Technical Paper 318

THE ARI PROTOTYPE SMALL GUN LASER ENGAGEMENT SYSTEM

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This report describes a research and development effort aimed at determining the feasibility of developing a small gun laser engagement system for field research and evaluation purposes. The prototype system developed has a capability for ~~(a)~~ realistic shooter performance requirements and weapons signature, ~~(b)~~ realistic simulation of weapons effects in terms of real-time casualty assessment and suppression, and ~~(c)~~ player-carried memory for collecting and recording time, casualty, and player identification data. → next page

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The prototype laser simulator demonstrates that the requirements for casualty assessment and data recording necessary for field research can be met using this system. Further research and development are necessary to make the system fully operational.

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FOREWORD

The research program of the Tactical Team Performance Work Unit of the U.S. Army Research Institute for the Behavioral and Social Sciences is concerned with increasing the effectiveness of team performance within Infantry, Armor, and Combined Arms units. Experiments are fielded having application to training and evaluation system effectiveness (ARTEP), extensions of engagement simulation methodology (SCOPES, REALTRAIN), and combat developments (tactics and techniques). Technological Base Exploratory Development research supporting the continuous refinement of technological and methodological capabilities for the conduct of research in these areas is conducted under RDT&E Project 2Q162722A764, Training and Education, FY 78 Work Program.

The present publication describes a prototype small gun laser engagement system incorporating capabilities both for the tactically realistic simulation of individual-weapon (M-16 rifle) effects and for the collection of data on the development of firing engagements. Application of the system to other individual and crew-served direct-fire weapon systems is shown to be feasible.

ARI technological base research is conducted as an in-house research effort augmented by research contracts with organizations selected as having unique capabilities for work in the area. The present developmental effort was conducted jointly by ARI personnel under the supervision of Dr. James H. Banks and by personnel of Manned Systems Sciences, Northridge, Calif., under the supervision of Mr. Douglass Nicklas. The work was conducted under a program directed by Mr. Jack J. Sternberg, ARI.

Joseph Zeidner

JOSEPH ZEIDNER
Technical Director

THE ARI PROTOTYPE SMALL GUN LASER ENGAGEMENT SYSTEM

BRIEF

Requirement:

To determine the feasibility of developing a small gun laser engagement system for field research and evaluation purposes.

Procedure:

Taking advantage of the latest developments in the state-of-the-art in laser technology and in packaging and miniaturization of electronic circuitry, ARI and contractor scientists and engineers developed and refined the design of a small gun laser engagement system (LES) to meet the requirements of field testing and experimentation. The approach taken was the concurrent development of three subsystems comprising the whole: a laser transmitter mounted on the M-16 rifle, a helmet-mounted laser receiver, and an off-line computer which receives the data from the receiver memory, reformats the data, and performs data reduction and analysis.

Findings:

The prototype LES demonstrates that the requirements for casualty assessment and data recording necessary for the conduct of field research can be met using this system.

Through achievement of a virtually constant hit-zone, the system provides accurate simulation of weapon effects out to the maximum effective range of the weapon. Players under fire receive real-time feedback on hits and near misses from helmet-mounted audio alarms.

Helmet-mounted memory provides for storage of time-tagged shooter identification, target identification, hit and near-miss data, and round count. This feature permits a stand-alone capability independent of on-line computer support.

The system is unobtrusive and does not degrade tactical realism: There is no external cabling to encumber the player; the small, lightweight transmitter and receiver alter neither weapon balance and aiming requirements nor helmet balance.

The system is safe and easy to use: Low-energy laser diodes permit use at close range; the laser transmitter in continuous pulse mode permits rapid and accurate weapon zeroing; and the transmitter can be easily and quickly removed from the weapon and need not be rezeroed when remounted.

The design concept, using multiple laser beams, can be adapted to a variety of direct-fire weapon systems.

Utilization of Findings:

The system has application to field research on a broad spectrum of Army problems, including the development of techniques for

- Assessment of combat readiness,
- Assessment of training effectiveness,
- Diagnosis of individual and unit training requirements,
- Evaluation of variations in tactics and doctrine, and
- Evaluation of variations in unit size and composition.

THE ARI PROTOTYPE SMALL GUN LASER ENGAGEMENT SYSTEM

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THE ARI PROTOTYPE SMALL GUN LASER ENGAGEMENT SYSTEM

BACKGROUND

The Army Research Institute for the Behavioral and Social Sciences (ARI) has been engaged in an in-house research and development program aimed at determining the feasibility of developing, for research purposes, a small gun laser engagement system (LES). The LES would be a major instrumentation element of the Combat Readiness Systems Measurement Bed (CORE-TEST) being developed for use in experimentation and testing of small infantry unit tactical performance. With a LES capability, the system measurement bed would (a) provide for tactically realistic simulation of small arms weapons fire, (b) permit two-sided free play with realistic, real-time casualty assessment and suppression by fire, and (c) provide standardized task and evaluation situations and measurement and recording techniques for the systematic and reliable assessment of individual and unit tactical performance.

A major requirement for the LES is that it provide good-fidelity small arms weapons simulation, casualty assessment, and data recording without being tied to an expensive and complex on-line computer system. To meet this requirement, the present prototype system utilizes a blank-activated gallium arsenide (GaAs) laser source mounted on the M-16 rifle to simulate weapon firing, and a pulse-coded beam pattern transmission to identify the player who is firing. Wide-field-of-view optical detectors mounted on each player's helmet allow him to be "hit" or "suppressed" if he is illuminated by the laser beam pattern. Audio alarms in the helmet notify a player if he has been hit or suppressed. Time, casualty, and player/weapon identification data are recorded in player-carried electronic memory modules.

PURPOSE

The purpose of this report is to describe the physical and functional characteristics of the prototype ARI small gun laser engagement system. The scope of the research and development effort is presently confined to the simulation of M-16 rifle fire. This capability probably can be extended to other infantry squad weapons (e.g., M-60 machine guns) if the present system is modified. The system and its components are described below. The appendixes provide more detailed technical coverage of particular system components; Appendix B discusses the eye safety of the system.

SYSTEM DESCRIPTION

General

The prototype ARI small gun laser engagement system consists of three major subsystems. When integrated, they provide simulated small arms fire, real-time casualty assessment, time-tagged data storage, and off-line data reduction and analysis. The three subsystems include the following:

1. A laser transmitter, mounted on an M-16 rifle, that consists of GaAs laser diodes and associated electronics, optics, and a power source;
2. A helmet-mounted laser receiver consisting of silicon photodiode detectors, a power source, receiver electronics, memory for data storage, and an acoustic hit indicator; and
3. An off-line computer that receives the data from the receiver memory, reformats the data, and performs data reduction and analysis.

