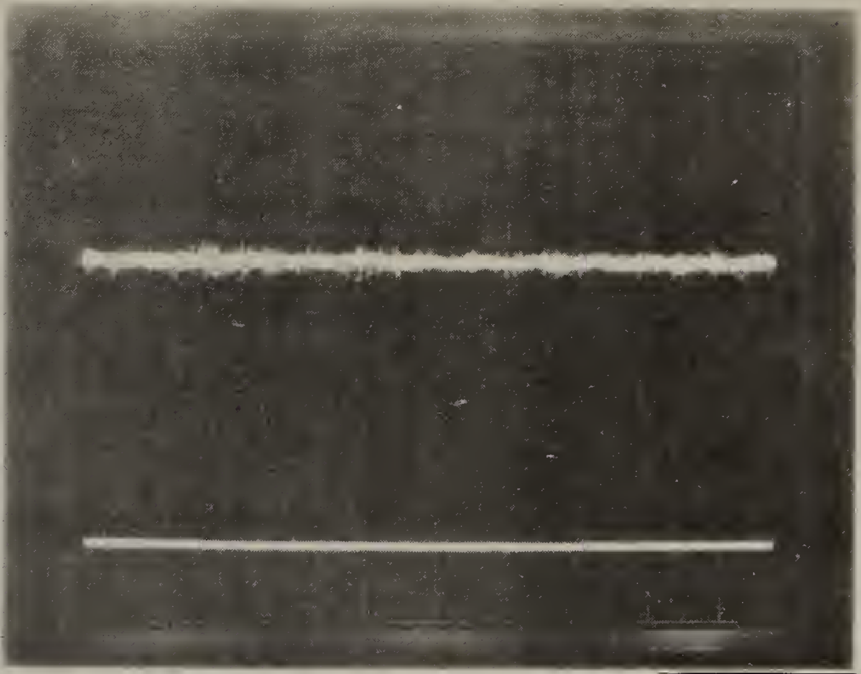
Table 1. Constants and values for selected alternate drilling speeds.

Crystal Frequency:	6 MHz					3 MHz			1 MHz		
Timer Count:	80 µs					160 µs			480 µs		
RPM	10,000	7500	5000	4800	3000	3000	2500	1500	1500	1000	500
TDY	-15	- 20	- 30	- 31	- 50	- 25	- 30	- 50	- 17	- 25	- 50
TPD	-75	-100	-150	-156	-250	-125	-150	-250	- 83	-125	-250
LEVFUL	255	250	167	160	100	100	83	50	50	33	17
XT	75	75	75	75	75	37	37	37	12	12	12
R1	36,000	20,000	33,000	33,000	24,000	24,000	30,000	24,000	24,000	36,000	36,000
C8 (µF)	0.1	0.22	0.22	0.22	0.47	0.47	0.47	1.0	1.0	1.0	2.0
Pulse (ms)	2.4	0.2	4.8	5.0	8.0	8.0	9.6	16	16	24	48

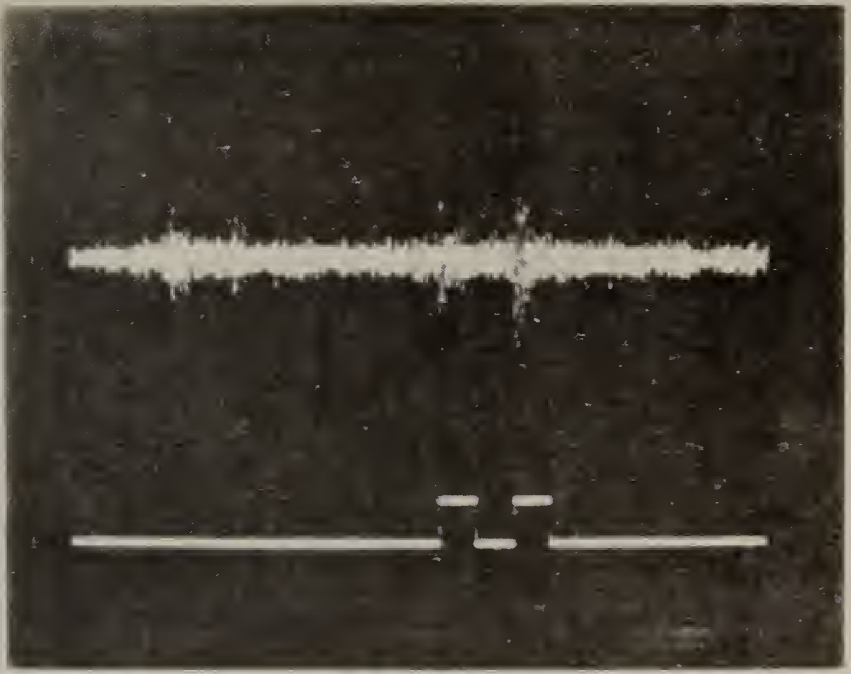
Note: values are in decimal; 255 is the maximum count possible; DRLLUP program example is for 4800 rpm.

