CLEAVER, H. E.

APR 15 1975

NOLTR 74-220

NOLTR 74-220

NOL TECHNICAL REPORT

THE NOL BALLISTIC PISTON COMPRESSOR III. ELECTRONIC INSTRUMENTATION

BY
H. E. Cleaver

18 December 1974

NAVAL ORDNANCE LABORATORY
WHITE OAK, SILVER SPRING, MARYLAND 20910

- Unlimited distribution; approved for public release

NAVAL ORDNANCE LABORATORY
WHITE OAK, SILVER SPRING, MARYLAND 20910

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER NOLTR 74-220	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) The NOL Ballistic Piston Compressor III. Electronic Instrumentation		5. TYPE OF REPORT & PERIOD COVERED Final July 1974 - December 1974
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Harry E. Cleaver		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Naval Surface Weapons Center White Oak Laboratory Silver Spring, Maryland 20910		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS ZR000-01-01/MAT-03L-000 Work Unit No. 167
11. CONTROLLING OFFICE NAME AND ADDRESS		12. REPORT DATE 18 December 1974
		13. NUMBER OF PAGES 27
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Electronic Instrumentation
Ballistic Piston Compressor

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

(U) A detailed description is given of the new electronic instrumentation package for the Ballistic Piston Compressor. Design considerations, including synchronization of compressor accessories and data acquisition schemes, are discussed and circuit diagrams are provided that permit construction of duplicate systems and maintenance or trouble-shooting of the present system.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE
S/N 0102-014-6601

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)

18 December 1974

THE NOL BALLISTIC PISTON COMPRESSOR III. ELECTRONIC INSTRUMENTATION

The work described in this report was performed primarily under Task IR 167, Thermodynamic Studies of High Pressure Gases. Portions of this work were also funded by the Army Materials and Mechanics Research Center, Watertown, Massachusetts under Task NSWC-1143/Army. The instrumentation described here is part of a continuing effort to improve the diagnostic techniques employed with the ballistic compressor to obtain equation of state data for hot, dense gases relevant to explosion and combustion phenomena.

ROBERT WILLIAMSON II
Captain, USN
Commander

Lloyd A. Kaplan
LLOYD KAPLAN
By direction

CONTENTS

ILLUSTRATIONS

I. INTRODUCTION

Ballistic Piston Compressor

The Naval Surface Weapons Center (formerly the Naval Ordnance Laboratory) Ballistic Piston Compressor, ERCA III, is a laboratory device that produces a hot, dense gas sample with a characteristic linear dimension of 5 cm at temperatures of the order of 5,000 K and pressure of 1,000 atm. These conditions persist for intervals of roughly 500 μs during which spectroscopic observations are made and pressure, temperature, volume and density measurements are recorded as functions of time. The device has most recently been used for spectral line broadening measurements and for studies of equations of state for gases subjected to these extreme conditions.

Figure 1 shows a schematic diagram of the principal components of ERCA III. The configuration is similar to a conventional shock tube. The distinguishing feature is the use of a heavy, tight-fitting, metal piston that is propelled along the eight-meter tube by compressed gas released from the reservoir by the quick-release plunger valve. Detailed descriptions of the mechanical and optical features of ERCA III can be found in references 1 and 2.

Diagnostic Measurements

The primary functions of the electronic systems described in this report are to provide signal conditioning for transducers installed in ERCA III, and to provide accurately timed trigger signals to optical and mechanical accessories that must be synchronized with compressor phenomena. These transducers and accessories are briefly described here.

A pressure analog signal is obained from a commercial quartz piezoelectric transducer. The unit presently in use is a Kistler High Pressure Transducer, Model 607B, which has a range of 0-5,000 atm and a rise time of 1.5 μs. The electrostatic signal is fed to a Kistler Charge Amplifier which provides a voltage analog of the gas pressure as a function of time.

The compressor operates in the free piston mode which results in a train of pressure pulses of decreasing amplitude until the piston comes to rest. Only the first pulse, which yields the maximum pressure, is of interest in the compressor experiments. This pulse is a symmetrical, "bell-shaped" curve with a typical width at half-maximum of 1 ms. Figure 2 shows a 1,000 atm pulse obtained with the present electronic system.

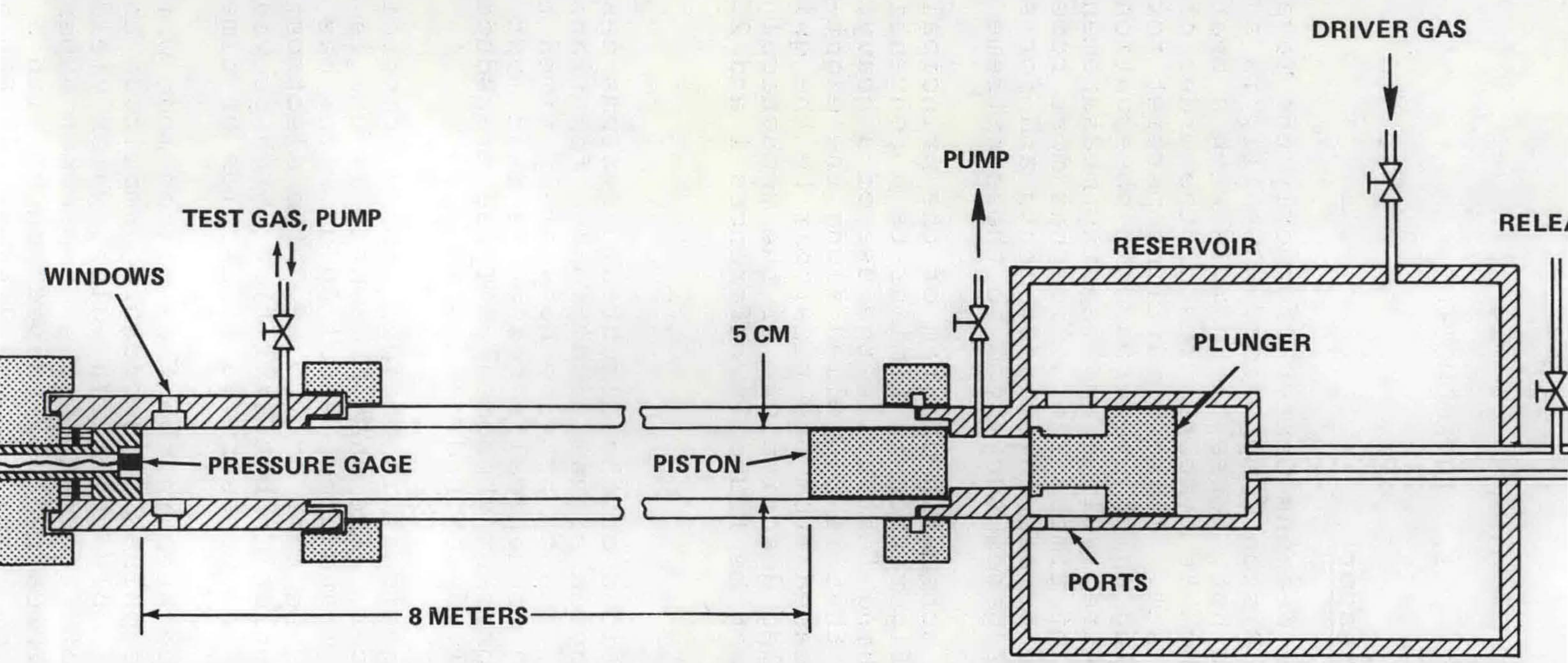

FIG. 1 SCHEMATIC DIAGRAM OF ERCA III.