Figure 1 shows the mounted system. The laser transmitter is clamped to the slipring immediately in front of the carrying handle of the weapon. The laser detectors and receiver power supply are mounted on a band fitted around the circumference of the helmet liner. The receiver electronic package, memory, and acoustic indicators are mounted inside the helmet liner. All system components are contained in either the transmitter package on the rifle or the detector/receiver package on the helmet. There are no cables connecting these subsystems.

Figure 2 shows a closeup of the laser transmitter on the right and the helmet-mounted receiver on the left.

The laser transmitter contains four laser diodes arranged in a square matrix that, when pulsed, produce an overlapping beam pattern at the target. The diodes are pulsed individually according to a predetermined timing sequence. The timing code permits identification of the weapon being fired and the beams that illuminate the target.

The receiver detects and decodes the pulses to determine which portion of the pattern was received. The decoding electronics establish the identification of the shooter, whether a hit occurred, or the direction of a near-miss. Acoustic indicators notify the target that he has been hit and put out of action or that he has been near-missed and perhaps suppressed. When a hit is scored on a target player, he deactivates his weapon so that it can no longer fire, and he remains in place as a casualty.

The data gathered during these operations are tagged and stored in the receiver memory for posttrial readout.

Figure 1. Rifle-mounted laser transmitter and helmet-mounted detectors/receiver.

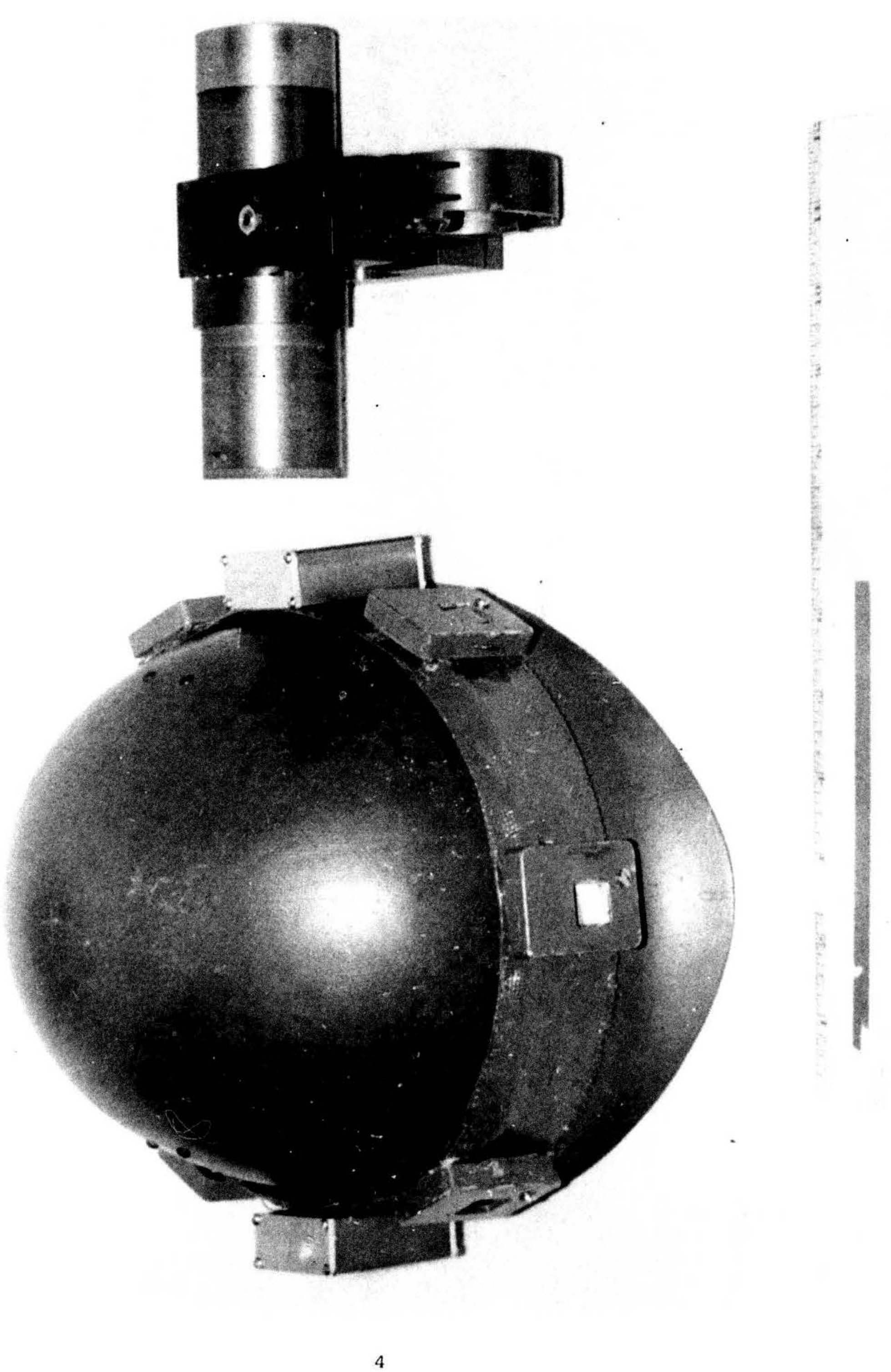

Figure 2. Laser transmitter and receiver.

Laser Transmitter

The rifle-mounted laser transmitter is shown in Figures 3 and 4. The transmitter is mounted above the carrying handle of the M-16 in such a position that balance, sighting, and handling characteristics of the weapon are not disturbed. No cable connections exist between the rifleman and his weapon.

Figure 5 shows a block diagram of the laser transmitter. The components include an acoustic transducer that is activated when a blank round is fired and thus initiates the laser firing sequence. (An internal trigger is also provided for test purposes.) The timing and control logic controls the firing sequence of the laser diodes. The power regulator provides low-voltage inputs to run the timing and control logic and high-voltage inputs to charge the trigger packs that pulse the diodes. The feedback link contains a light-emitting diode (LED) that provides round-count information back to the receiver memory through the detectors in the shooter's helmet. Figures 6 and 7 are mechanical cutaways of the transmitter housing showing the physical location of the various components.

Trigger Mechanisms

Acoustical Transducer. The laser transmitter is activated by an acoustical transducer that detects and discriminates the sound of the blast from other weapon-produced sounds. The transducer is mounted in a small insulated compartment in the transmitter clamp assembly (Figure 6). The transmitter itself is clamped to the weapon so that the transducer compartment is close to the gas port near the base of the carrying handle.