Symbols:

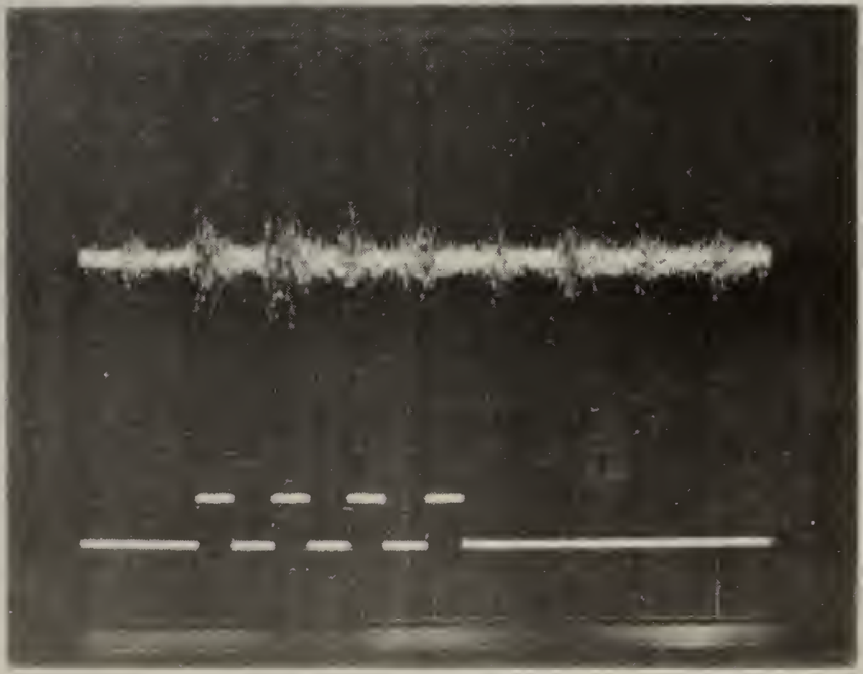
RPM = drilling speed in revolutions per minute
Period = 60/RPM (seconds)
TDY = -(number of timer counts in 0.2 Period)
TPD = -(number of timer counts in 1.0 Period)
LEVFUL = number of pulses till normal level is found during calibration
= 2 x (revolutions per second)
= RPM/30
Timer Count = 480/crystal frequency
XT = number of timer cycles in 1.5 seconds



A



B



C

Figure 7. Waveforms. Vertical: 2V/div.
Horizontal: 10ms/div.

less, should result. This will not be the case when hard spots or potential breakage are encountered during the cycle. The value in these cases will be excessively high and should be rejected.

The system is now ready for operation. Turn the retract enable switch on whenever the retract function is desired. When the retract enable switch is not on, the red retract indicator will still show that a retract would have been initiated. The threshold setting should continue to be suitable, if no significant change in the drilling process occurs. This includes the drill bit, material hardness, coolant or lubricant, sensor location, etc. A new calibration may be run at any time. Remember that the drill is not protected during the calibration cycle. The threshold value will be lost whenever the power to Drill-Up is turned off. The power-up value of about 3.3 V will automatically reappear. It is for this reason that the manual threshold is provided. With the retract switch turned off, change the threshold switch S4 to manual. Adjust variable resistor R21 for the same threshold level that was obtained during the calibration. This value will be retained, even if power is lost, and is useable after power-up without a need to recalibrate. Turn the enable switch back to on. The threshold switch must be changed back to automatic before another calibration can be run, or the calibration cycle may never terminate. If this should occur, turn the power switch off to reset the calibration in progress and return the program back to the operating mode. It is recommended that the calibration be taken on a new (or newly resharpened) tool. If the drill bits are from the same lot, recalibration after a tool change is generally not necessary. If a second tool, operating at the same rpm--but with a signficantly different normal vibration level--is to be used, the remotely-selectable attenuator must be adjusted. The tool having the lowest threshold level, when calibrated, must be the one in use when the attenuator relay K2 is not energized. The attenuator adjustment R12 should be varied such that the second tool, with the relay energized, has about the same threshold level when calibrated. Alternatively, it may be adjusted for about the same peak signal level at the amplifier output connector.