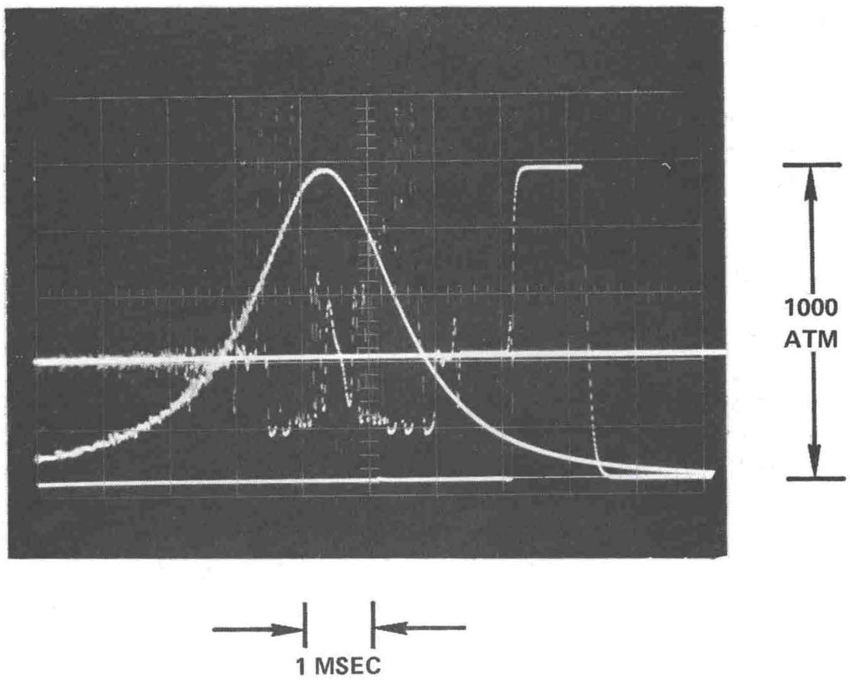

FIG. 2 PRESSURE-TIME RECORD, WITH CALIBRATION PULSE AND MPU OUTPUT.

The piston moves slowly near the end of its stroke when the gas pressure is high. During this high pressure interval, the piston motion is monitored by a magnetic pick-up (MPU) transducer mounted in the side-wall of the high pressure section of the compressor. The MPU senses the passage of steel rings mounted along the circumference of the piston body. The steel rings are separated by nonmagnetic rings and are arranged in a pattern that yields a characteristic "signature" signal from the transducer. This signature can be interpreted to yield piston position, velocity and test gas volume as functions of time.

The compressor is free to recoil on ball bushing mounts in response to forces created by piston motion. To ensure that compressor side-window alignment is correct during the moments of maximum compression, the compressor motion relative to its mounting tables is monitored with a linear motion potentiometer. Compressor recoil motion is highly reproducible for a given piston mass, and the motion potentiometer system permits recoil motion measurements that are more accurate than is required to ensure adequate optical alignment.

For spectroscopic observations during the roughly 100 μs interval corresponding to maximum gas pressure and temperature, a high-speed, electromechanical shutter (reference 3) is installed at the spectrograph entrance slit. To synchronize the shutter opening with the moment of maximum gas pressure, a triggering pulse is derived from the pressure analog signal. Since there is a delay time inherent in the shutter mechanism equal to the interval between trigger pulse arrival and the fully open shutter condition, the triggering point can be obtained by measurement of a pressure record from a previous compressor shot that yielded the desired maximum pressure and temperature. The high voltage firing circuit for this shutter is described in reference 3.

Absorption spectroscopy experiments have been performed with the compressor in a search for new opacity mechanisms in the ultraviolet spectrum of hydrogen (reference 4). For this work, a high intensity flashlamp was used that emitted an intense, short duration light pulse that was directed through the hot, compressed gas via two diametrically opposed side windows in the compressor high pressure test section. The electronic circuitry developed for this flashlamp (reference 5) requires a trigger pulse to synchronize the flash with the peak gas pressure. This trigger pulse is also derived from the pressure analog signal, and a delay time is adjusted to yield good synchronization.

The electronic system discussed in detail in the following sections brings together into one compact package the circuitry required to perform all of the functions described above.

II. TRANSDUCER SIGNAL CONDITIONING AND LOGIC CONTROL CIRCUITS

Block Diagram

Figure 3 is a diagram of the compressor with the transducer signal recording systems. All voltage analog signals from the transducers are processed, displayed on oscilloscopes and photographed with Polaroid cameras. As shown, the pressure transducer signal is displayed on three oscilloscopes along with the motion transducer signal, the raw magnetic pickup signal, and a processed form of the magnetic pickup signal. Signals from the pressure transducer are also sent to the control system that fires the spectrograph shutter and flashlamp high voltage circuits. All oscilloscope sweeps are triggered by external signal sources located in the control systems.

Both the pressure transducer system and the magnetic pickup system have a test switch for operational testing of the circuits and for adjusting the oscilloscope displays. The switch labeled PISTON SEATED serves two purposes. In preparing the compressor for firing, it is used to verify that the piston is properly seated at the reservoir end of the tube. Just before firing the compressor, the switch is connected into the pressure transducer system where it serves as an ON-OFF control switch.

System Timing Considerations

The time required for the piston to travel from the reservoir end of the tube to the test section is variable depending on the mass of the piston and the initial gas pressure ratio across the piston. Because of the variable time, oscilloscope display recording is synchronized to the occurence of the first pressure pulse generated in the test section rather than to some starting point event such as the release of the piston.