The transducer element is a small dynamic earphone consisting of a metal plate suspended on a diaphragm whose frequency response is in the audio range. When the weapon is discharged, the pressure wavefront emerging from the gas port vibrates the diaphragm, which in turn drives a pickup coil into a step-up transformer. The transformer's output is wired into a transistor discriminator that rejects all noises except that of the rifle blast. The output of the transformer is interfaced to the timing and control module by a single transistor. Appendix C contains additional information on the acoustical transducer.

Automatic Trigger. The transmitter package contains a selector switch (Figure 6) that allows the lasers to be internally pulsed. In this "test mode," the laser is automatically pulsed at approximately one shot per second. This internal trigger function allows (a) the lasers to be tested for reliability, and (b) the transmitter to be boresighted simply and without requiring that the rifle be fired. This feature saves ammunition and greatly facilitates boresighting.

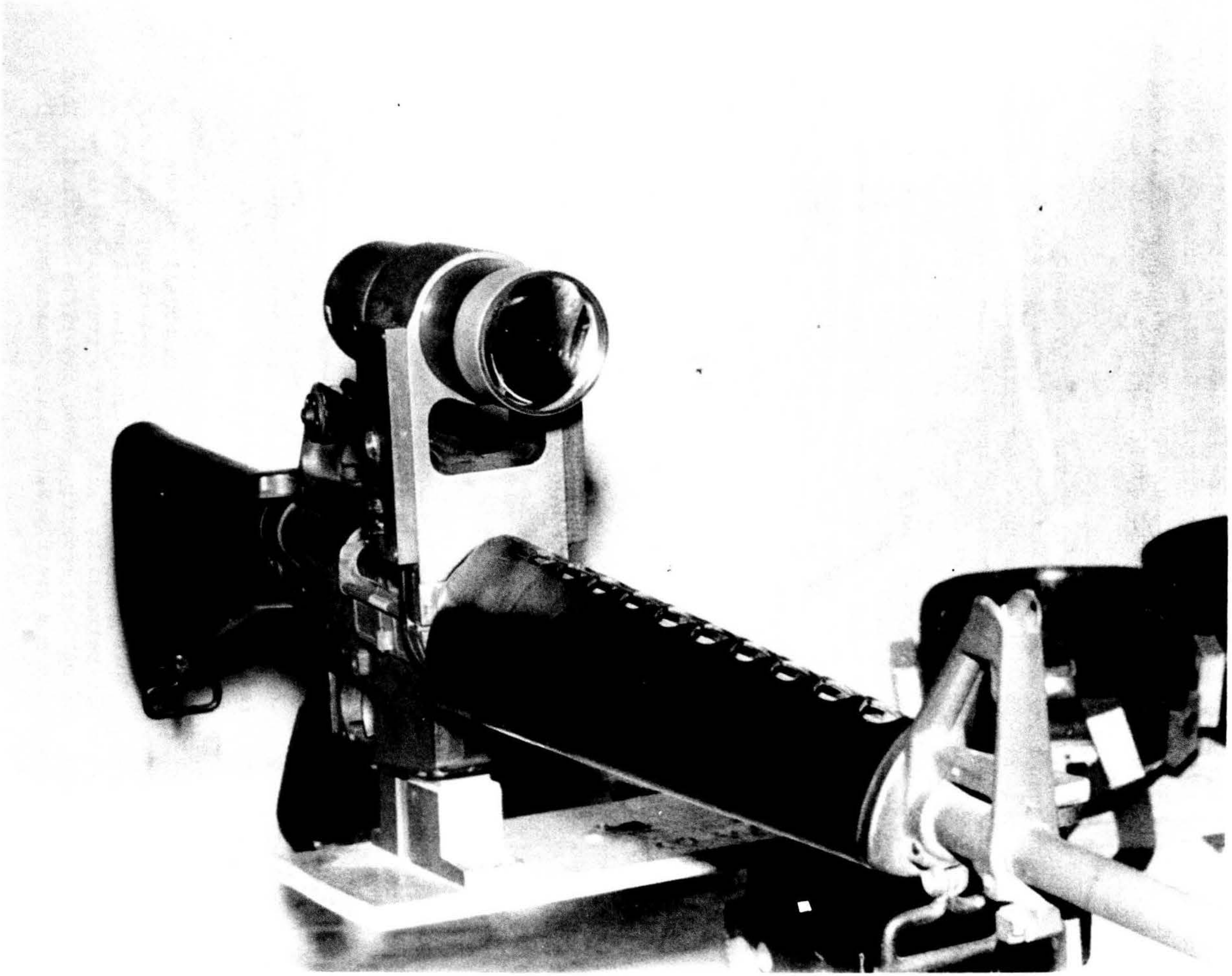

Figure 3. Rifle-mounted laser transmitter, three quarter front view.