Since the present design is for a retract circuit requiring a normally-closed contact, a retract will occur immediately when power is lost. The machine controller is likely to be locked in retract and be inoperable. To prevent this problem, the retract enable switch should be turned off whenever power is removed from Drill-Up.

8. POTENTIAL OPERATING PROBLEMS

As previously mentioned, ground loops may induce noise in the sensor input to Drill-Up. Similarly, the lack of a single earth-ground to the Drill-Up common may result in ac pick-up. The signal from the sensor can be expected to vary in amplitude as the distance varies from the sensor to the location of the drilling. This is usually not a problem, if the variation is not more than about 1/3 relative to that from the location at which the calibration was taken. A calibration may be run at various drilling locations on the work piece to measure this variation. If the variation is excessive, the sensor may have to be relocated as the drilling location changes.

The signal level also varies depending on the rigidity of the workpiece and the mounting on the machine table. Thick materials, firmly positioned on the table, will, of course, require higher gain settings to obtain a useable threshold level. Large workpieces with long unsupported spans cause much more variation in the signal level vs drilling location. Intermediate supports to damp large low-frequency vibrations are recommended. Best results have frequently been obtained by positioning the sensor directly over one of these supports.

The speed of the drill must remain within the allowable tolerance which is ± 5 percent from the nominal speed. If the expected variation for the drilling machine in use exceeds these limits, but the change is primarily a speed reduction under load, Drill-Up can be programmed for a nominal speed which is between the no-load and full-load speeds to make better use of the available tolerance.

Drill-Up will not prevent every drill bit from breaking! Some will break without being detected. Testing and operating experience have shown, however, that Drill-Up prevents over 90 percent of the breakages that would otherwise occur. For the machining center used at NBS, there is a significant time-delay between the opening of the retract circuit and the physical movement of the head (a few tenths of a second). This delay results in occasional breakage during retract. The break, however, is clean and the tip of the bit is not driven into the hole. Also, failure modes have been observed, not related to the cutting edges of the drill bit, which may not produce the type of vibration signature being sensed. An example is binding along the body of a bit when cutting a deep hole, which is caused by chips lodged in the hole.

9. REFERENCES

1. Yee, K. W., and Blomquist, D. S., "An On-Line Method of Determining Tool Wear by Time-Domain Analysis", Technical Paper MR82-901, Soc. of Mfg. Engineers, Dearborn, MI, 1982.

2. Yee, K. W., and Blomquist, D. S., "Checking Toolwear by Time Domain Analysis", Manufacturing Engineering, Vol. 88, No. 5, May 1982.

3. Office of Government Inventions and Patents, Attn: Mr. George Kudravetz, National Technical Information Service, P.O. Box 1423, Springfield, VA 22151 (703-487-4732).