Since the compressor is operated in the free piston mode, several compression cycles occur during each firing resulting in several pressure pulses of diminishing amplitude being sent to the recording system. At the same time, if the piston passes by the magnetic pickup, signals from that transducer would also be sent to its recording system. As it is only the first compression cycle that is of interest, these unwanted transducer signals are prevented from being recorded by the oscilloscope cameras. To do that, the circuits that trigger the oscilloscope sweeps are disabled at the completion of the first compression cycle. Resetting the control systems is done automatically for the pressure transducer

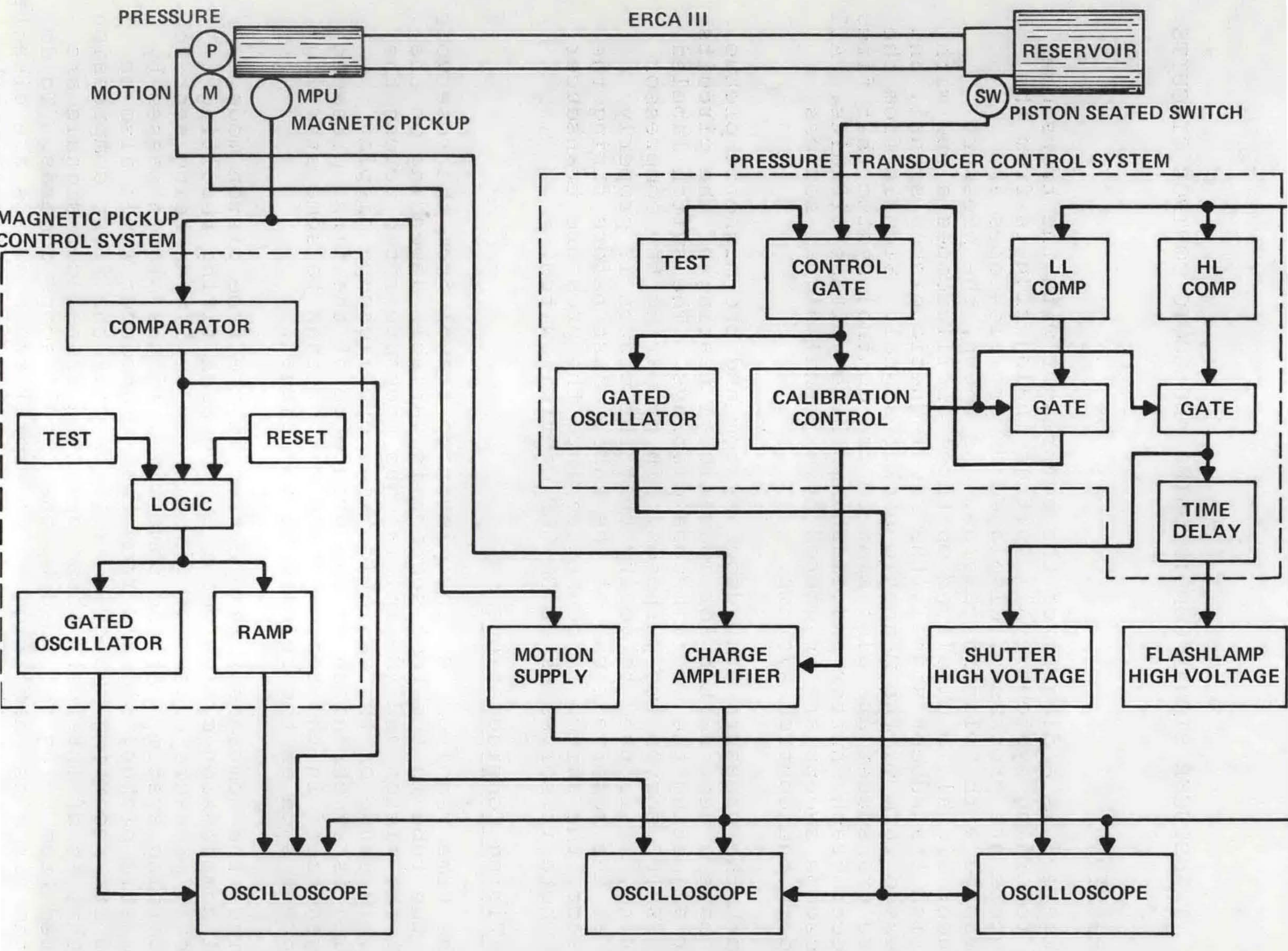

FIG. 3 TRANSDUCER SIGNAL RECORDING SYSTEMS

system by reseating the piston at the reservoir end of the compressor. Manual resetting is required for the magnetic pickup system.

An unfortunate characteristic of the PISTON SEATED switch is that it is operated by shock waves generated in the compressor firing. Unscheduled firing of the switch will recycle the pressure transducer control system and allow the oscilloscopes to be retriggered on successive compression cycles. In order to prevent this, the system will respond to only the first switch opening that occurs when the compressor is fired.

Circuit Functions

Synchronizing external events to the first pressure pulse in the compressor and controlling the oscilloscope display to be photographed with Polaroid film are the two main functions of the control systems.

Synchronizing

It is necessary to synchronize the spectrograph shutter action and the flashlamp discharge with the peak of the first pressure pulse. Figure 4 shows the typical voltage analog of the pressure pulse and how synchronization is done.

In order to photograph the pressure pulse shown on the oscilloscopes, the time base sweep circuits must be triggered at the proper time to catch the desired display. This is done by using a voltage comparator circuit to monitor the pressure pulse signal. The function of the voltage comparator is to provide a digital one (HIGH) or zero (LOW) output which corresponds to the value of the input signal compared with a reference voltage. The operator selects a point on the expected voltage curve at a level to ensure proper display of the pulse on the oscilloscope trace as shown as V_1 in Figure 4. Voltage level V_1 is used as the reference voltage on one input to the Low Level Comparator (LL Comp). When the pressure signal voltage, applied to the other input to the comparator, rises above the LL Comp reference level, the output of the comparator changes logic state and turns on a gated oscillator circuit. This is shown at t_1 in traces B and C in Figure 4. As the signal voltage falls below the reference level at t_5, the comparator output reverts to its initial state and the oscillator is turned off. Signals from the gated oscillator are used to trigger oscilloscope sweep circuits.

In order to synchronize the spectrograph shutter action with the peak of the pressure pulse, the voltage that will be developed under the given operating conditions must be known. In addition, the total offset travel time of the shutter plate must also be known. Offset travel time is the time required for the shutter plate to travel from its rest position to the point where it just begins to uncover the spectrograph slit. Knowing that time, the operator measures backward on the voltage-time curve from the desired slit