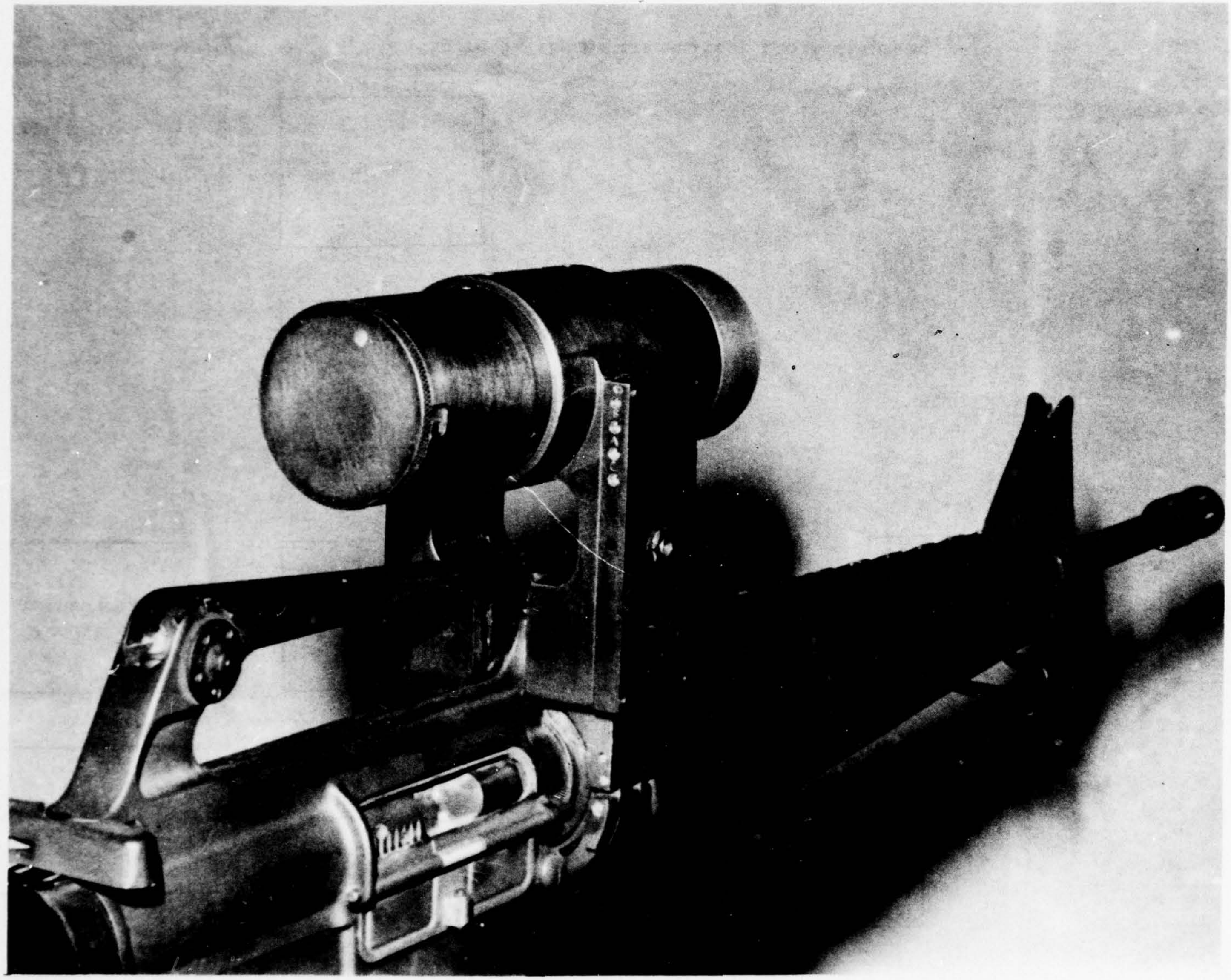

Figure 4. Rifle-mounted laser transmitter, three quarter rear view.

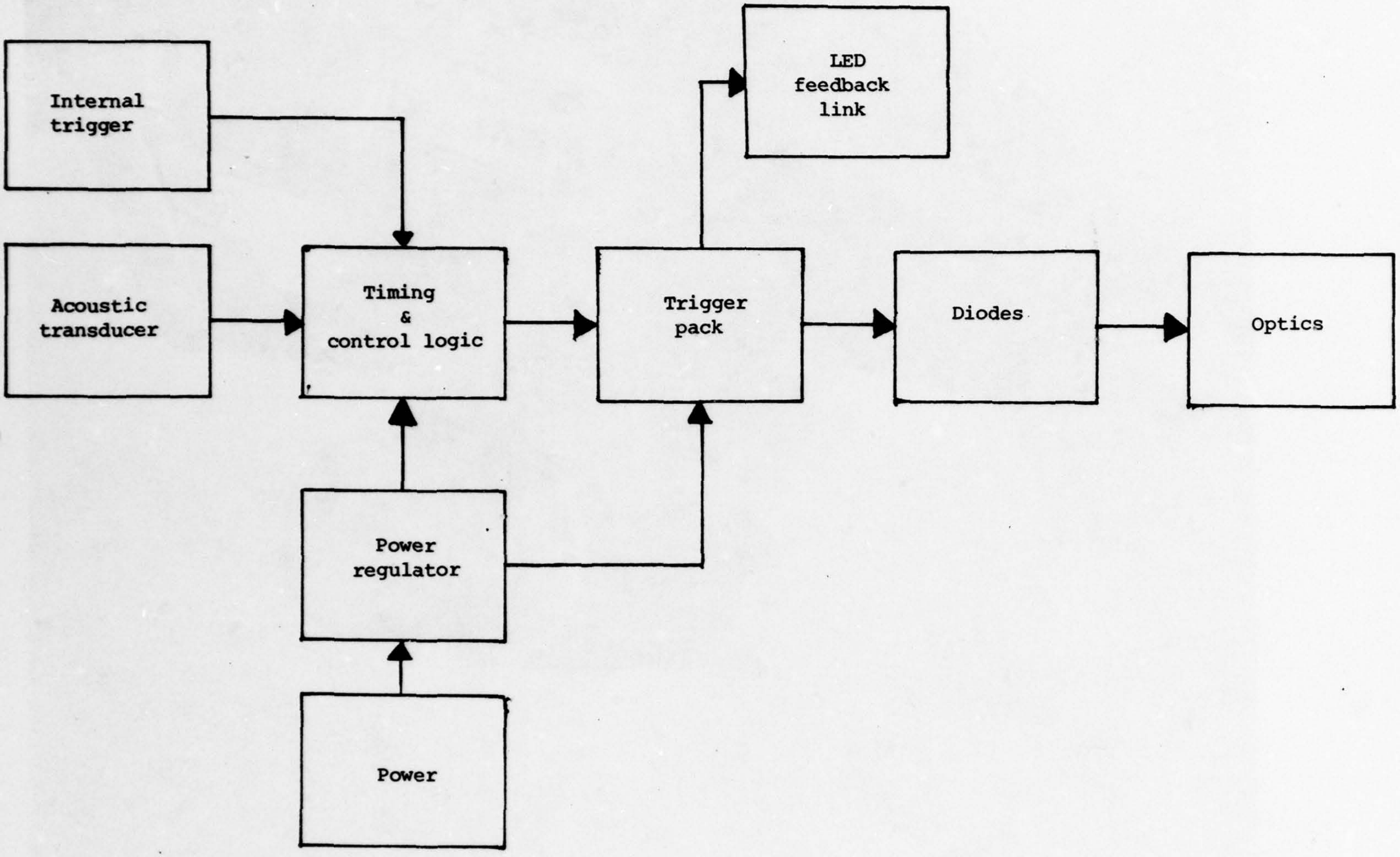

Figure 5. Laser transmitter block diagram.

