AD-A132 247 A FREQUENCY STABILIZATION AND TRIGGER CONTROL UNIT FOR HYBRID TEA-CO2 LASERS(U) DEFENCE RESEARCH ESTABLISHMENT VALCARTIER (QUEBEC) J M CRUICKSHANK ET AL. JUN 83 1/1

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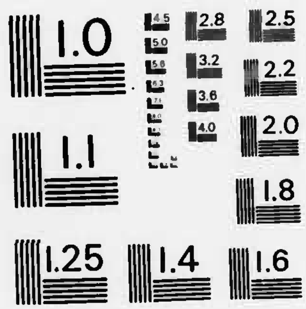

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A FREQUENCY STABILIZATION AND TRIGGER CONTROL UNIT FOR HYBRID TEA-CO_2 LASERS

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A FREQUENCY STABILIZATION AND TRIGGER CONTROL UNIT FOR HYBRID TEA-CO_2 LASERS

by

J.M. Cruickshank, V. Larochelle and P. Pace

CENTRE DE RECHERCHES POUR LA DEFENSE

DEFENCE RESEARCH ESTABLISHMENT

VALCARTIER

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June/juin 1983

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ABSTRACT

A simple, reliable technique is described for frequency stabilizing a CW-TEA hybrid laser for use as a transmitter in a laser radar system with heterodyne detection. In this technique, modulation is applied to the laser cavity, the output frequency of the laser is monitored when operating in the CW mode, and the TEA laser discharge is triggered when the desired output laser frequency is detected. Details are given of the electronics used to implement the technique, as well as those for controlling the pulse repetition rate and protecting the laser itself if arcs are generated in laser discharge.

RÉSUMÉ

Ce document décrit une technique simple et efficace pour stabiliser en fréquence la sortie d'un laser hybride CO_2 TEA. Le laser composé d'une section TEA et d'une section à onde entretenue dans un même résonateur est utilisé comme transmetteur dans un système de radar à laser à détection hétérodyne. Dans cette technique, une modulation est appliquée à la cavité laser, la fréquence du signal de sortie du laser est mesurée en mode continu, et la décharge du laser TEA est déclenchée à la fréquence désirée. On donne les détails des circuits électroniques utilisés pour effectuer la stabilisation en fréquence, pour contrôler le taux de répétition, et assurer la protection du laser lorsque des arcs se produisent dans la décharge.

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1.0 INTRODUCTION

Laser radar systems based on TEA-CO_2 laser transmitters and heterodyne detection techniques are being designed both for use on 'hard' targets (e.g. aircraft) and for atmospheric sensing (Refs. 1, 2). To develop a ranging system which has a high sensitivity and is capable of extracting the doppler-shifted returns from moving targets, it is desirable to use a transmitter having a single, stable output frequency. The CW-TEA hybrid laser configuration (Refs. 3,4) is capable of producing a single frequency output (i.e. there is a single longitudinal mode in the laser cavity). However, the output frequency is not stable. The frequency stabilization and trigger control unit described in this report was designed for this hybrid transmitter to provide a frequency stability superior to that dictated by the system requirements of the experimental Infrared Ranging and Tracking System (IRATS) being developed at DREV (Ref. 1). In the present configuration of IRATS, where a 10-MHz IF bandwidth is used, a pulse-to-pulse transmitter frequency variation of less than 1 MHz would be considered acceptable. A frequency variation of an order of magnitude less than this value is obtained with the technique described in this document.

Because the triggering of the laser is controlled by the frequency stabilization circuit in this scheme, repetition rate and transmitter protection circuits have been incorporated with the stabilization circuit to produce a single unit for both frequency stabilization and trigger control.

The technique developed for the frequency stabilization of CW-TEA hybrid CO_2 lasers has been used in the study of pulse-to-pulse and intrapulse output frequency characteristics (Refs. 5,6). In the present report this technique is outlined, and the circuits for the frequency stabilization and laser trigger control are presented. The evaluation of this unit in stabilizing the laser frequency, discussed in Refs. 5 and 6, has shown that a pulse-to-pulse standard deviation of 50 kHz can be achieved in the beat frequency between the pulsed hybrid transmitter and a CW local oscillator laser.

This work was performed at DREV between January 1979 and June 1981 under PCN 33H06, Investigation of Ladars at 10.6 μm.

2.0 PRINCIPLE OF FREQUENCY STABILIZATION

The CW-TEA hybrid laser configuration with the CW laser section operating above the lasing threshold has been investigated as an effective method of obtaining a single longitudinal mode in a laser cavity during the generation of the output pulse (Refs. 3,4). The insertion of an iris in the cavity eliminates unwanted transverse cavity modes and limits the output radiation to the TEM_{00} mode. The remaining problem, which is the subject of this report, is to accurately stabilize the resulting single frequency output pulse relative to a frequency stable CW laser source which would also act as the local oscillator when performing heterodyne detection.

In the schematic of the frequency stabilization network shown in Fig. 1, a portion of the CW output of the transmitter is split off and mixed with the local oscillator beam on a sensitive wideband infrared detector operating in the heterodyne detection mode. With modulation applied to the piezoelectric transducer (PZT) on which the laser output coupler is mounted, the cavity length is varied by slightly more than $\lambda/2$ during each half cycle of the modulation. Thus, the cavity is driven through its full frequency range twice during each cycle. The detector produces a beat frequency output at each point of the sweep where the difference frequency between the transmitter output and the local oscillator output is within the bandwidth of the detector. This

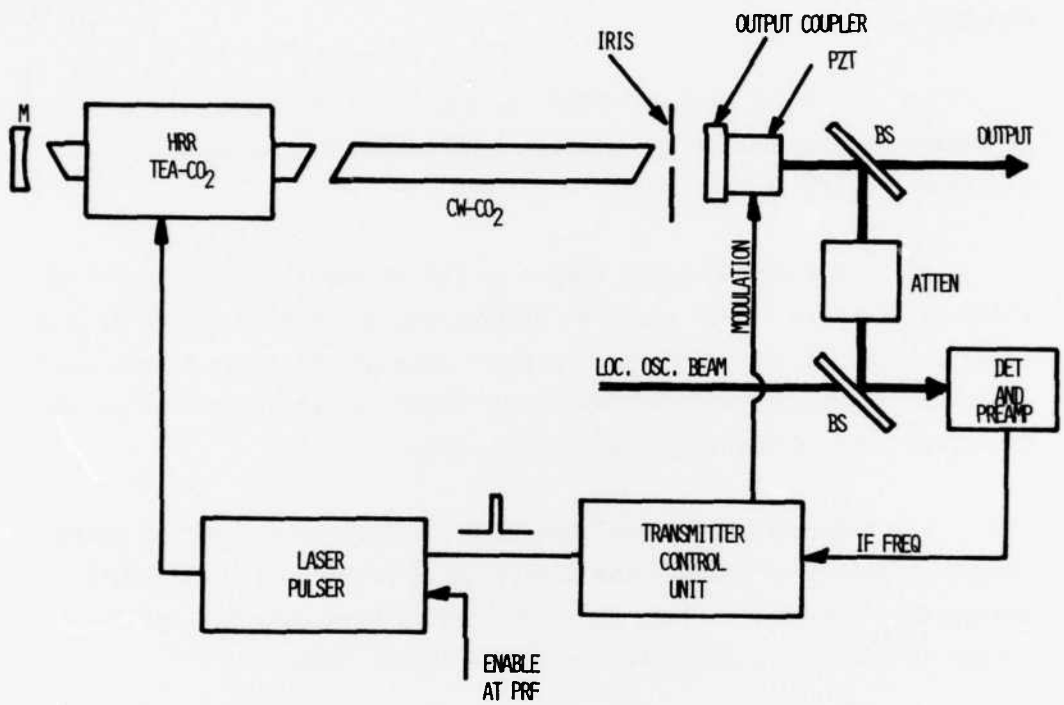

FIGURE 1 - Schematic diagram of the frequency stabilization network

intermediate frequency (IF) beat signal from the detector is fed into a frequency selecting circuit in the transmitter control unit which emits a trigger pulse each time the desired frequency difference between the lasers is encountered. The trigger pulse is then used to initiate the discharge in the TEA-CO_2 laser section, and a high-power pulse is emitted at a frequency close to that of the CW laser output at the instant of triggering. The small frequency difference between the high-power pulse and the CW laser output has been discussed previously (Refs. 5,6).