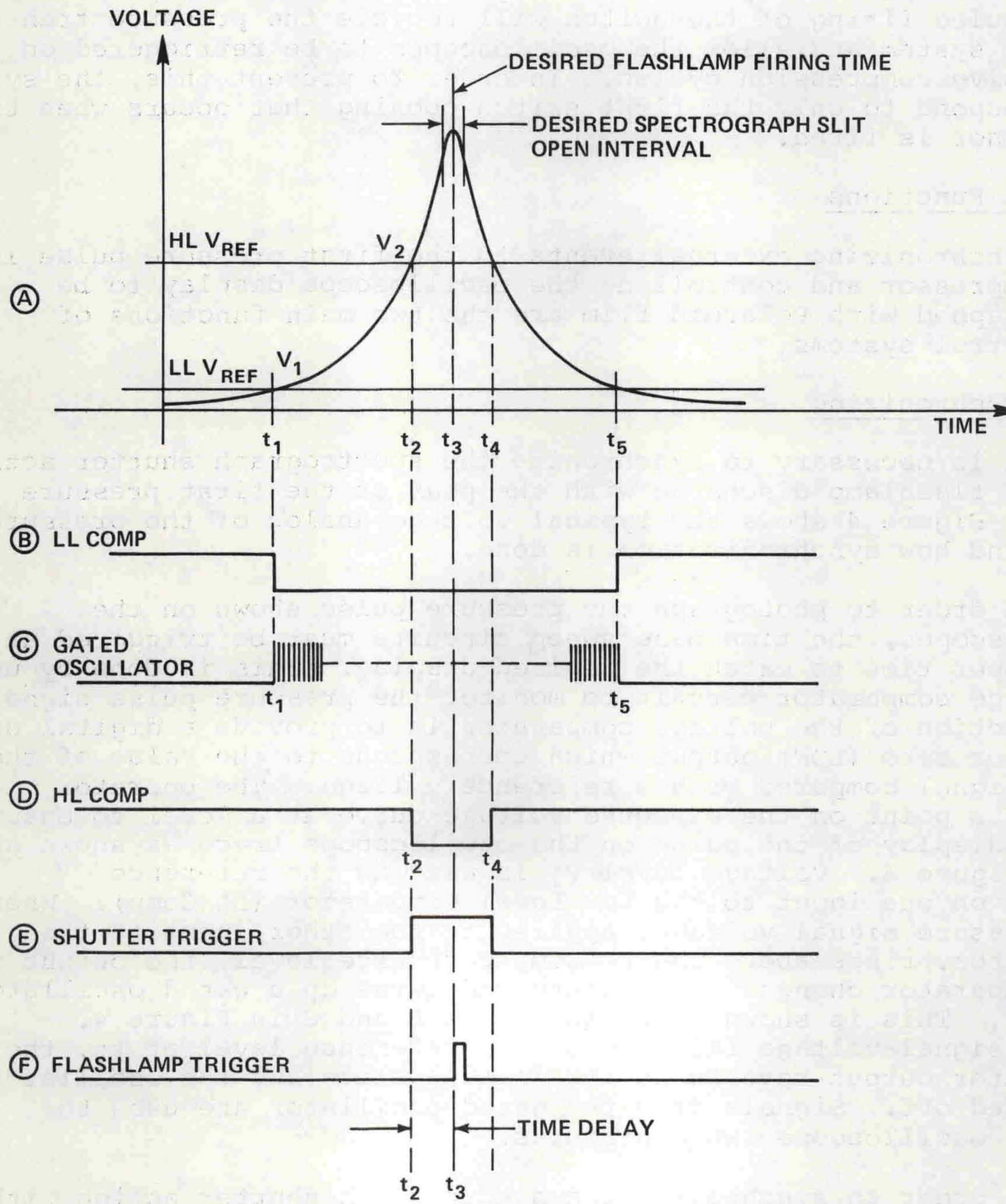

FIG. 4 PRESSURE PULSE LOGIC TIMING DIAGRAM

open-time and arrives at a time t_2 and a corresponding voltage v_2. This is the point on the pressure signal where shutter action should be initiated. Since the discharge of the flashlamp is a relatively instantaneous event, triggering of that circuit should occur at the peak of the pressure pulse during the spectrograph slit open-time as shown at t_3 in trace A.

To set up synchronization, the voltage level measured at v_2 is used as the reference voltage level on a second voltage comparator referred to as the High Level Comparator (HL Comp). When the pressure signal voltage rises above the reference level, the comparator changes output logic states as shown in trace D. Again, the comparator will revert to its initial state when the signal voltage falls below this reference level at t_4.

When the HL Comp changes states at t_2, the level transition fires the spectrograph shutter high voltage circuit by the pulse shown as trace E. At that same moment, the HL Comp signal also starts a time-delay circuit set to the interval between t_2 and t_3. At the end of the time delay period, a trigger pulse is sent to the flashlamp high voltage firing circuit as shown in trace F.

Figure 5, the more complete timing diagram for the pressure transducer system, contains all the information shown on Figure 4. Figure 5 also shows the steps taken to cope with the timing problems already discussed.

The magnetic pickup transducer system also uses a gated oscillator to synchronize its oscilloscope triggering time. Triggered by the first positive magnetic pickup signal, the oscillator will remain on for a fixed, pre-set interval. Once triggered, the oscillator will operate for one interval only and must be manually reset before it can be triggered again.

Signals from the motion transducer do not need synchronization; they are simply recorded along with the pressure pulse.

Display

Two methods have been used to display the pressure transducer signal on oscilloscopes. First is the straightforward single sweep of the oscilloscope trace showing one complete pressure pulse as shown in Figure 2. This technique requires only one trigger pulse to the oscilloscope sweep circuit. The second technique is to operate the oscilloscope sweep rate at a faster speed and cause the oscilloscope to sweep several times during the pressure pulse. Each trace then covers only a portion of the total signal so that, in effect, a time expansion of the signal is displayed. Triggering the oscilloscope for this type of display is accomplished by using the continuous oscillator signal as shown in Figure 4, trace C. Each time the oscilloscope retraces after a sweep, the oscillator signal will retrigger the sweep as long as the oscillator is gated on.