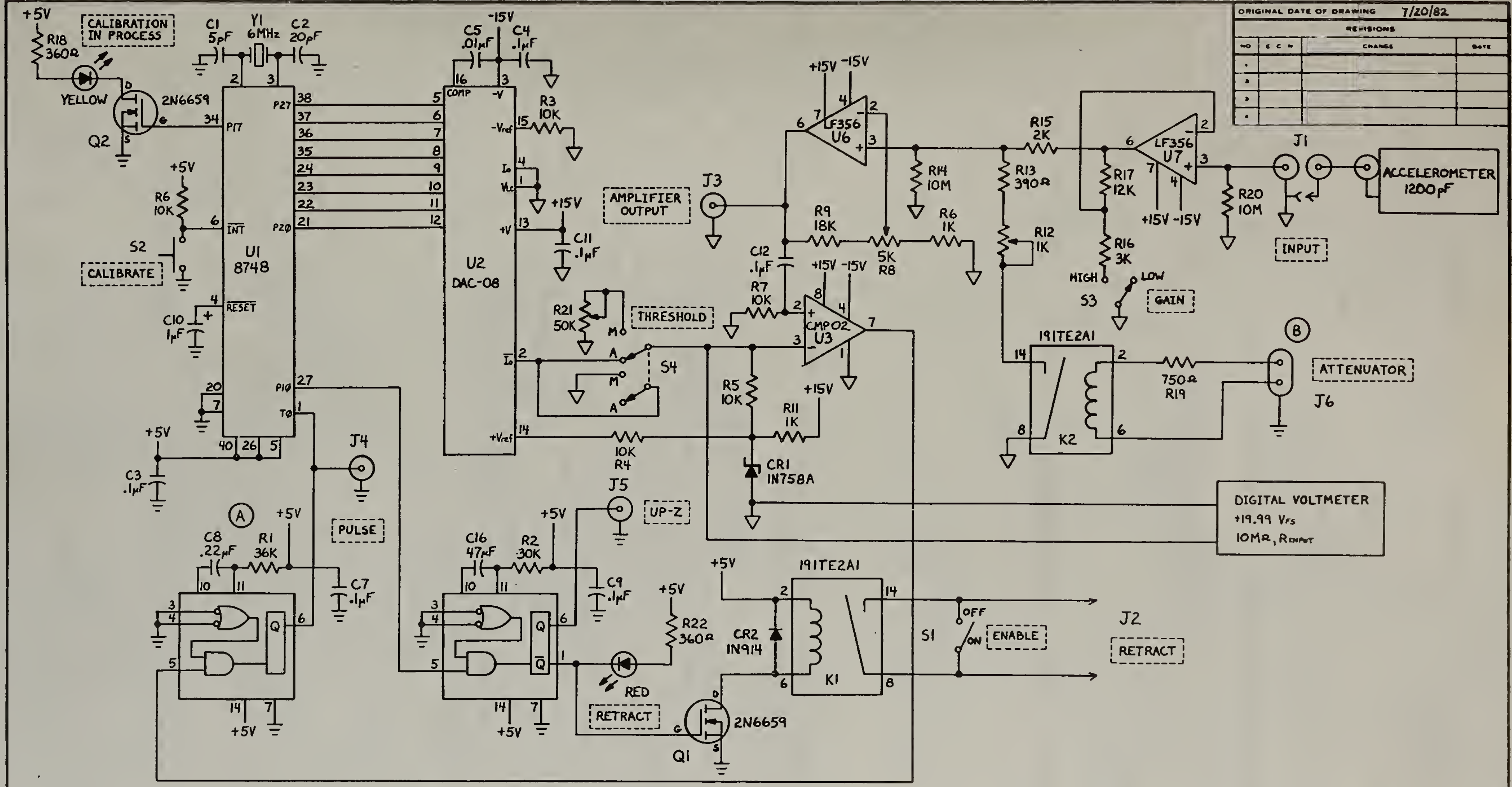
APPENDIX A

```
:FO:ASM48 :F1:DRLLUP.SRC SYMBOLS XREF PAGELENGTH(60) MACROFILE MACRODEBUG GEN TITLE('DRLLUP')
ISIS-II MCS-48/UPI-41 MACRO ASSEMBLER, V4.2             PAGE    1
DRLLUP

 LOC  OBJ         LINE        SOURCE STATEMENT
                     1 ;*******************************************************************************
                     2 ;DRLLUP
                     3 ;A PROGRAM TO PREVENT DRILL BREAKAGE ON AN AUTOMATIC DRILLING MACHINE
                     4 ;THIS VERSION INCLUDES AUTOMATIC CALIBRATION OF THE THRESHOLD LEVEL
                     5 ;IF N PULSES AFTER THE FIRST ARE DETECTED AT TIME INTERVALS TPD=60/RPM
                     6 ;ASSUME BREAKAGE IS IMMINENT AND OUTPUT AN UP-Z AXIS COMMAND (UPZ).
                     7 ;APPLY THE INPUT PULSE TO THE MICROCOMPUTER ON INPUT TO
                     8 ;OUTPUT TO DAC FROM THE MICROCOMPUTER APPEARS ON P2
                     9 ;BUSY DOING CALIBRATION FLAG APPEARS ON P17
                    10 ;UPZ APPEARS ON P10
                    11 ;CONSTANTS IN EQUATES ARE FOR  RPM = 4800  (TPD = 12.5 MILLISECONDS)
                    12 ;THE NUMBER OF PULSES IN A ROW TO BE FOUND IS 4 (N=3)
                    13 ;PROGRAM IS FOR A 8748-6 MICROCOMPUTER, OPERATING WITH A 6 MHZ CLOCK
                    14 ;*******************************************************************************
                    15
                    16 ;----------------------------------------------------------------------------
                    17 ;MACROS:
                    18
                    19 TIME     MACRO NAME,PERD
                    20
 -                  21 NAME:    MOV A,#PERD;            SET TIMER
 -                  22          MOV T,A;
 -                  23          STRT T;                START TIMER
                    24          ENDM
                    25 ;--------------------------------------------------------------------------
                    26
                    27 ;EQUATES·
                    28
 0003               29 N        EQU 3;  NUMBER OF PULSES AFTER FIRST BEFORE UPZ
 FFE1               30 TDY      EQU -31; DELAY 2.5MS (31*80uS)
 FF64               31 TPD      EQU -156; WAIT 12.5MS(156*80uS)
 0000               32 TZUP     EQU 0; UPZ PERIOD 20MS (256*80uS)
 00A0               33 LEVFUL   EQU 160; NORMAL LEVEL FOUND AFTER THIS NUMBER OF PULSES (RPM/30)
 004B               34 XT       EQU 75; CHANGE LEVEL AFTER XT*20MS (XT=1.5/MAX TIME)
 0005               35 XL       EQU 5;  OPERATING LEVEL = XL* NORMAL LEVEL
                    36
                    37 ;-------------------------------------------------------------------------
                    38
                    39 ;BANK 0 REGISTER ASSIGNMENTS
 0002               40 COUNT    EQU R2; N COUNTER
 0003               41 FULBMP   EQU R3; COUNT PULSES
                    42                ; DURING CALIBRATION
 0004               43 XTIMER   EQU R4; COUNT TIMER FLAGS
 0005               44 XNLEVL   EQU R5; NUMBER OF TIMES OPERATING LEVEL IS GREATER THAN NORMAL LEVEL
 0006               45 DANCNT   EQU R6; NORMAL D TO A COUNT