The following additional comments will help in understanding the technique.

a) The block marked "ATTEN" in Fig. 1 is an attenuator used to protect the sensitive IR detector from permanent damage when the high-power pulse is emitted.

b) For a pulsed laser output on the stronger laser lines (e.g. P(20) at 10.59 μm in our case) no diffraction grating is needed in the laser cavity. As the CW output is swept through the laser lines, beats can only be detected and the resulting trigger pulses generated on the operating line of the local oscillator laser.

c) External vibrations have little effect on the output pulse frequency stability because the technique is based on cavity length modulation. Angular variations of the cavity need only be kept low enough to maintain a sufficiently stable output beam.

d) The pulse repetition rate is a function of the applied cavity modulation frequency and thus, the laser cannot be triggered at a precise instant from an external source. In other words, the laser trigger can only be enabled; the actual triggering occurs when the predetermined difference frequency in the frequency sweep is obtained.

3.0 TRANSMITTER CONTROL UNIT - ELECTRONIC CIRCUITS

A block diagram of the control unit is given in Fig. 2. From the difference frequency between the local oscillator and the CW output of the transmitter, the frequency detector circuit determines the instants at which the TEA laser section of the transmitter can be pulsed. The sweeping of the output frequency of the transmitter is controlled by the laser cavity modulation oscillator. The arc detector provides a protective interlock which inhibits the triggering of the laser if arcs are detected in the pulsed laser discharge. The repetition rate counter and display/limit alarm section consists of monitoring circuits.

The repetition rate controller provides the pulses for triggering the TEA laser section of the transmitter. In this chapter, each block of Fig. 2 is discussed in detail.

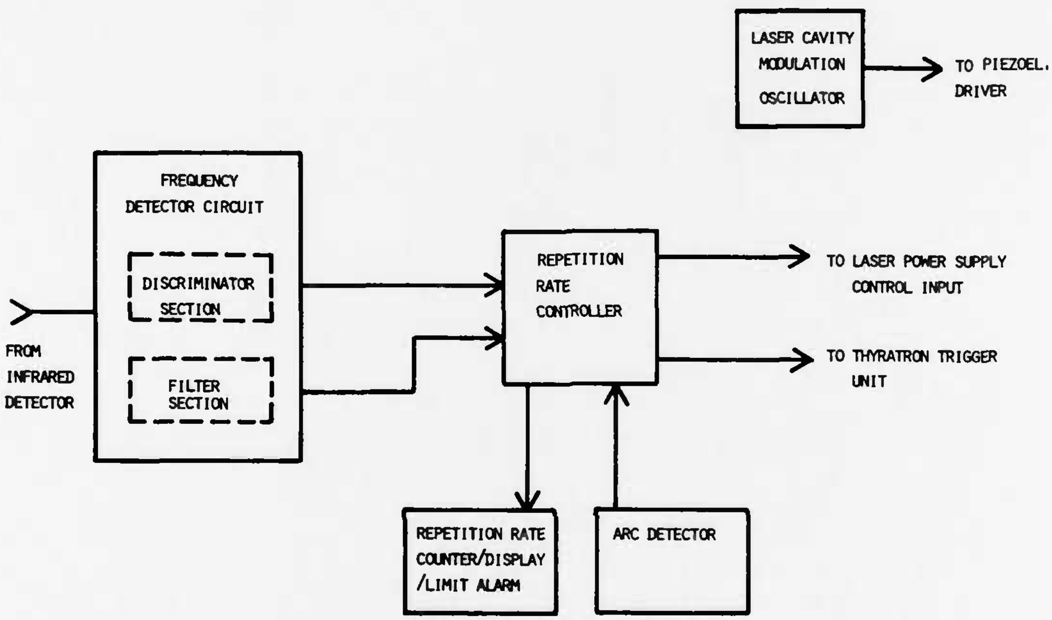

FIGURE 2 - Block diagram of the laser transmitter control unit

3.1 Frequency Detection Circuit

The circuit in Fig. 3 was designed to detect a 30-MHz IF frequency generated by beating the output of the local oscillator laser with the swept CW output of the transmitter laser. In the frequency detection circuit, the swept IF signal from the infrared detector is first amplified and filtered before being fed into a power splitter. The signal from output #3 of the power splitter is passed through a 2.5-MHz bandwidth filter, and then detected, amplified and low-pass filtered before being applied to a threshold device (U49). With this arrangement, the threshold device gives an output each time the input signal frequency approaches the 30-MHz centre frequency of the 2.5-MHz