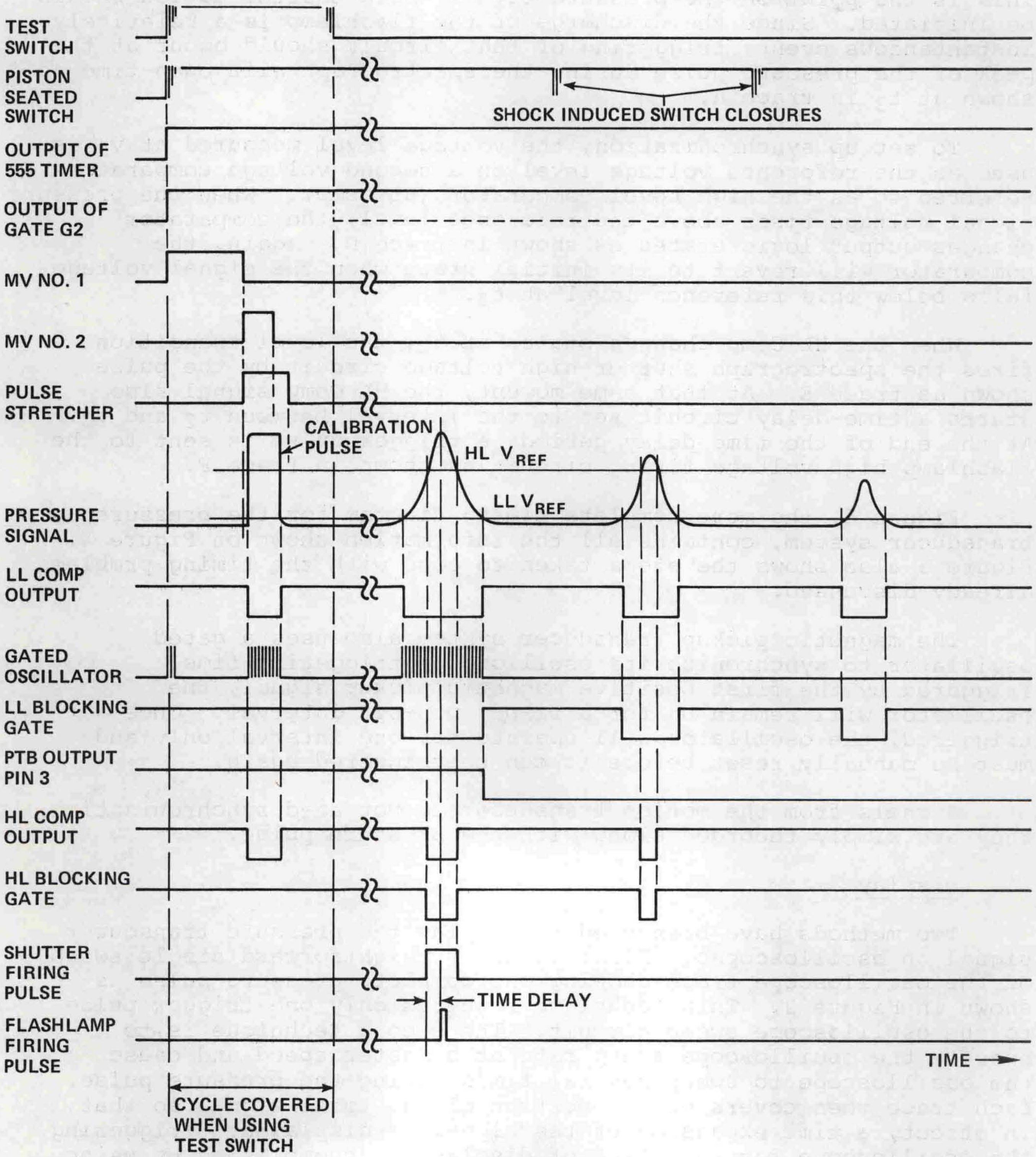

FIG. 5 PRESSURE TRANSDUCER SYSTEM TIMING DIAGRAM

A calibration voltage signal is recorded on the camera film along with the pressure pulse during each firing of the compressor as may be seen to the right of the pressure pulse in Figure 2. The calibration pulse generator system is triggered by the action of the PISTON SEATED switch when the piston is fired. Calibration pulse generation occurs during the first 10 ms after firing as the piston is traveling down the tube as shown in the pressure signal trace in Figure 5.

Signals from the magnetic pickup are recorded in two forms on the oscilloscopes. The recorded sinusoidal analog signals from the MPU are interpreted by the operator to determine the turn-around point of the piston with good resolution. Analog signals from the MPU are also converted into a digitally compatible rectangular waveform for recording on another oscilloscope. Using a voltage ramp on one input to the oscilloscope and the gated oscillator triggering technique described above for producing multiple sweeps, a positive going raster is generated as the oscilloscope display. Mixing the digital waveform of the MPU with the ramp signal in a dual-trace plug-in yields a time-expansion of the MPU signal as the final oscilloscope display.

III. CIRCUIT OPERATION

Pressure

Figure 6 is the pressure transducer control system schematic. These circuits are contained in three of the five plug-in modules in the instrument package.

Starter Circuit Gates

The starter circuit gates are the necessary interface between the mechanical TEST and PISTON SEATED switches and the digital integrated circuits. Their purpose is to provide a "bounce-free" logic level change to trigger the calibration circuit multivibrators and to enable other circuits in the system.

Besides exhibiting the characteristic contact bounce associated with mechanical switches, the PISTON SEATED switch undergoes false operation during a firing due to shock waves as mentioned earlier. To prevent unwanted triggering of the recording system by these spurious switch closures, the PISTON SEATED switch triggers a 555 Timer circuit operated as a one-shot multivibrator. When triggered, the timer produces a clean pulse on its output with a duration in excess of 6S. During the pulse interval, the timer can not be reset or retriggered by spurious closures of the PISTON SEATED switch. This interval is long enough to cover the duration of a firing of the compressor.

Initially, the piston is seated at the reservoir end of the tube holding the PISTON SEATED switch closed. At the moment the piston is fired, the switch opens causing the output of the 857 NAND gate G1 to change logic states from HIGH to LOW. This negative-going level transition triggers the 555 Timer generating a positive pulse on pin 3. The positive pulse is converted to the needed negative pulse by an 834 INVERTER circuit and sent to the 857 NAND gate G2.

When the TEST switch is used in preparing for a compressor firing, a bounce suppressor circuit formed by 857 NAND gates G3, G4, and G5 sends a negative going level change to gate G2. Thus, both switches will cause the output of gate G2 to go to logic HIGH.

Gate G2 is the control gate for the remainder of the circuits in the system. Its logic state establishes the initial conditions of the circuits and prevents spurious operation of various sections by disabling certain gates during standby.