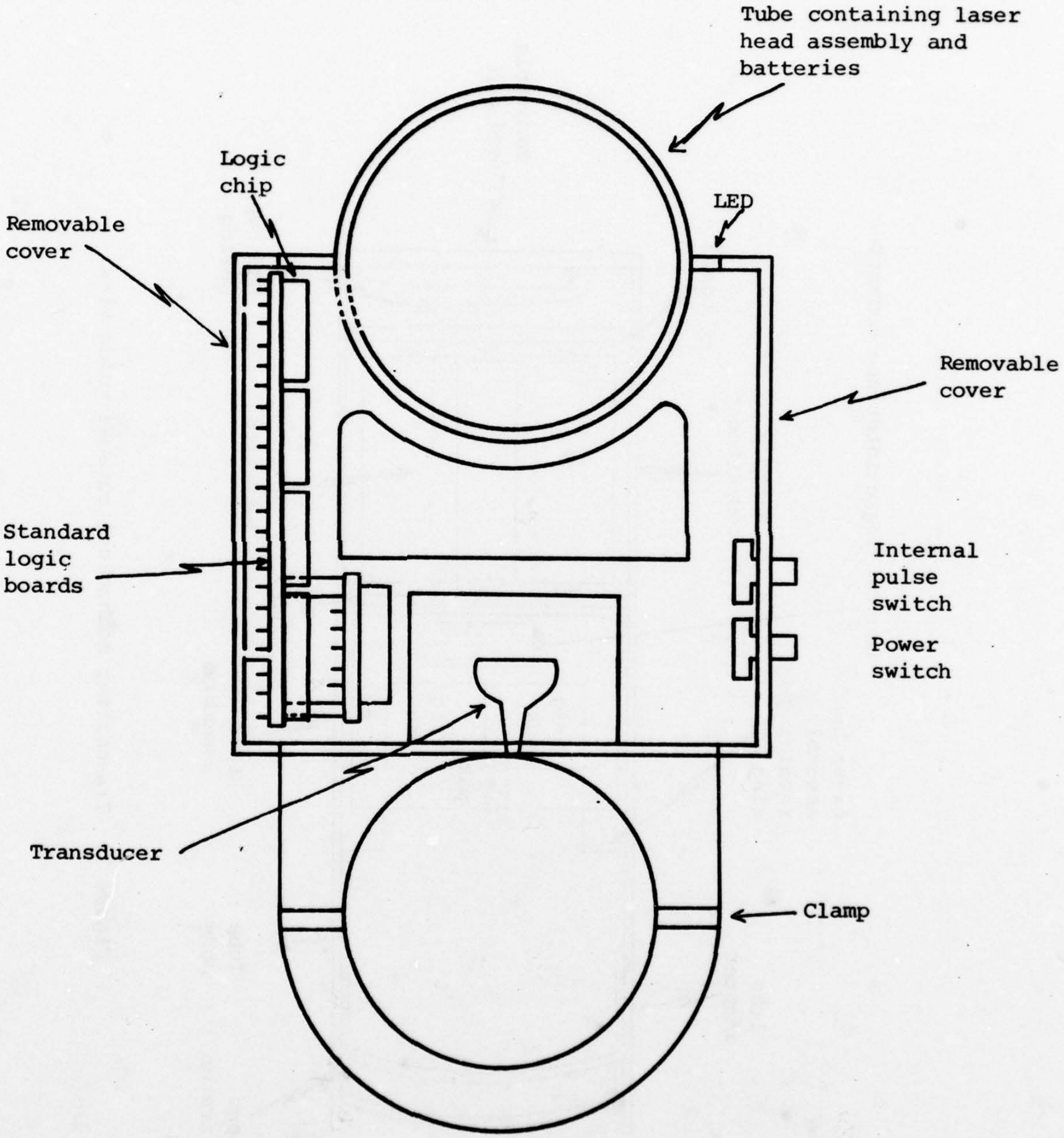

Figure 6. Transmitter mechanical cutaway--end view.

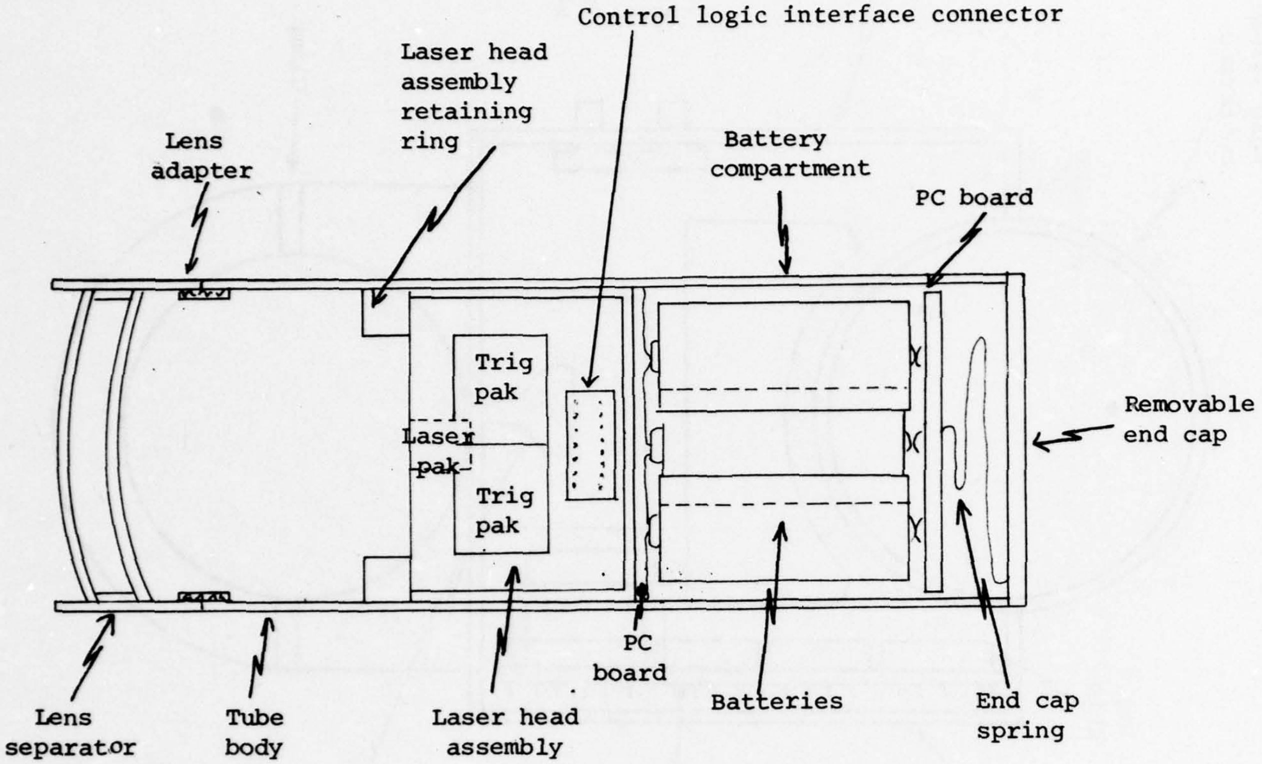

Figure 7. Transmitter mechanical cutaway--side view.

Timing and Control Logic

The timing and control logic that controls the diode firing sequence consists of a crystal clock, a counter, and the main controller. When a trigger pulse "signal" is received, the controller enables the master clock and the main counter. The counter is synchronized with the input trigger pulse and starts from a zero count. Thus the counter initiates the laser pulse train at a known time from the trigger pulse. Each laser beam is shot at a preset time during the firing cycle so that the laser receiver can differentiate and identify the beams. When the last beam pulse has been fired, the counter resets the main controller to its initial state and waits for the next firing signal (trigger pulse).