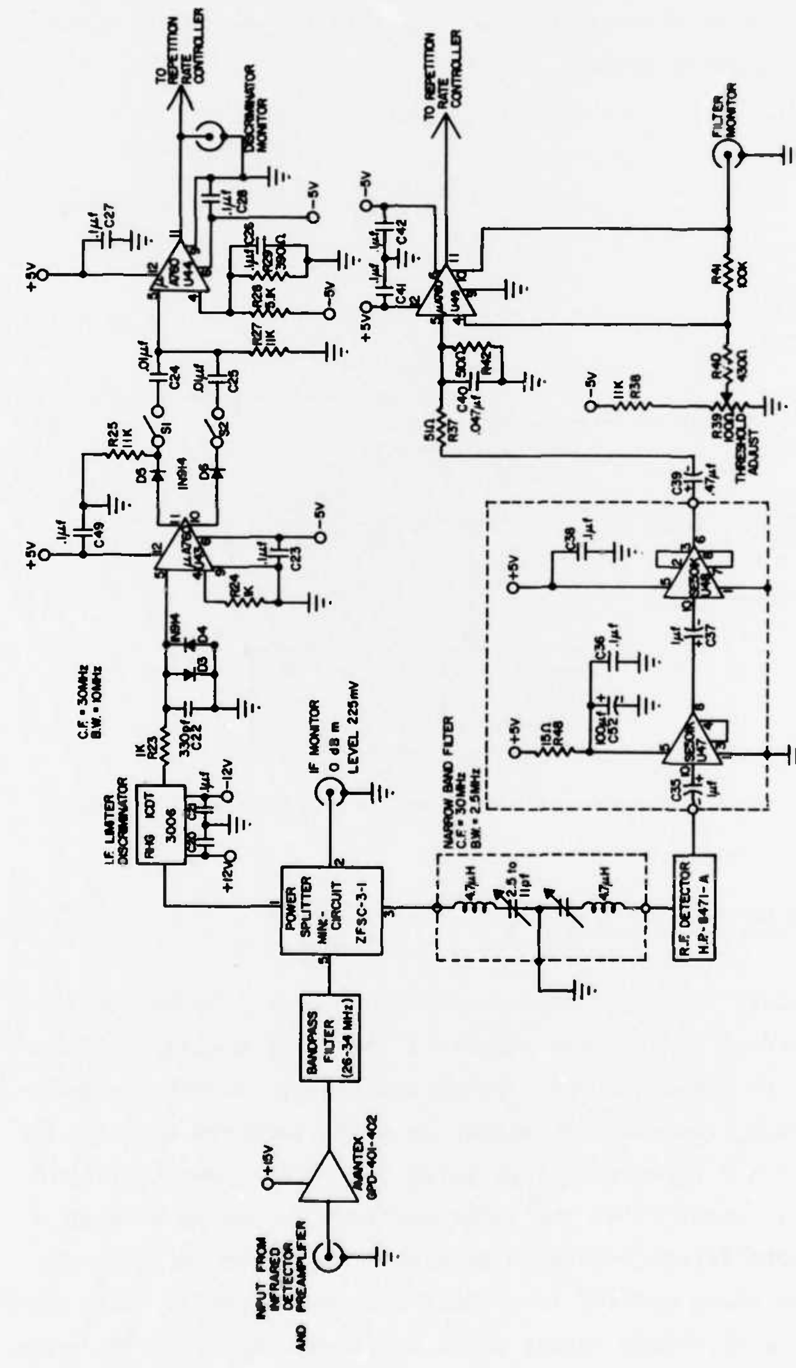

FIGURE 3 - Frequency detector circuit

bandwidth filter. The accuracy in detecting a 30-MHz frequency with a filter and a threshold device is limited by the width of the narrow-band filter, especially if the input signal amplitude is not constant. Furthermore, the minimum acceptable bandwidth of the filter is limited by the sweep rate of the input signal. To increase the accuracy of the frequency detection circuit, the signal from output #1 of the power splitter in Fig. 3 is passed through a frequency discriminator followed by a zero-crossing detector (composed of U43 and U44). Switches S1 and S2 enable laser triggering on either or both upsweeping or downsweeping frequencies. Since the frequency discriminator produces zero output voltage when the signal frequency is outside its 10-MHz bandwidth as well as the required zero output at its centre frequency, undesired outputs are produced by the zero-crossing detector. Therefore, to ensure that only the 30-MHz IF frequency is detected, an AND gate must be used to detect the presence of a simultaneous output on both this frequency discrimination branch and the previously described narrow-band filter branch of the circuit. For proper operation, the bandwidth of the discriminator must be superior to that of the narrow-band filter. The AND gate function is fulfilled by a monostable multivibrator (U45-A) located in the repetition rate controller section of the control unit (Fig. 5).

Figure 4 shows the signal present at the three monitor points indicated on the circuit diagram of the frequency detector (Fig. 3). To obtain these signals, the transmitter control unit was used with the hybrid-laser frequency stabilization configuration shown in Fig. 1.

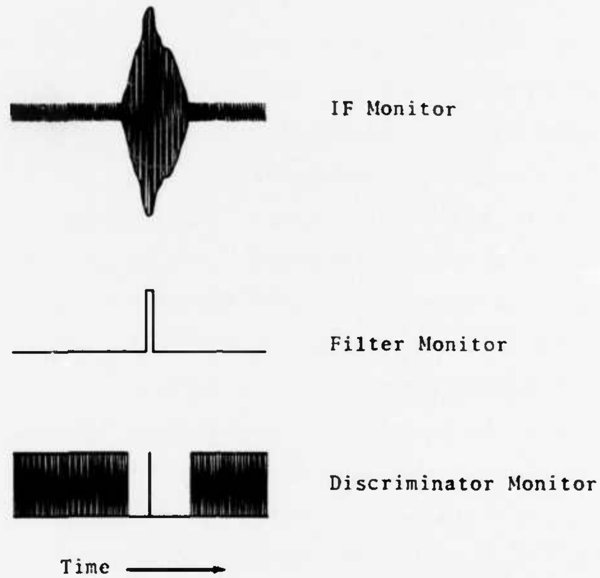

FIGURE 4 - Illustration of signals on frequency-detector monitor outputs during sweep of IF frequency through 30 MHz

3.2 Repetition Rate Controller

As shown in Fig. 2, the block entitled repetition rate controller accepts the inputs from the frequency detection circuits and generates signals that control the pulsing of the laser.

As illustrated in Fig. 5, two different modes of operation can be selected using the front panel switch. In the frequency stabilized mode, the laser is triggered from the frequency detection circuits, and in the free running (unstabilized) mode from a 300-Hz pulse generator. The third switch position puts the unit into a standby state. Depending on the selected mode, the output of the frequency detection circuit or the output pulse generator reaches the repetition rate controlling part of the circuit composed of monostable multivibrators U45 and U52. The repetition rate is chosen by varying the output pulse width of the nonretriggerable multivibrator U52, using the external

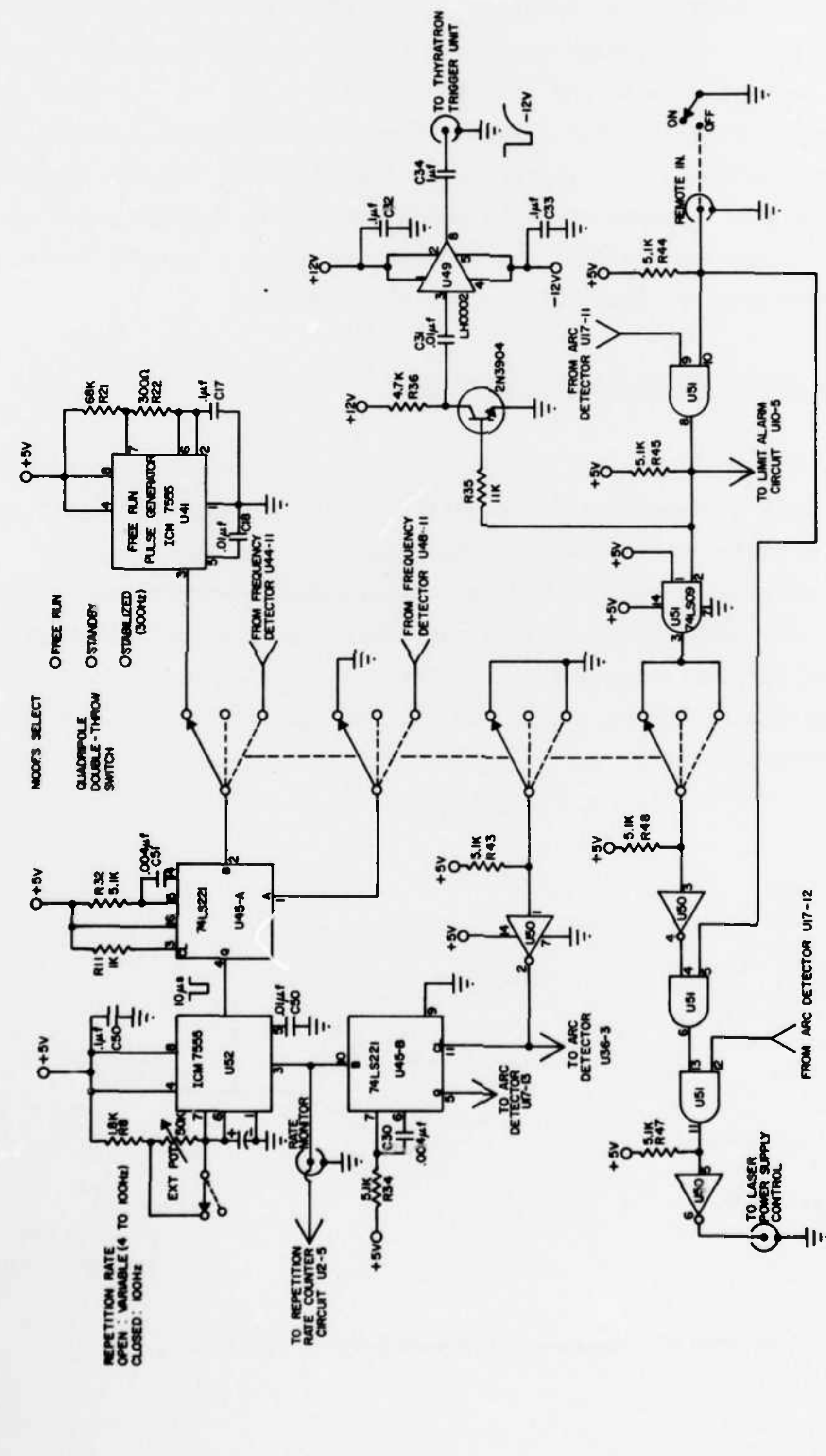

FIGURE 5 - Repetition-rate controller

timing potentiometer or an external switch which selects a fixed 100-Hz repetition rate. The pulses generated in this part of the circuit are sent, via a logic gate in the arc detector block, to the circuits generating the laser control pulses. When laser arcs are present, the arc detector inhibits the triggering of the thyratron and the charging of the laser power supply (Candela Model HVD-1000A) through gates of U51. The remote input allows the operator to enter a standby state from a remote control panel with a switch to ground.