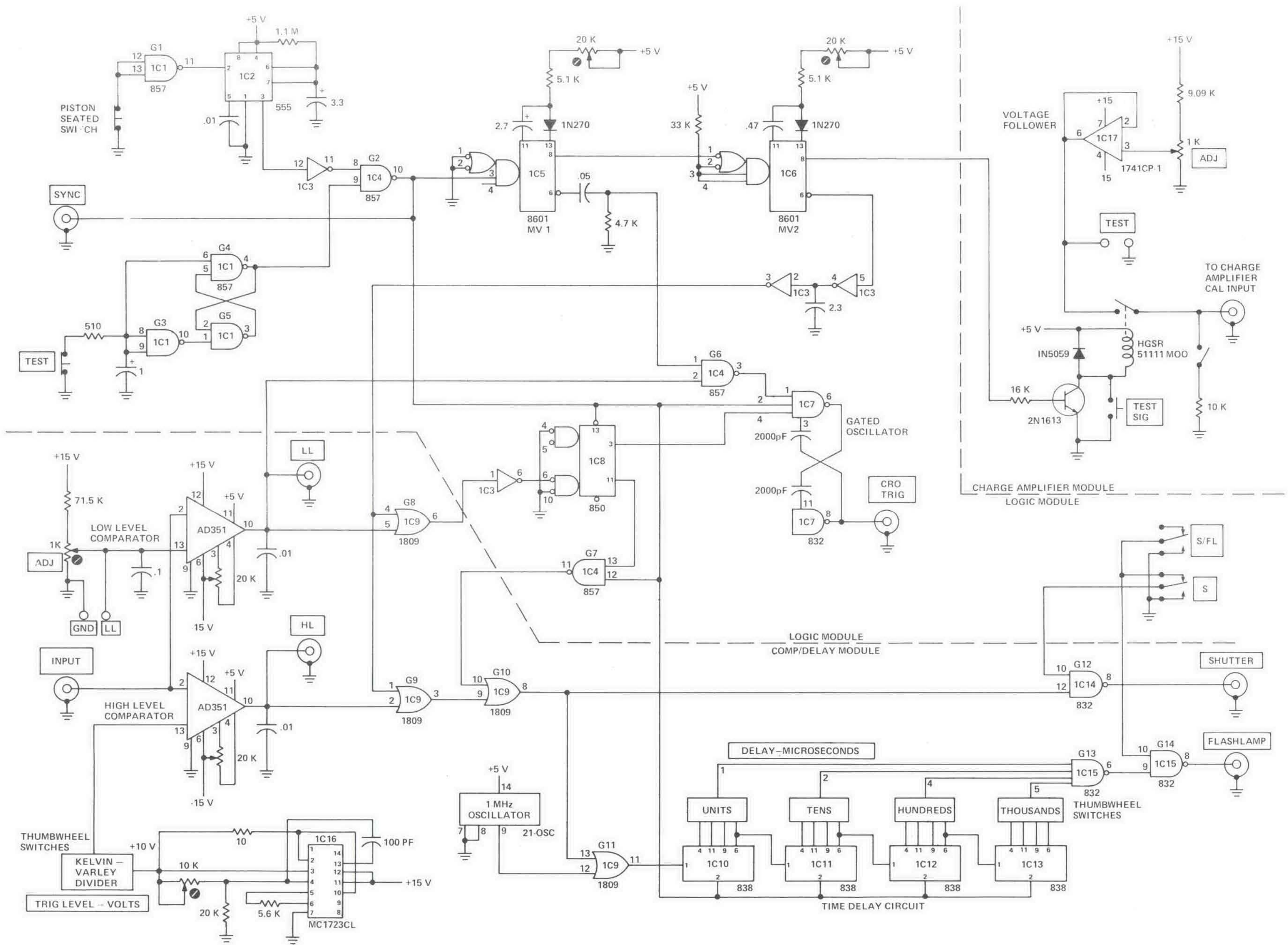

FIG. 6 PRESSURE TRANSDUCER SYSTEM SCHEMATIC

(PTB) and the 838 Decade Counters and also prevents them from being triggered. The LOW state also disables the gated oscillator and 1809 OR gate G10 preventing their operation. Disabling OR gate G10 prevents unscheduled firing of the shutter and flashlamp high voltage firing circuits. When the output of G2 is caused to go HIGH by either switching action described above, it enables the circuits mentioned and triggers multivibrator No. 1 on the positive going transition. Eventually, at the end of a cycle of the system, the output of G2 is taken back to logic LOW by the switch returning to its initial state. The circuits in question are reset and disabled and the cycle is ended.

Multivibrators

Two 8601 Retriggerable Multivibrators (MV) are used in generating the voltage calibration step shown in Figure 2 and Figure 5. Adjusting the time constant on MV1 will position the calibration step where desired in the oscilloscope display. MV2 is used to adjust the pulse width of the calibration step. Present requirements call for the calibration step to appear approximately 7 milliseconds into the display and last for 1 millisecond when the oscilloscope is operated at a sweep rate of 1 millisecond per centimeter, as shown in Figure 2.

Connected to be positive-edge triggered, MV1 responds when gate G2 goes from LOW to HIGH and produces output pulses on pins 6 and 8. The negative-going pulse on pin 6 is differentiated by a .05 μF capacitor, 4.7 kΩ resistor network that sends a narrow negative pulse through 857 NAND gate G6 to turn on temporarily the gated oscillator formed by two 832 NAND gates. This action serves to turn on the oscillator for about 0.2 ms just to trigger the oscilloscope sweep circuits and is illustrated in the gated oscillator trace in Figure 5.

At the end of the time constant determined by the R-C network connected to pins 11 and 13, the output pulses of MV1 are terminated. As the pulse on pin 8 of MV1 reverts from HIGH to LOW, it triggers MV2 which has been wired to accept a negative-edge trigger.

When MV2 is triggered, the positive pulse output on pin 8 energizes the calibration step relay, via the 2N1613 transistor, and the calibration reference voltage signal is impressed on the Kistler Charge Amplifier. The charge amplifier in response generates the voltage step that is sent to the oscilloscope displays and to the voltage comparator circuits. Since the calibration voltage amplitude is usually set at or near the expected maximum pressure signal, it will have sufficient amplitude to operate both the low level and high level comparator circuits. Because the comparators drive other circuits which are scheduled triggering of these circuits by the calibration step signal must be prevented.

Two 1809 OR gates, G8 and G9, placed just after the comparators, are used for blocking signals during the calibration step interval. These gates are disabled during the calibration interval by a signal from MV2 causing both comparator output signals to be blocked. Due to mechanical delay on pull-in and drop-out inherent in the relay, the calibration voltage step generated by the charge amplifier is not in exact time register with the control signal coming from MV2. Therefore, the turn off of MV2's control signal sent to gates G8 and G9 is extended in time beyond the signal turning off the relay so that the calibration voltage signal is removed before the OR gates are unblocked. Two 834 INVERTERS and a 2.3 μF capacitor form the pulse stretcher circuit. All of the above is illustrated in the traces shown in Figure 5.

Gated Oscillator

Two 832 NAND gates cross-coupled with 2000 pF capacitors form a free running multivibrator used for the gated oscillator. When any of the input pins 1, 2, and 4 are at logic LOW, the circuit will not oscillate and the output on pin 8 is at logic LOW. Pin 2 is used to disable the oscillator during standby using the logic state on gate G2. Pin 1 uses the signals from gate G6 to turn on the oscillator at the appropriate times. The signal from the PTB to pin 4 disables the oscillator at the end of the first pressure pulse in a sequence yet to be described.

If all of the input pins 1, 2, and 4 are HIGH, the circuit will oscillate at about 82 kHz with an approximately squarewave output. During a compressor firing, the oscillator is turned on three times as shown in Figure 5 by either MV1 or the Low Level Comparator.

Calibration Step Circuit

A mercury-wetted relay is used to apply the reference voltage signal to the calibration input terminal on the Charge Amplifier. Reference voltage level is adjusted using a 10-turn potentiometer and is passed through a voltage follower amplifier to prevent loading by the Charge Amplifier circuit.