 0007               46 ASAVE    EQU R7; HOLD ACCUMULATOR DURING CALIBRATION INTERRUPT
                    47 ;-------------------------------------------------------------------------
                    48
```

```
ISIS-II MCS-48/UPI-41 MACRO ASSEMBLER, V4.2           PAGE    2
DRLLUP

 LOC  OBJ         LINE        SOURCE STATEMENT
                    49
                    50 ;PROGRAM STARTS HERE
                    51
 0000               52          ORG 0                  ;WAKE-UP HERE
 0000 2400          53          JMP INIT;               JUMP TO INITIATE AND BEGIN
                    54
 0003               55          ORG 3                  ;INTERRUPT HERE
 0003 0430          56          JMP LEVEL;              GO TO CALIBRATION ROUTINE
                    57
 0030               58          ORG 30H                ;CALIBRATION ROUTINE STARTS HERE
 0030 AF            59 LEVEL:   MOV ASAVE, A ;          SAVE ACCUMULATOR
 0031 BBA0          60          MOV FULBMP, #LEVFUL;    NORMAL LEVEL FOUND WHEN COUNTED DOWN TO ZERO
 0033 BC4B          61          MOV XTIMER, #XT;        NUMBER OF TIMER FLAGS BEFORE DECREMENT
 0035 BD05          62          MOV XNLEVL, #XL;        OPERATING LEVEL IS XL TIMES NORMAL LEVEL
 0037 BE32          63          MOV DANCNT, #50;        START AT 1/5 SCALE (FULL SCALE/XL)
 0039 8980          64          ORL P1,#80H;            SET P17 AS BUSY DOING CALIBRATION FLAG
 003B FE            65          MOV A, DANCNT;
 003C 3A            66          OUTL P2,A;              SET D TO A TO 1/5 SCALE
                    67          TIME  DL1,0;            START TIMER FOR MAXIMUM TIME
                    68+
 003D 2300          69+DL1:    MOV A,#0;           SET TIMER
 003F 62            70+         MOV T,A;
 0040 55            71+         STRT T;                 START TIMER
                    72
                    73
 0041 1647          74 LOOK:    JTF LTIME;              FIND TIMER FLAG
 0043 3650          75          JTO LBUMPS;             FIND PULSE
 0045 0441          76          JMP LOOK;               LOOK AGAIN
                    77
                    78
 0047 EC41          79 LTIME:   DJNZ XTIMER,LOOK;       TIME TO CHANGE LEVEL?
 0049 CE            80          DEC DANCNT;             DECREMENT D TO A AND
 004A FE            81          MOV A, DANCNT;          OUTPUT NEW
 004B 3A            82          OUTL P2, A;             LEVEL
 004C BC4B          83          MOV XTIMER, #XT;        RELOAD XTIMER
 004E 0441          84          JMP LOOK
                    85
 0050 3650          86 LBUMPS:  JTO LBUMPS;             HOLD TILL END OF PULSE TO COUNT ONLY ONCE
 0052 EB41          87          DJNZ FULBMP, LOOK;      COUNT PULSE AND GO LOOK
 0054 27            88          CLR A
                    89
 0055 6E            90 MULT:    ADD A, DANCNT;          MULTIPLY D TO A LEVEL BY XL
 0056 ED55          91          DJNZ XNLEVL, MULT;
 0058 3A            92          OUTL P2, A;             OUTPUT OPERATING LEVEL TO D TO A
                    93
 0059 997F          94          ANL P1, #7FH;           RESET CALIBRATION FLAG