3.3 Laser Cavity Modulation Oscillator

For the stabilization technique, the output mirror of the cavity is driven with a piezoelectric translator and a high-voltage amplifier such as the Burleigh Model RC-42 ramp generator. An oscillator to drive the external input of the high voltage ramp generator was developed (Fig. 6), because the minimum ramp duration internally available from the RC-42 generator is 20 ms, which would limit the maximum transmitter repetititon rate to less than the desired 100 Hz. It uses an Intersil 8038 oscillator followed by an operational amplifier (μA 747) to produce a 0-10 V, 100 Hz sinusoidal signal.

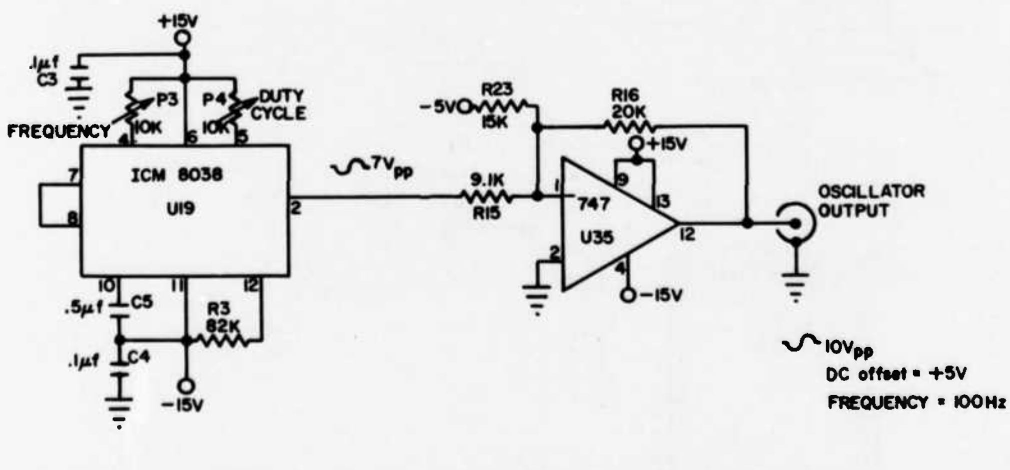

FIGURE 6 - Laser-cavity modulation oscillator

3.4 Arc Detector

In the TEA laser section of the hybrid laser, a constrictive arc can develop in the discharge volume when its normal operating conditions are not satisfied. This arcing could result from an improper gas mixture, a diminished transverse gas flow, an incorrect power supply voltage or a malfunction of one of the electronic components (thyratron, capacitor, etc.). To prevent damage to the system from an arcing discharge, a circuit (Fig. 7) that detects these arcs and inhibits the laser power supply was incorporated into the transmitter control unit. In this circuit a phototransistor, positioned inside the transmitter box to look at the TEA laser discharge, produces a detectable signal each time an arc occurs. Although the background signal originating from the laser discharge is about -0.2 V, an average arc produces a signal pulse at the transistor collector with an amplitude in excess of -0.5 V and a width of more than 50 μs. At the output of the phototransistor, a band-pass filter eliminates the dc voltage and limits the bandwidth of the signal. A voltage comparator U30 generates a trigger pulse for each laser arc. It has an adjustable threshold level and is connected in a configuration which provides hysteresis to avoid multiple triggering. The leading edge of the trigger pulse is then used to generate a 7-μs pulse in the 74LS221-U31-A monostable multivibrator.

The 74LS393-U39-A binary counter and the 74LS221-U31-B monostable multivibrator determine the minimum arc pulse rate necessary to inhibit the laser power supply. Two series of dip switches, units U32 and U38, set the arc pulse rate limit from 05 to 36 arcs per second. If the arc pulse rate equals or exceeds the limit selected, the 74LS76-U36-A flip-flop multivibrator generates a 5-V inhibit signal. The FL200-U27 unit (from Projects Unlimited Company) receives this signal from the LH0002-U34 driver and illuminates a flashing light-emitting

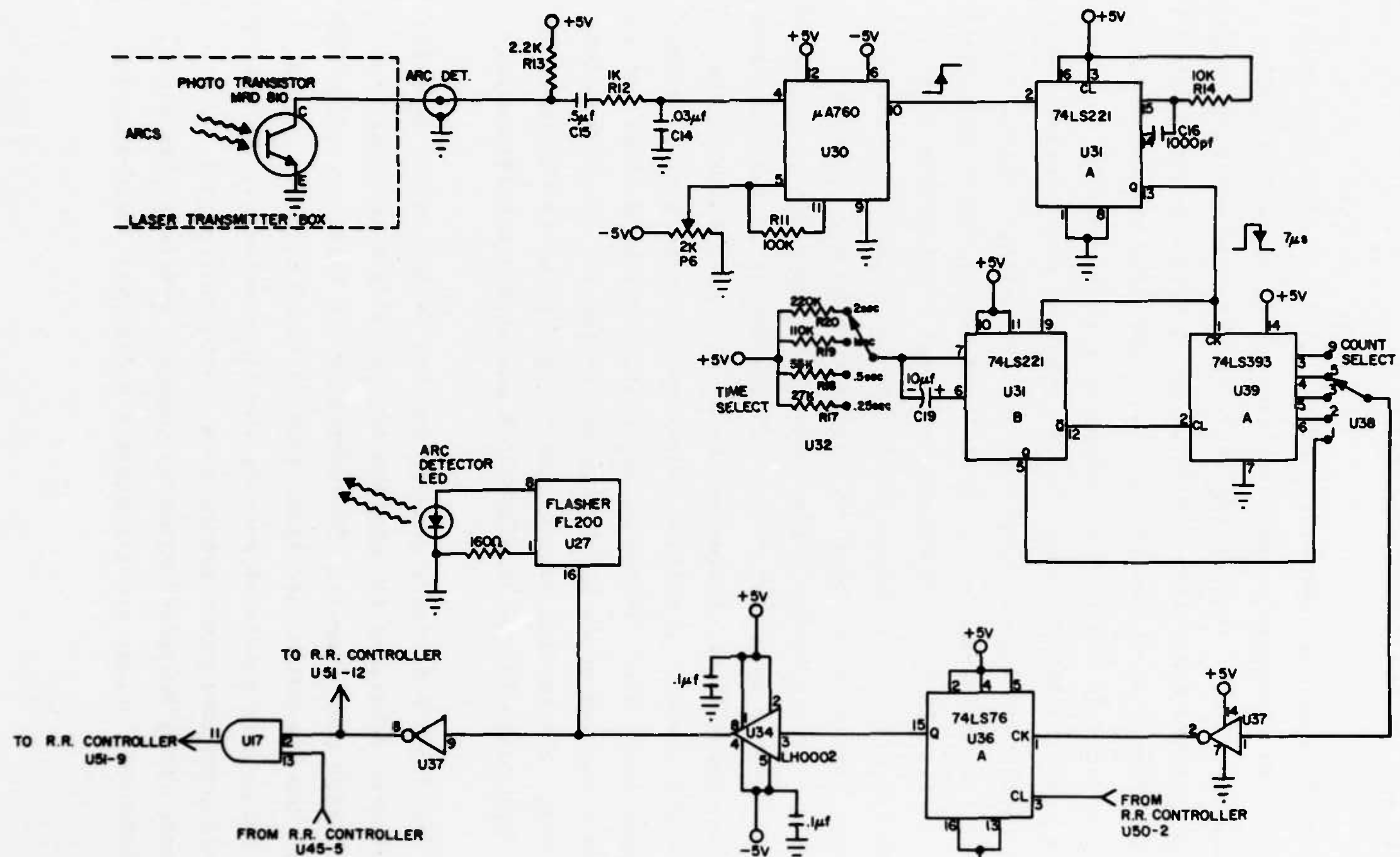

FIGURE 7 - Arc detector

diode (LED) on the front panel. The inhibit signal is also sent through a series of logic gates to the power supply input and prevents the laser energy storage capacitors from being charged. To reset the arc detection circuit, the mode selection switch on the front panel must be returned to the standby position.