The test switch tied to the collector of the 2N1613 transistor may be used to apply a static calibration signal to the oscilloscopes while making adjustments in the display. Generating a calibration signal in this way, or by using the test switch on the Charge Amplifier itself, will trigger both voltage comparators. During standby, signals from the comparators will pass through OR gates G8 and G9 but gate G10 and the 850 PTB are disabled by the logic state on G2 thereby preventing any unwanted operation of the oscillator or firing circuits.

Note that the output of the LL Comp goes directly to gate G6. During the calibration step interval, the output from the LL Comp passes through G6 to turn on the gated oscillator as seen in Figure 5. This action provides oscilloscope triggering for displaying the calibration step when the oscilloscopes are operated in the multiple sweep mode.

Voltage Comparator Circuits

Two Analog Devices Model AD351 voltage comparator integrated circuits are used. These comparators have an output that can be operated at a level compatible with the logic circuits used. The function of the LL Comp is to turn on the oscillator in response to the calibration and pressure signals from the Charge Amplifier. Triggering the spectrograph shutter and flashlamp high voltage firing circuits in response to the first pressure pulse is the function of the HL Comp.

When the pressure signal voltage on pin 2 of the LL Comp rises above the reference level on pin 13, the output on pin 10 changes state from HIGH to LOW. This corresponds to the time t_1 in Figure 4. For the best oscilloscope display, the reference voltage is set to about 0.10 V. The signal from the comparator turns on the oscillator and is passed through OR gate G8, is inverted and applied to the PTB on pin 6.

When the pressure signal falls below the reference voltage level, the LL Comp reverts to its initial logic state turning off the oscillator. At the same time, the turn-off level transition as applied to the PTB on pin 6, will trigger that circuit. Once triggered, the PTB will change output logic states and remain that way until reset at a later time by the signal to pin 13. Pin 3's output change from HIGH to LOW disables the gated oscillator and OR gate G10 via gate G7. Thus, triggering the PTB at the end of the first pressure pulse disables the oscillator to prevent further oscilloscope triggering. Disabling gate G10 prevents any possibility of retriggering the shutter or flashlamp circuits during subsequent pressure pulses. These results are also illustrated in Figure 5.

As explained earlier, the HL Comp operates on the pressure signal voltage to initiate spectrograph shutter and flashlamp firing at the desired time. Reference voltage for this comparator is obtained from a set of four thumbwheel switches acting as a Kelvin-Varley voltage divider on a stable 10 V source. A range of 0 to 9.999 V is covered with 1 mV resolution.

When the comparator changes output logic states, the signal is passed through OR gates G9 and G10 to gates G11 and G12. Gate G12 immediately changes state with its output going HIGH for a positive pulse to serve as a trigger signal for the spectrograph shutter high voltage firing circuit. This is shown as line E in Figure 4.

At the same time, the HL Comp signal out of G10 turns on gate G11. Signals from a 1 MHz oscillator then pass through gate G11 to the first stage of a decade counter system. Four decade counters, each connected to a binary-coded-decimal thumbwheel switch, make up a digital time delay circuit. Range of the circuit is 0 to 9999 μs with 1 μs resolution. Stability, accuracy, and resolution of the time delay system are dependent on the clock oscillator characteristics.

When the desired time delay is reached by counting pulses from the oscillator, each thumbwheel switch provides a positive-going level transition to the inputs of the 832 NAND gate G13. When all inputs go HIGH, gate G13 changes logic state causing gate G14 to produce a positive going pulse to serve as the trigger signal to the flashlamp high voltage firing circuit as shown in Figures 4 and 5.

The mechanical switches tied to gates G12 and G14 are for manually firing the spectrograph shutter and flashlamp circuits. The switch labeled S will fire only the shutter circuit while the one labeled S/FL will fire both circuits together.

When the piston is reseated at the reservoir end after a compressor shot, the PISTON SEATED switch is closed and gate G2 goes from HIGH to LOW. Then the PTB is reset, the gated oscillator is disabled via its pin 2, gate G10 is disabled via its pin 10, and the decade counters are disabled and reset to a count of zero. One cycle of the pressure transducer control circuits is then complete and the system will be in a standby condition.

Magnetic Pickup

Analog signals from the magnetic pickup are connected to the circuit shown in Figure 7 where they are converted into a digital level pulse train by a LM211D voltage comparator. Connected as shown, the comparator operates on the positive portion of the MPU signal with the reference voltage being ground potential as applied to pin 4. A 1N5223 zener diode on the input pin 3 limits the MPU signal applied to the comparator to a value less than the supply voltage. The output of this comparator is also operated at a level to make it compatible with the logic circuits used. Signals from the comparator are sent to an oscilloscope for recording and to the 844 NAND gate G3.

The first output pulse from the comparator passes through gate G3 and triggers an 850 PTB and an 8601 multivibrator. Triggering the 850 PTB causes its outputs to change logic states. When pin 3 goes from HIGH to LOW, gate G3 is disabled and no more signals from the comparator are allowed to pass.

When the 8601 MV is triggered, its output changes logic states for the duration of the time constant determined by the network tied to pins 11 and 13. The timing is variable by using the 50 kΩ