 005B FF            95          MOV A, ASAVE;           RESTORE ACCUMULATOR
 005C 93            96          RETR;                   GO BACK TO MAIN PROGRAM
                    97
```

```
ISIS-II MCS-48/UPI-41 MACRO ASSEMBLER, V4.2             PAGE    3
DRLLUP

 LOC  OBJ          LINE        SOURCE STATEMENT
                     98
                     99
 0100               100          ORG 100H              ;MAIN PROGRAM STARTS HERE
 0100 2355          101 INIT:    MOV A, #85;            SET DAC TO NOMINAL 1/3 FULL SCALE
 0102 3A            102          OUTL P2, A
 0103 05            103          EN I;                  ENABLE INTERRUPT WHICH CAUSES LEVEL SET
                    104
 0104 9900          105 START:   ANL P1,#0;             RESET UPZ
 0106 65            106          STOP TCNT;             STOP TIMER
 0107 BA03          107          MOV COUNT,#N;          LOAD N
                    108
 0109 2609          109 FBUMP:   JNTO FBUMP;            DETECT FIRST PULSE
                    110          TIME  DELAY,TDY;       START TIMER FOR DELAY
                    111+
 010B 23E1          112+DELAY:    MOV A,#TDY;            SET TIMER
 010D 62            113+         MOV T,A;
 010E 55            114+         STRT T;                START TIMER
 010F 1613          115 ENDELY:  JTF  WAIT;             END OF DELAY
 0111 240F          116          JMP ENDELY
                    117
                    118          TIME WAIT, TPD;        START TIMER FOR WAIT
                    119+
 0113 2364          120+WAIT:    MOV A,#TPD;            SET TIMER
 0115 62            121+         MOV T,A;
 0116 55            122+         STRT T;                START TIMER
 0117 161B          123 ENWAIT:  JTF BUMP;              END OF WAIT
 0119 2417          124          JMP ENWAIT
                    125
 011B 2604          126 BUMP:    JNTO START;            IF NO PULSE, START OVER
 011D EA13          127          DJNZ COUNT,WAIT ;      IF PULSE, COUNT, CHECK N, WAIT FOR ANOTHER
                    128
 011F 8901          129 OUTUPZ:  ORL P1, #1;            SET UPZ TO 1
                    130          TIME UPZTM, TZUP;      START TIMER FOR UPZ TIME
                    131+
 0121 2300          132+UPZTM:    MOV A,#TZUP;            SET TIMER
 0123 62            133+         MOV T,A;
 0124 55            134+         STRT T;                START TIMER
 0125 1604          135 ENPULS:  JTF START;             AT END OF TZUP JUMP TO START TO RESET UPZ AND
                    136                    ;            START OVER
 0127 2425          137          JMP ENPULS
                    138
                    139          END                   ;END OF MAIN PROGRAM

USER SYMBOLS
ASAVE  0007   BUMP   011B   COUNT  0002   DANCNT 0006   DELAY  010B   DL1    003D   ENDELY 010F   ENPULS 0125
ENWAIT 0117   FBUMP  0109   FULBMP 0003   INIT   0100   LBUMPS 0050   LEVEL  0030   LEVFUL 00A0   LOOK   0041
LTIME  0047   MULT   0055   N      0003   OUTUPZ 011F   START  0104   TDY    FFE1   TIME   0000   TPD    FF64
TZUP   0000   UPZTM  0121   WAIT   0113   XL     0005   XNLEVL 0005   XT     004B   XTIMER 0004   .E
```