3.5 Repetition Rate Counter and Display/Limit Alarm Circuit

In either mode of operation, frequency stabilized or free running, the TEA laser section of the transmitter can be triggered at an adjustable repetition rate. As a result a circuit that determines and displays this rate is useful (Fig. 8).

The ICM 7224 integrated circuit (from Intersil Company) is a digital counter that drives a 3-digit liquid-crystal display (LCD) 8654 (from Shelly Associates). To use the counter for measuring frequency, a gating signal is provided by the ICM 7556-U8 astable multivibrator which gives a positive output for approximately one second and a negative output for 300 μs. The timing is calibrated with potentiometer P2 as a coarse control, and potentiometer P1 as a fine control. The store signal is provided by the 74LS221-U25-A monostable multivibrator triggered by the falling edge of the gating signal. When the one-shot multivibrator times out, the store and the reset signals switch to the low state and the counter is reset for the next measurement.

The counted pulses are produced by the ICM 7557-U52 monostable multivibrator in the repetition rate controller circuit (Fig. 5) (rate monitor connector on the rear panel).

A high repetition rate may be demanded for a short period of time (a burst mode), but cannot be sustained indefinitely without altering the proper discharge characteristics of the gas. Therefore, the

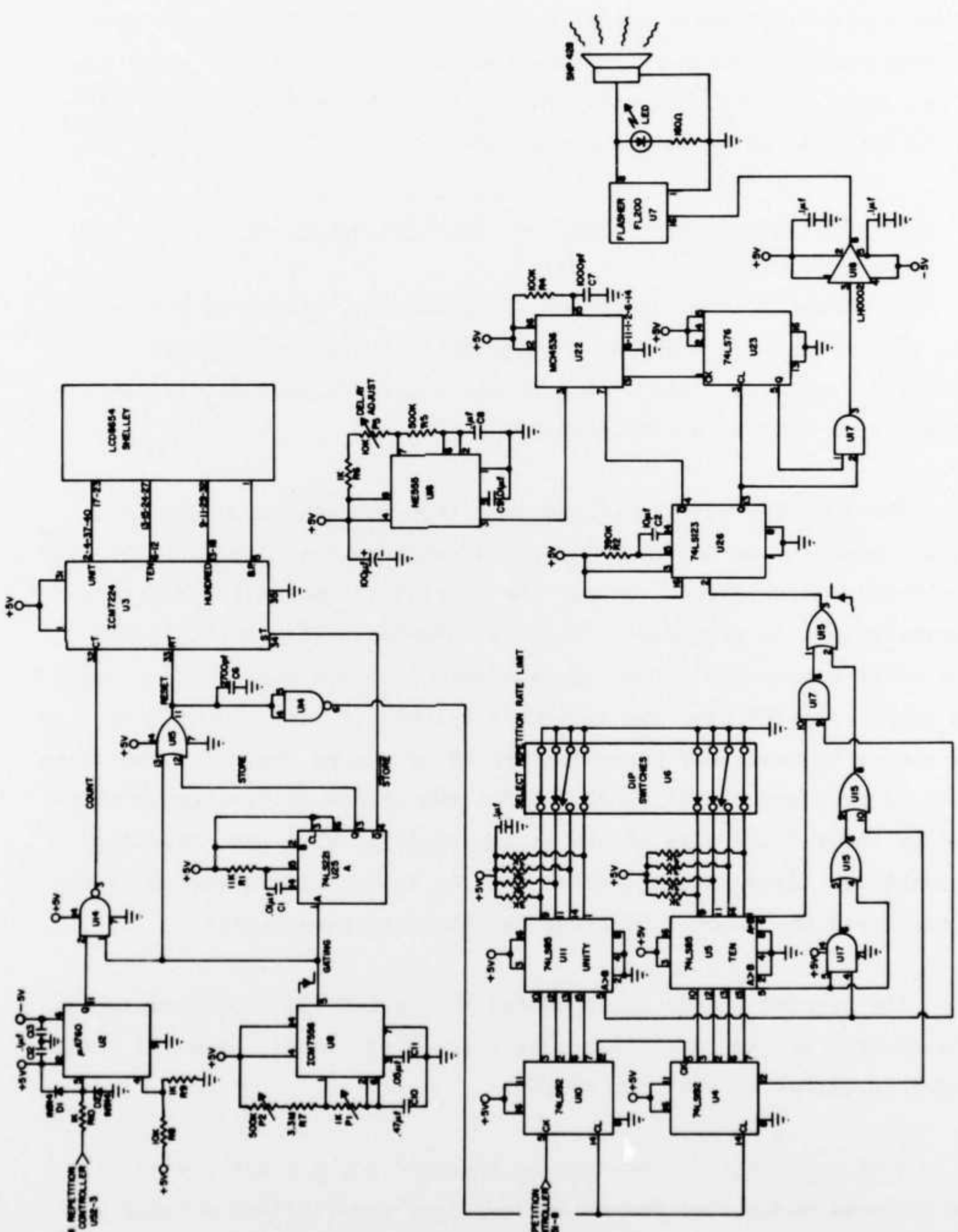

FIGURE 8 - Repetition rate counter and display/limit alarm circuit

system is protected by a warning circuit with a light and a buzzer which alerts the operator after a predetermined duration. The circuit described here (Fig. 8) does not affect the laser transmitter operation.

The TEA laser trigger pulses coming from the 74LS09-U51-8 in the repetition rate controller circuit (Fig. 5) are sent to the two cascaded decade counters (74LS192-U10 and U4), where both series of outputs are connected to the A inputs of comparators 74LS85-U11 and U5. The counters are reset every second so that the maximum count reached is the effective repetition rate of the transmitter. The B inputs of the comparators are connected to two series of 4 dip switches (U6) used to select fc, the lowest value of the transmitter repetition rate for which the warning system will be enabled. Since the counters are operating in the BCD (binary-coded-decimal) code, the value of fc must be selected using the same code.

If the transmitter repetition rate is equal to or greater than fc, which has a maximum value of 99 Hz, the comparators produce a negative pulse to trigger the 74LS123 one-shot multivibrator.

The one-shot multivibrator output pulse enables the circuit that determines the time delay before initiating the light and buzzer alarm. This pulse must have a width longer than 1 s to get a continuous alarm because the repetition rate is measured every second.

The time delay circuit is formed by the NE555-U16 astable multivibrator, the MC14536-U22 divider and the 74LS76-U23 flip-flop multivibrator. The frequency of the pulses produced by the NE555 is adjustable using potentiometer P5, and this, with the MC14536 divider, gives 100-μs pulses at intervals varying from 12 to 110 s. The 74LS76 flip-flop waits the selected delay time before being triggered; then its output, driven by the LH0002-U18, turns on the flashing light and the buzzer, alerting the operator.

4.0 CASE ARRANGEMENT

The dimensions of the case which contains the electronic circuit are 43 cm × 26 cm × 17 cm; its weight is approximately 2 kg. (Fig. 9). The distribution of the modules, electronic boards, power supplies and regulators in the case is shown in Fig. 10. Figures 11 and 12 give the integrated circuit positions on the two internal boards. Figure 13 identifies the discrete components on their respective sockets, and Fig. 14 identifies the pins of all the connectors of the boards.

5.0 CONCLUSION

A unique technique of frequency stabilizing the output of a CW-TEA hybrid laser intended for use as a laser radar transmitter has been described. From the inherent simplicity of this stabilization technique, the immunity to external vibration, and the high transmitter frequency stability reported in Refs. 5 and 6, it is apparent that this technique is well suited for use with CW-TEA hybrid lasers which are located in a non-laboratory environment.

6.0 ACKNOWLEDGEMENTS

The authors wish to thank Mr. G. Beaudin for his expert technical assistance in the construction and testing of the electronic circuits.