Figure 8 shows the timing diagram for one firing cycle. In a normal pulse sequence, all four laser diodes are simultaneously fired to give a synchronization (sync) pulse; the rest of the firing cycle follows automatically. This first pulse, if on target, establishes the initial shooter-target pairing and enables the receiver timing and control logic to decode the message contained in the remainder of the pulse train. Following the initial sync pulse, another four-laser pulse is fired, in 1 of 32 time-encoded slots, to identify the weapon firing. The four diodes are then fired individually in a specified sequence at specified delay intervals to provide the identification codes of the individual beams.

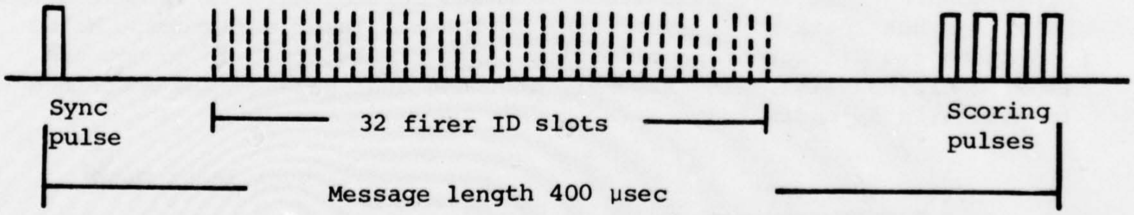

Figure 8. Timing diagram for one firing cycle.

When a target sensor is illuminated by these laser beams, the receiver electronics decodes the pulse sequence to determine from which weapon the laser beams originated, as well as the actual individual beams by which the target sensor is being illuminated. Thus, the receiver has all the information necessary to determine beam pattern, which is the basis for scoring hits and near-misses. Appendix D shows the logic flow chart for the laser transmitter.

The total message length from sync pulse to the last beam-pattern pulse is approximately 400 microseconds (μsec). The majority of this time is used in the timeslotting for the identification pulse. An individual laser pulse actually takes 100 nanoseconds. Once a firing sequence has started, the electronic controller rejects any new triggering pulses until half the cyclic time of the firing cycle has elapsed. This procedure ensures that only one laser message is fired for each rifle shot fired.

To ensure high reliability and minimum power consumption, crystal clocks are used for all timing requirements, and complementary metal oxide semiconductor (CMOS) logic is used in all digital and memory sections.

Laser Diodes and Trigger Packs

The heart of the laser transmitter is a laser diode module containing four laser diodes. The quad laser sources are fabricated as two separate packages with two laser diodes in each package. Each dual pack is a thin rectangular metal package with two laser diodes mounted at one end. A square glass fiber optic is attached to the face of each diode to provide optical coupling from the lasers to the source exit aperture at the opposite end. The optic tubes are secured flush to one surface of the metal package. Thus, when two dual packs are placed face to face, the four radiating ends of the optic tubes are juxtaposed to form a square array (Figure 9). Fiber coupling the laser diodes to a common radiating plane ensures that the laser light is mixed sufficiently to eliminate the holes and hot spots normally present in the raw laser emissions. Holes and spots are a frequent problem with laser simulators that do not use fiber optic coupling. The assembly of these dual packages is described in detail in Appendix E.

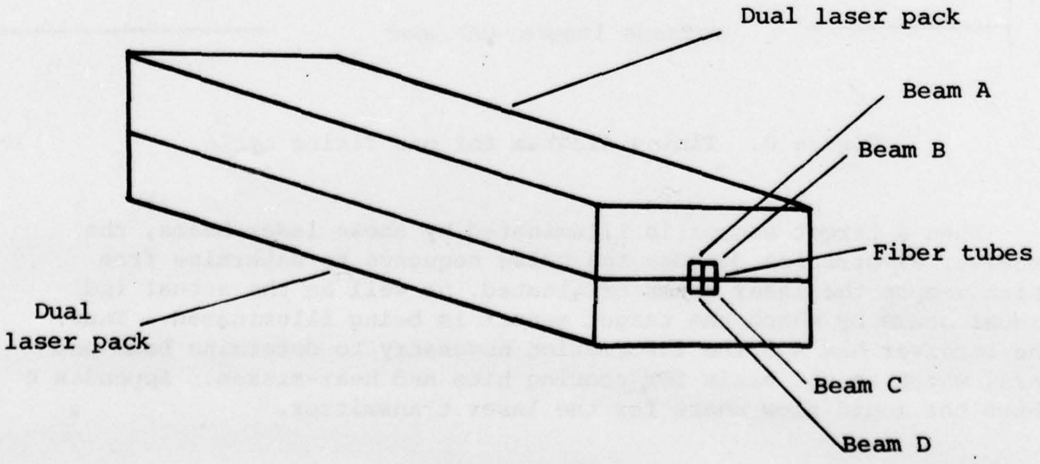

Figure 9. Fiber optic tube configuration.

The laser diodes themselves are single, heterojunction GaAs injection diodes manufactured by Laser Diode Laboratories, Inc.[1] The light emitted by each diode has a peak power of approximately 7 watts and a peak spectral irradiance in the infrared (IR) region at 904 nanometers. Detailed specifications of the diodes are given in Appendix E.

Each laser diode is interfaced directly to a drive circuit consisting of a quad trigger pack. This arrangement allows each diode to be pulsed a maximum of four times without the need to recharge the circuit. Therefore, the pulse train in a complete firing cycle is accomplished without a recharge of the drive circuits after each pulse. Figure 10 shows the schematic diagram for one quad trigger pack.

Collimating Lens

After the output of the diodes is brought to a common radiating plane by fiber optics, a collecting and collimating lens is used to project the beam pattern from the source plane. The laser light is collected and collimated by a 2-inch compound lens (focal length of 2 inches). The lens is defocused to provide the four-beam overlap area shown in Figure 11. The square shape is achieved because the light is emitted through the square fiber optics. The overlap area has a cross shape; the center of the cross contains all four laser beams and the arms of the cross contain combinations of two laser beams. Appendix F contains a more detailed discussion of the lens optics.

Beam Geometry

Each laser shot is scored as either a hit, a near-miss (suppression), or a miss, independent of computer control. This scoring requires that the beam pattern have certain properties to provide for the accurate and realistic scoring of hits and near-misses. Figure 11 shows the configuration of the beam pattern projected downrange. The letters in each segment of the pattern show the individual beams and the beam overlap. The overlap of the four beams (A, B, C, D) illuminates an area approximately 2 feet square; this is considered the hit zone. The hit zone is surrounded by a larger area, approximately 10 feet square, that is considered the near-miss zone. The scoring electronics in the helmet receiver can decode this beam pattern (i.e., determine which beams are illuminating the target) and thus determine whether a hit or near-miss occurred and the direction of the near-miss. (The "Laser Receiver" section discusses the scoring logic in more detail.)