APPENDIX B



NOTES:

Ⓐ R1,C8 CHOSEN FOR PULSE WIDTH EQUAL TO 0.4 OF THE PERIOD OF ROTATION

Ⓑ 24V DC CONTROL SIGNAL FROM MACHINING CENTER CONTROLLER

Ⓒ ANALOG COMMON ⏚ AND DIGITAL COMMON ⏚ CONNECTED AT ONE POINT

PIECE NO
NOMENCLATURE
NO REQ'D

NATIONAL BUREAU OF STANDARDS
WASHINGTON D C 20234

CIRCUIT DIAGRAM
FOR DRILL-UP

MODEL
TYPE
SCALE
DIMENSIONS IN INCHES
unless otherwise specified
TOLERANCES
unless otherwise specified
DECIMALS ±.000
FRACTIONS ±.015
ANGLES ±½
DO NOT SCALE THIS PRINT
DRAFTSMAN MIKE HUFF
CHECKED
PROJECT ENGR KEN YEE
PROJECT ENGR
SUBMITTED BY
CHIEF SEC
EXAMINED BY
CHIEF ENGINEER
APPROVED BY
CHIEF DIV
DIV SEC 738
THIS PRINT ISSUED 7/15/82

NBS-114A (REV. 2-80)

U.S. DEPT. OF COMM.

BIBLIOGRAPHIC DATA SHEET *(See instructions)*

1. PUBLICATION OR REPORT NO.
NBSIR 82-2590

2. Performing Organ. Report No.

3. Publication Date
October 1982

4. TITLE AND SUBTITLE
A Guide for the Construction and Operation of Drill-Up

5. AUTHOR(S)
Kenneth W. Yee

6. PERFORMING ORGANIZATION *(If joint or other than NBS, see instructions)*

NATIONAL BUREAU OF STANDARDS
DEPARTMENT OF COMMERCE
WASHINGTON, D.C. 20234

7. Contract/Grant No.

8. Type of Report & Period Covered

9. SPONSORING ORGANIZATION NAME AND COMPLETE ADDRESS *(Street, City, State, ZIP)*

10. SUPPLEMENTARY NOTES

☐ Document describes a computer program; SF-185, FIPS Software Summary, is attached.

11. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here)*

This guide provides detailed information for the construction of a single-speed version of Drill-Up and instructions for its installation and operation. Drill-Up is an instrument designed to prevent breakage of small-diameter drills used on automatic-feed drilling machines with a spindle retract ability. The method and applications have been previously described in the references given. The hardware and software necessary to construct an instrument for use at a single selected drilling speed are described. The circuit diagram and source program are included. The description is of a preliminary design implemented at the National Bureau of Standards and in use in its central machine shope. Sufficient details are included for those equipped to use the common 8048 family of microcomputers to build a "cookbook" instrument. The information should be adequate for others, familiar with the use of any specific microcomputer of microprocessor, to implement the instrument on that device.

12. KEY WORDS *(Six to twelve entries; alphabetical order; capitalize only proper names; and separate key words by semicolons)*

Drill breakage; Drill-Up; drill wear; time-domain analysis; tool breakage; vibration sensing.

13. AVAILABILITY

☒ Unlimited
☐ For Official Distribution. Do Not Release to NTIS
☐ Order From Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.
☒ Order From National Technical Information Service (NTIS), Springfield, VA. 22161

14. NO. OF PRINTED PAGES
26

15. Price
$7.50

USCOMM-DC 6043-P80