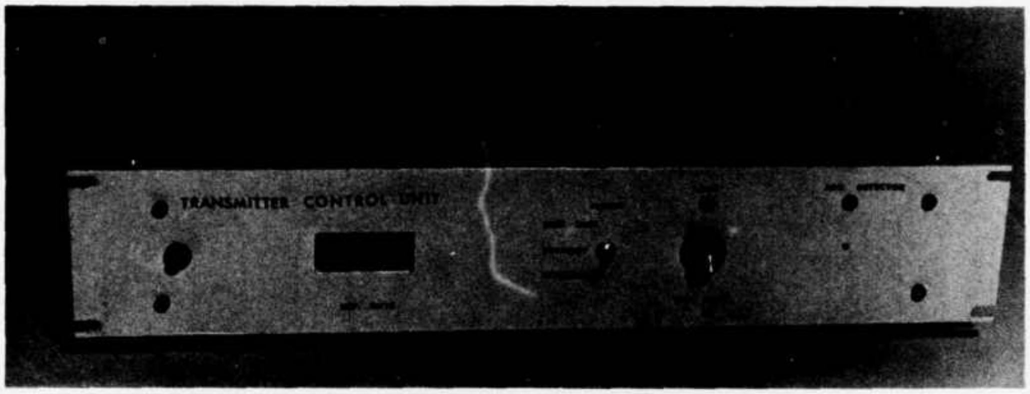

FIGURE 9 - Transmitter control unit

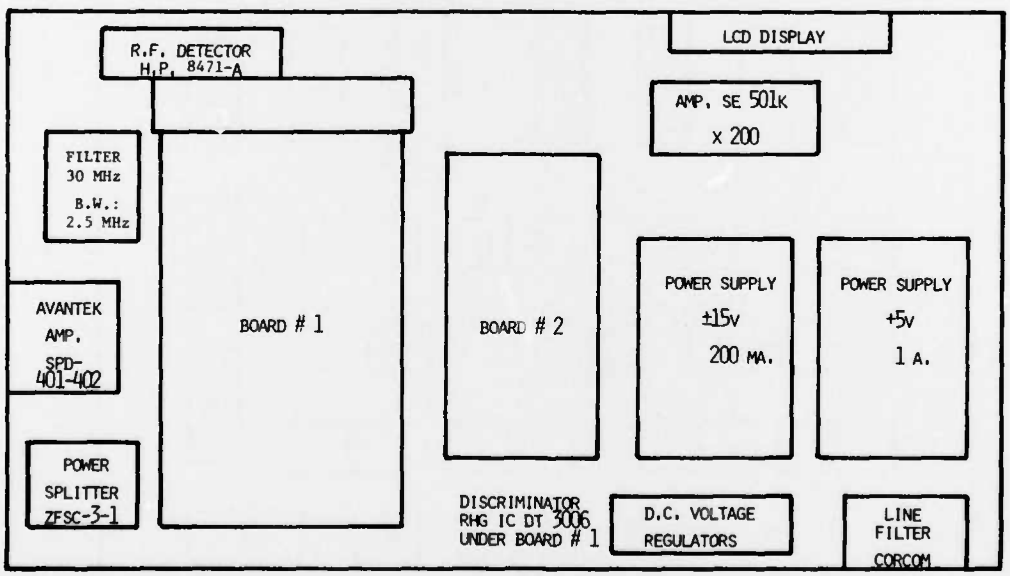

FIGURE 10 - Case arrangement

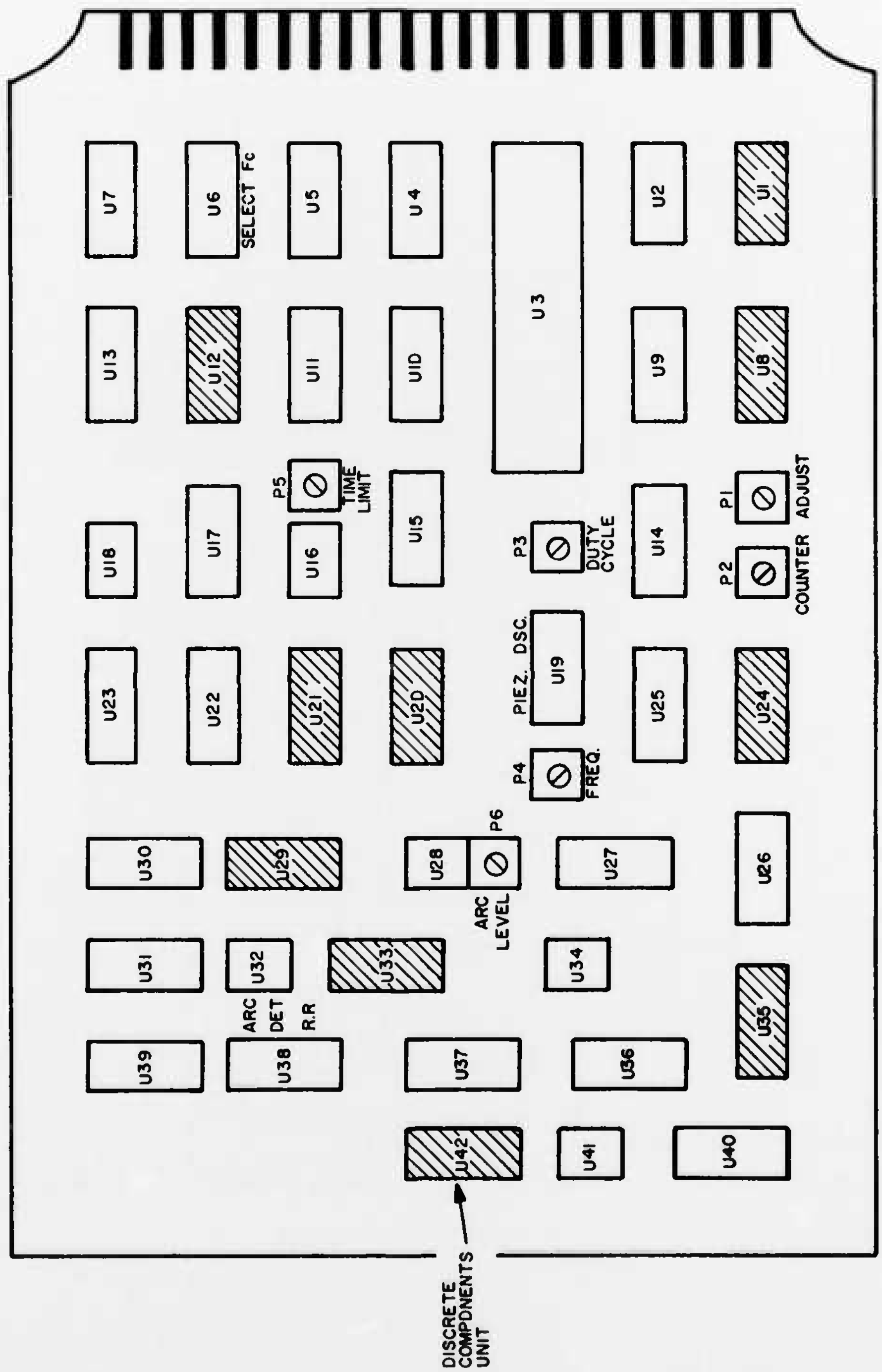

FIGURE 11 - Board #1 layout

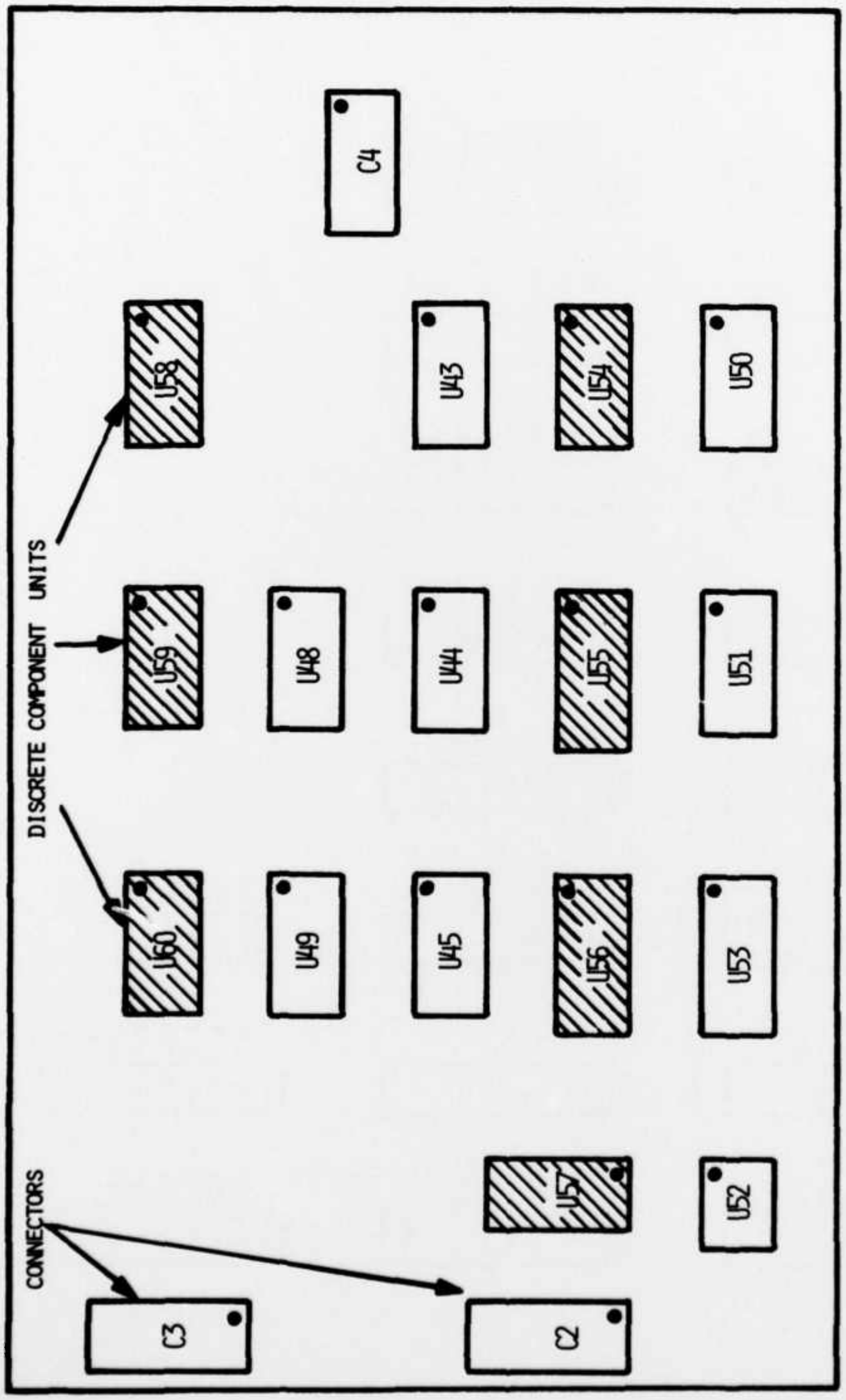

FIGURE 12 - Board #2 layout

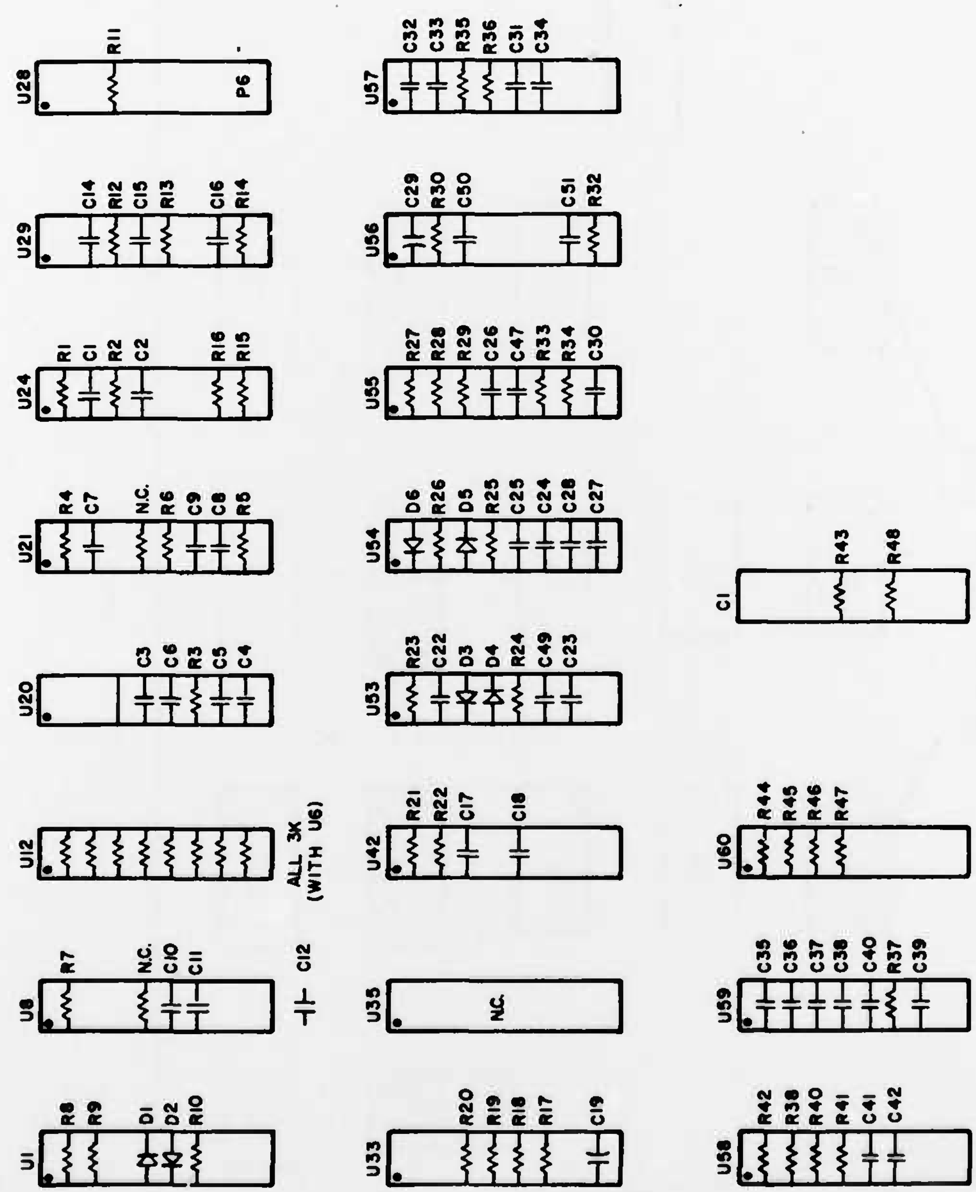

FIGURE 13 - Discrete component units

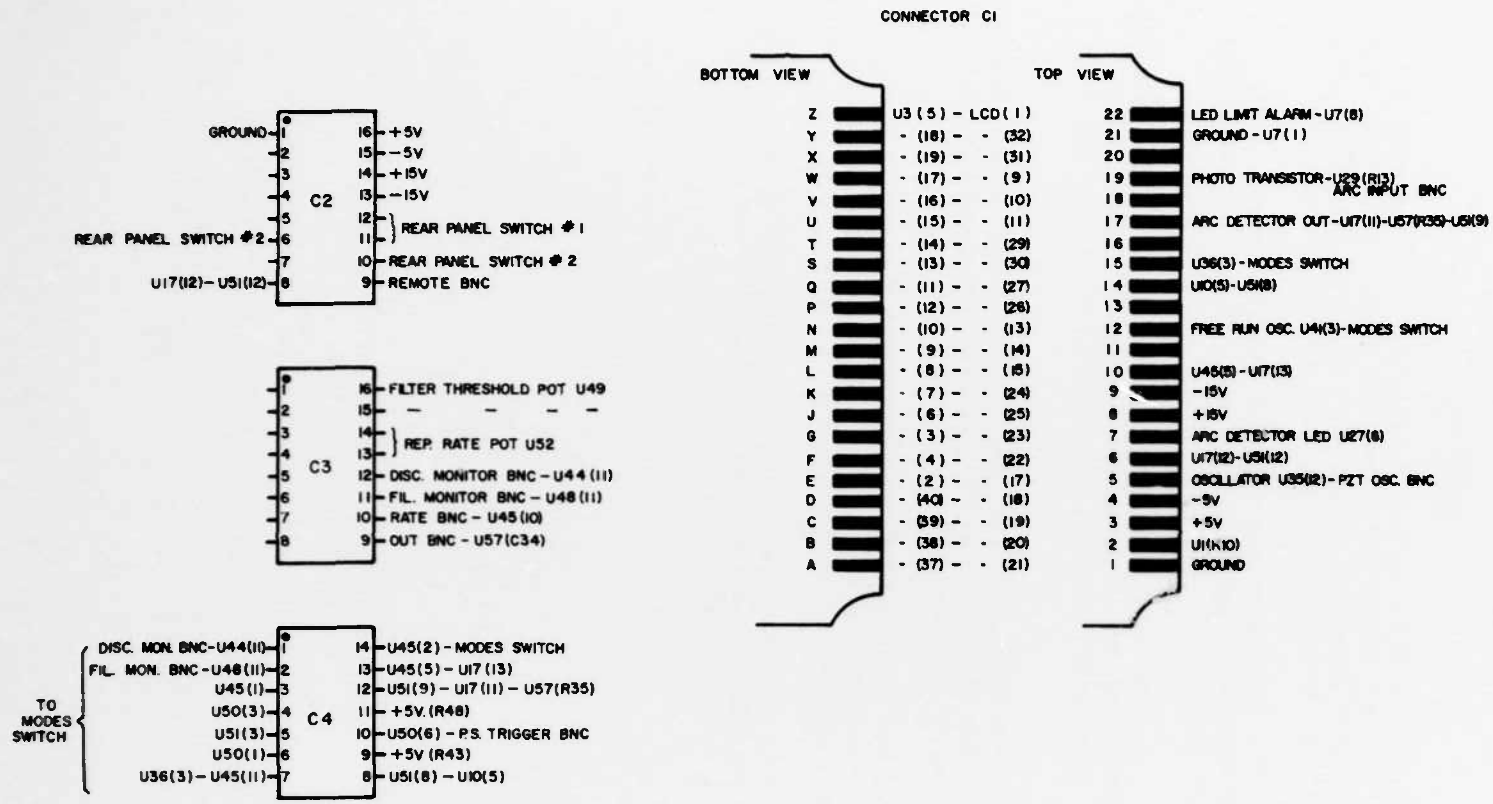

FIGURE 14 - Connector pin identification

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APPENDIX A

Integrated Circuits Identification

1. RHG ICDT 3006: IF limiter discriminator from RHG
2. H.P. 8471-A: RF detector from Hewlett-Packard
3. ZFSC-3-1: 3-way power splitter from Mini-Circuits
4. SPD-401-402: amplifier from Avantek
5. SE 501 K: video amplifier from Signetics; U47, U48
6. Comparator μA760: U2, U30, U43, U44, U49
7. Monostable multivibrator 74LS221: U25, U31, U45
8. Monostable multivibrator 74LS123: U26
9. Astable multivibrator 7555: U41, U52
10. Astable multivibrator 7556: U8
11. Binary counter 74LS393: U39
12. Decade counter 74LS192: U4, U10
13. Comparator 74LS85: U5, U11
14. Flip-flop multivibrator 74LS76: U23, U36
15. Driver LH0002: U18, U49

16. AND gate 74LS08: U17

17. OR gate 74LS32: U15

18. NAND gate 74LS00: U14

19. Inverter 74LS04: U37, U50

20. Open-collector AND gate: U51

21. FLASHER FL200 (Projects Unlimited): U7, U27

22. ICM 7224: 4½ digit counter/decoder/drivers; U3