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[1] Commercial names are used only in the interest of precision in reporting. Their use does not constitute endorsement by the Army Research Institute or the Army.

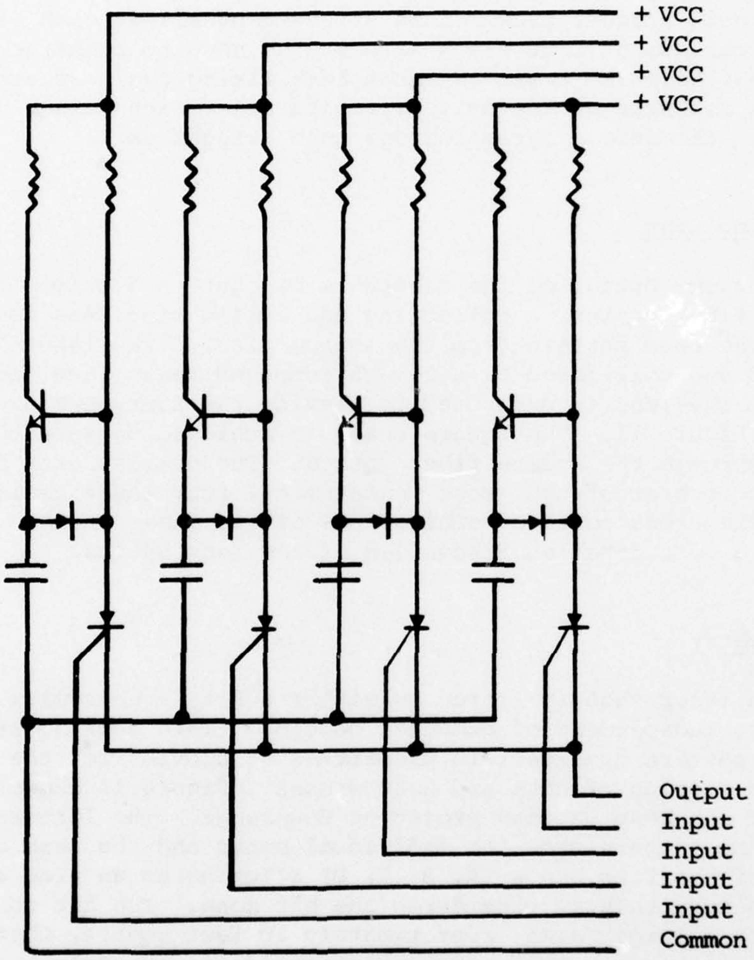


Figure 10. Quad trigger pack schematic.

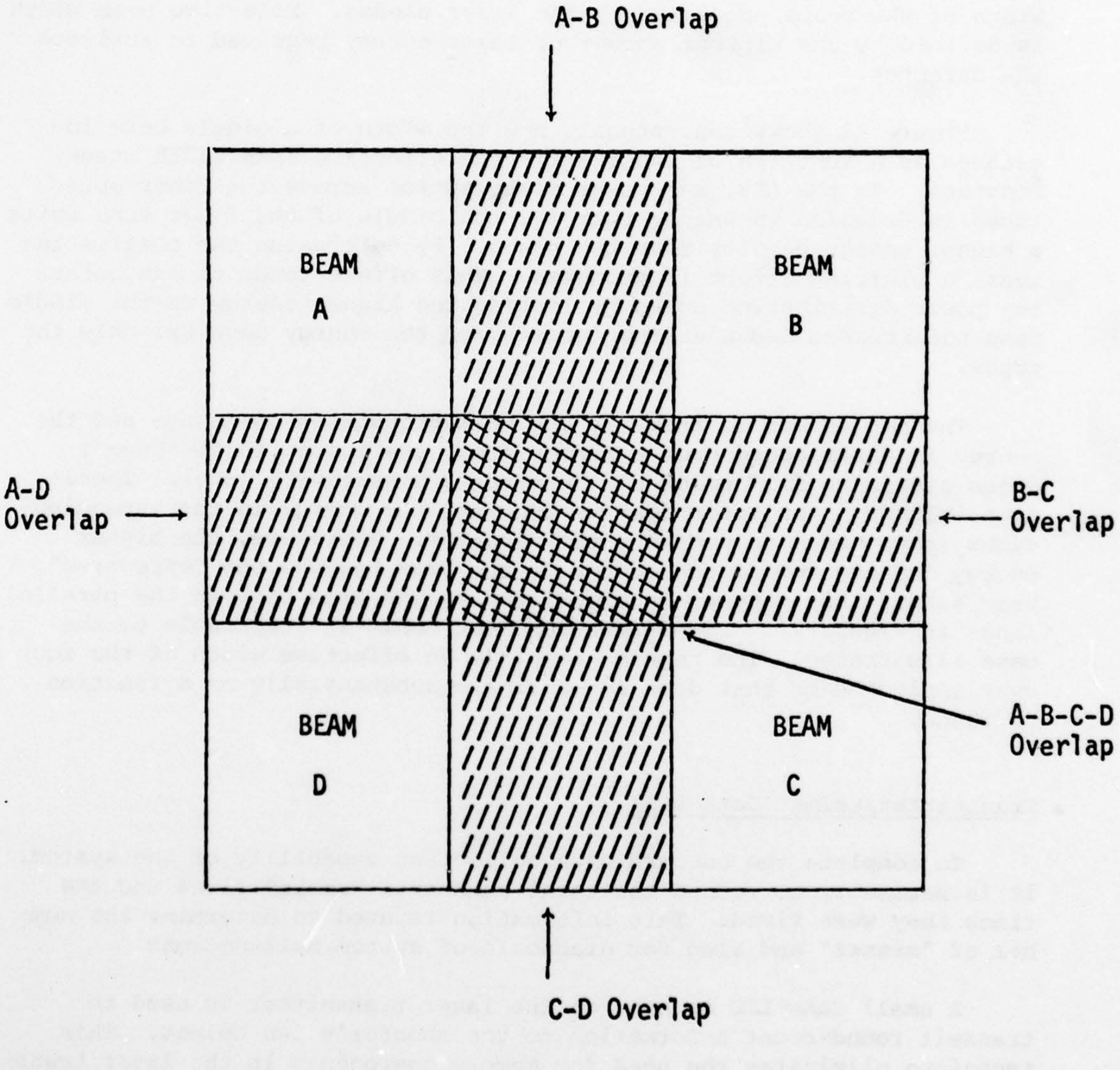


Figure 11. Overlapping beam-pattern configuration.