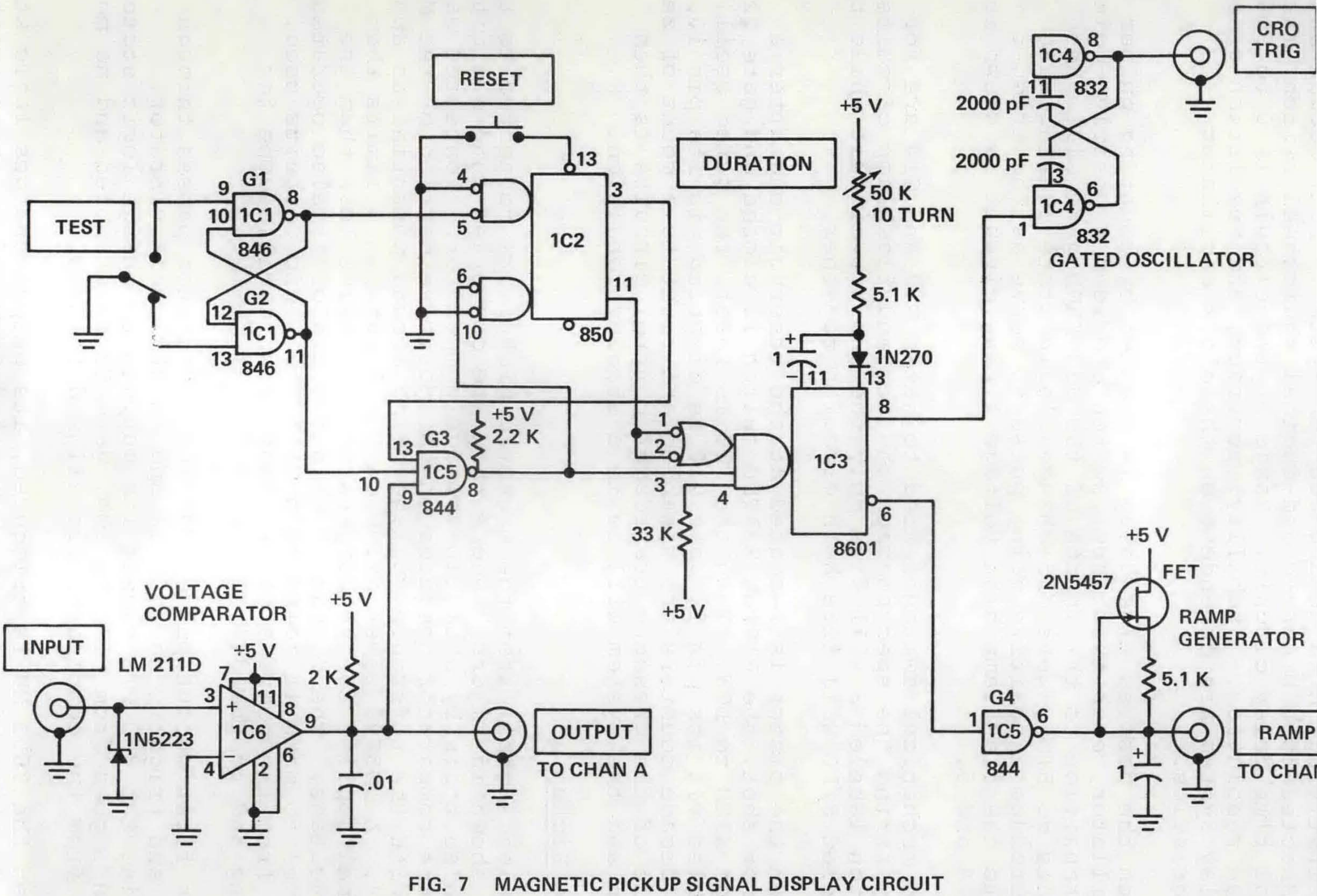

FIG. 7 MAGNETIC PICKUP SIGNAL DISPLAY CIRCUIT

potentiometer and determines the duration of the linear ramp to be generated. The output signal on pin 8 turns on the gated oscillator formed by the 832 NAND gates and 2000 pF capacitors for triggering the oscilloscope sweep circuit. Gate G4, a NAND gate with an open collector in the output transistor, is turned off by the signal from pin 6 of the multivibrator. A 2N5457 field effect transistor connected as shown makes a constant current generator. Initially, current flows from the generator through the 844 gate to ground. When the gate is turned off, current flows into the capacitor charging it at a constant rate. The linear ramp developed across the capacitor is sent to one input of a dual trace plug-in.

At the end of the multivibrator time constant, the ouputs revert to their initial logic state turning off the oscillator and ending the ramp. Voltage on the ramp capacitor is drained off by the output transistor in gate G4 and the system can be recycled.

Once the 850 PTB is triggered, the outputs will remain in their new logic states until the circuit is manually reset by grounding pin 13. With G3 disabled, successive signals from the magnetic pickup will not cause retriggering of the oscillator or ramp circuits. The system must be manually reset before another test firing of the compressor.

A TEST switch and its bounce suppressor circuit composed of two 846 NAND gates Gl and G2 may be used to generate a ramp and oscillator signal while adjusting the oscilloscope display. In this case the system is automatically reset upon release of the test switch due to the connection of Gl to pin 5 of the PTB. When the TEST switch is pressed the output of Gl goes from LOW to HIGH. When the switch is released the output of Gl reverts to LOW. The negative-going transition on pin 5 resets the PTB.

Motion Transducer

The transducer used to monitor motion of the compressor relative to its base is simply a linear potentiometer. Power for the transducer comes from the power supply used for the digital logic circuits. The body of the transducer is mounted to the base and the slider is fastened to the compressor. The transducer signal is a variable DC voltage.

Power Supplies

All circuits in the system are powered by three modular DC power supplies located in one plug-in module in the instrument rack. The power supplies are made by Computer Products, Inc. of Fort Lauderdale, Florida. All logic circuits and the motion transducer receive power from a Model PM534, 5V, 500 mA supply. Analog circuits are powered by two Model PM576 15V, 100 mA supplies connected to form a $\pm$ 15 V output with respect to ground.

The plug-in module containing the power supplies also contains the AC power line switch, indicator light, and fuse. The AC power line input to the module is bypassed with .05 μF capacitors for transient voltage suppression. Additional capacitors for bypassing the DC power supply leads are located at various points throughout the system.

IV. SUMMARY AND SUGGESTIONS FOR IMPROVEMENTS

While the system as a whole performs as it was intended, there is at least one feature which has not proven to be as useful as expected. This is the expanded time-base display of the magnetic pickup signals. It now appears that it is possible to lose display of an MPU pulse during the retrace time of the oscilloscope beam while the raster is being generated. Future work calls for the construction of a symetrical raster to overcome this deficiency.

A problem that may arise in the future is the high frequency noise structure that can occur in the pressure pulse. While the signal shown in Figure 2 shows only some slight structure, greater noise has been seen in signals generated when the compressor has been operated under different initial conditions. If the noise signal becomes too large, it could interfere with the proper operation of the voltage comparators. In the event noise does become a problem, solutions may be low-pass filtering of the signal, increasing the hysteresis of the comparators, or some sort of logic gating using delay circuits.

V. REFERENCES

1. Hammond, G. L., and Lalos, G. T., "The NOL Ballistic Piston Compressor II. Operation up to 5000 Atm.", NOLTR 71-228, Dec 1971
2. Hammond, G. L., "The Broadening of Calcium II H and K Lines by Helium", Astrophys. J. 196, Feb 1975
3. Kendall, P. A., "Improved Microsecond-Response Electromechanical Spectrograph Shutter", Applied Spectroscopy 22, 1968
4. Lalos, G. T., and Hammond, G. L., "Gas Opacity Measurements with a Ballistic Piston Compressor", NOLTR 70-15, Nov 1969
5. Cleaver, H. E., "Electronic Circuitry for a High Intensity Flashlamp", NOLTR 71-130, Jul 1971

DISTRIBUTION

	Copies
Defense Documentation Center Cameron Station Alexandria, Virginia 22314	12
Army Materials and Mechanics Research Center Watertown, Massachusetts 02172 Dr. J. W. Johnson	5
High Pressure Data Center P. O. Box 60, Univ. Station Provo, Utah 84601 Dr. L. Merrill, Asst. Director	1
University of Oregon Physics Department Eugene, Oregon 94703 Prof. S. Y. Ch'en	2
Los Alamos Scientific Laboratory P. O. Box 1663 Low Alamos, New Mexico 87544 Dr. H. Helmick, Mail Stop 560	1