23. LCD 8654: 3½ digit LCD display from Shelley Associates

24. Programmable timer MC 14536: U22

25. Astable multivibrator NE555: U16

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par J.M. Cruickshank, V. Larochelle et P. Pace

Ce document décrit une technique simple et efficace pour stabiliser en fréquence la sortie d'un laser hybride CO_2 TEA. Le laser composé d'une section TEA et d'une section à onde entretenue dans un même résonateur est utilisé comme transmetteur dans un système de radar à laser à détection hétérodyne. Dans cette technique, une modulation est appliquée à la cavité laser, la fréquence du signal de sortie du laser est mesurée en mode continu, et la décharge du laser TEA est déclenchée à la fréquence désirée. On donne les détails des circuits électroniques utilisés pour effectuer la stabilisation en fréquence, pour contrôler le taux de répétition, et assurer la protection du laser lorsque des arcs se produisent dans la décharge.

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"Circuit pour la stabilisation en fréquence et le contrôle de déclenchement des lasers hybrides CO_2 TEA"
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Ce document décrit une technique simple et efficace pour stabiliser en fréquence la sortie d'un laser hybride CO_2 TEA. Le laser composé d'une section TEA et d'une section à onde entretenue dans un même résonateur est utilisé comme transmetteur dans un système de radar à laser à détection hétérodyne. Dans cette technique, une modulation est appliquée à la cavité laser, la fréquence du signal de sortie du laser est mesurée en mode continu, et la décharge du laser TEA est déclenchée à la fréquence désirée. On donne les détails des circuits électroniques utilisés pour effectuer la stabilisation en fréquence, pour contrôler le taux de répétition, et assurer la protection du laser lorsque des arcs se produisent dans la décharge.

DREV R-4301/83 (UNCLASSIFIED)

Research and Development Branch, DND, Canada.
DREV, P.O. Box 8800, Courcelette, Que. G0A 1R0

"A Frequency Stabilisation and Trigger Control Unit for Hybrid TEA-CO_2 Lasers"
by J.M. Cruickshank, V. Larochelle and P. Pace

A simple, reliable technique is described for frequency stabilising a CW-TEA hybrid laser for use as a transmitter in a laser radar system with heterodyne detection. In this technique, modulation is applied to the laser cavity, the output frequency of the laser is monitored when operating in the CW mode, and the TEA laser discharge is triggered when the desired output laser frequency is detected. Details are given of the electronics used to implement the technique, as well as those for controlling the pulse repetition rate and protecting the laser itself if arcs are generated in laser discharge.

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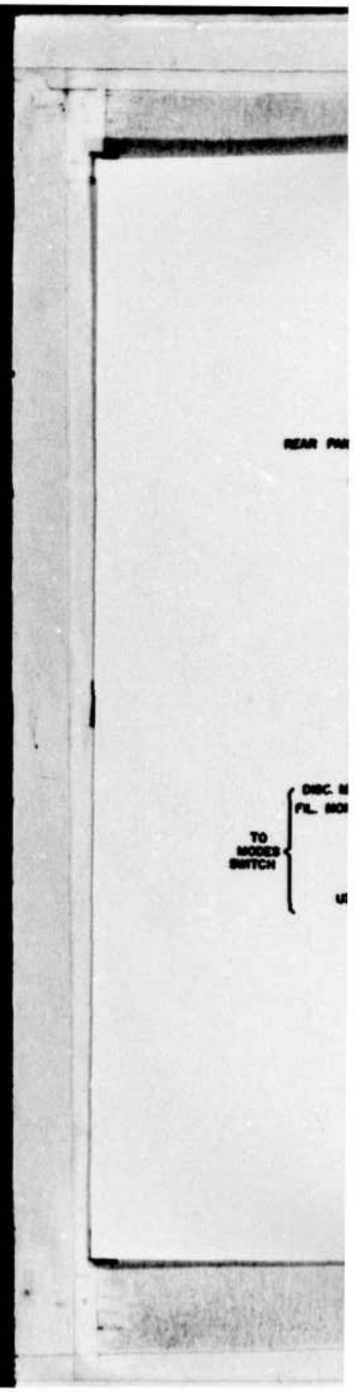
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