Laser emissions are IR light beams that increase in size as a function of the distance from the source. Therefore, for a laser to maintain some fidelity with live fire, the size of the beam must be controlled so that it does not increase appreciably as a function of increasing range. This control is achieved by manipulating the effective width of the beams projected by the laser diodes. Effective beam width is defined by the minimum amount of laser energy required to activate the detector.

Figure 12 shows conceptually how the width of a single beam increases as a function of range while the effective beam width stays constant. In the LES, the power distribution across the fiber optic tubes is Gaussian in shape; that is, the middle of the fiber tube emits a higher energy density than the edges. By defocusing the collimating lens, a blurring effect is produced. This effect tends to exaggerate the power distribution curve by letting the higher energy in the middle pass undisturbed and blurring (decreasing the energy density) only the edges.

The net effect is that, as the beam propagates downrange and the energy is distributed over a larger area, the energy in the beam's edges starts to fall below the detector's sensitivity level. Therefore, although the laser beam is growing, the energy in the expanding edges is too weak to activate the detector. Therefore, the higher energy density toward the center of the beam becomes the "effective" beam size. This pattern is symbolized by the area between the parallel lines in Figure 12. The effect for four beams is comparable to the case illustrated. The result, then, is an effective width of the four overlapping beams that does not increase substantially as a function of range.

Transmitter/Helmet Data Link

To complete the onboard data collection capability of the system, it is necessary to record the total number of "shots" fired and the times they were fired. This information is used to determine the number of "misses" and also for diagnosis of system malfunctions.

A small GaAs LED mounted on the laser transmitter is used to transmit round-count information to the shooter's own helmet. This technique eliminates the need for memory components in the laser transmitter unit and avoids the use of a cable connecting the rifle and the man.

The LED is positioned so that it faces back toward the helmet. When the laser transmitter is activated, the sync and address pulses activate the LED. The light pulse from the LED is detected by a sensor mounted on the helmet. When the receiver detects its own identification code, this information is stored in memory as the round count. Because

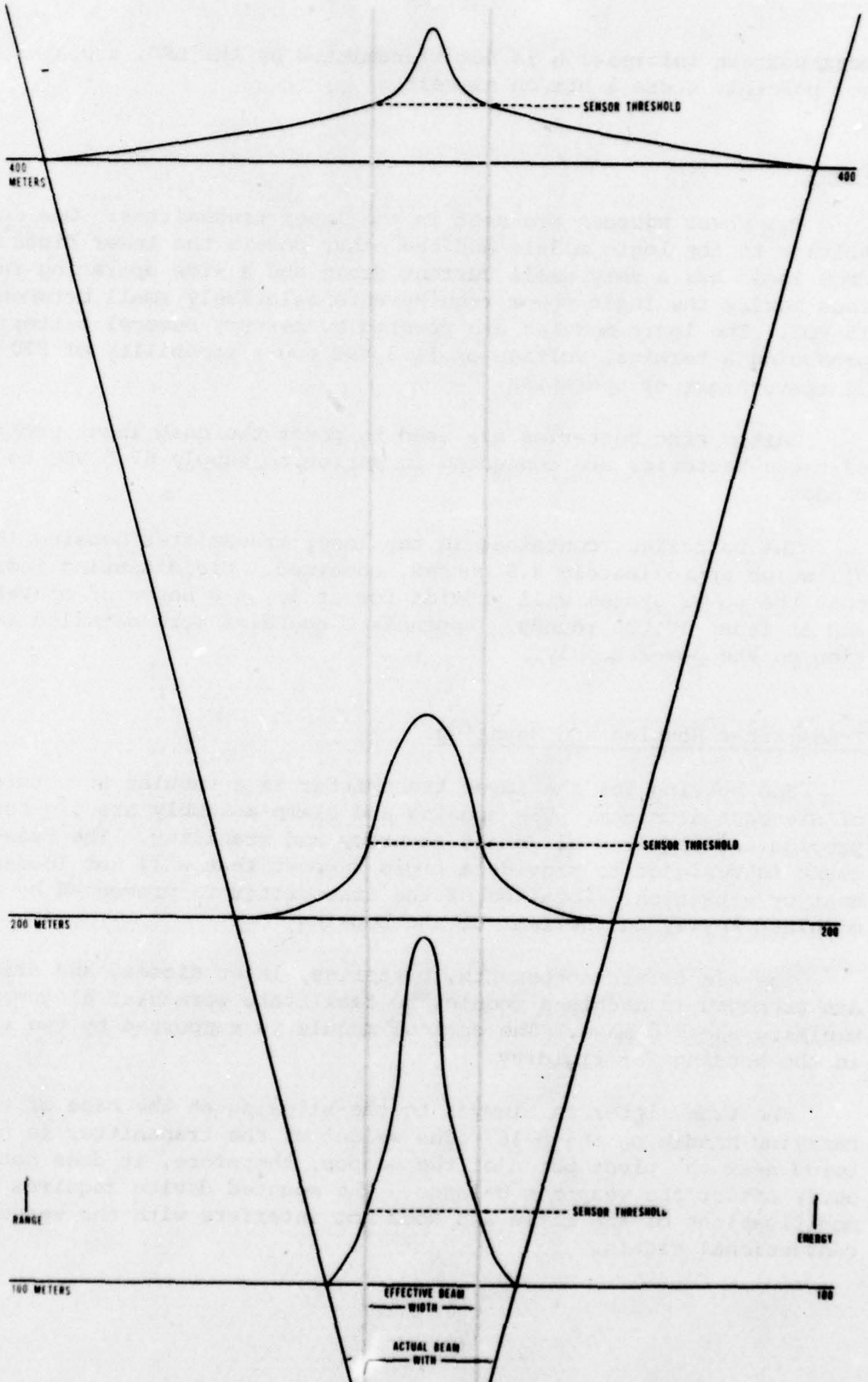


Figure 12. Range invariant beam-size concept.

beam-pattern information is not transmitted by the LED, a player cannot possibly score a hit on himself.

Power

Two power sources are used in the laser transmitter: One supplies voltage to the logic module and the other powers the laser diodes. The CMOS logic has a very small current drain and a wide operating range, thus making the logic power requirements relatively small between 9 to 15 VDC. The logic modules are powered by mercury Duracel batteries producing a terminal voltage of 11.2 VDC and a capability of 250 milliampere-hours of operation.

Carbon zinc batteries are used to power the quad laser pack; three of these batteries are connected in series to supply 67.5 VDC to the diodes.

The batteries, contained in the laser transmitter housing (Figure 7), weigh approximately 3.5 ounces, combined. Field testing indicates that the power system will provide for at least 8 hours of operation and at least 30,000 rounds. Appendix G contains more detailed information on the power supply.

Transmitter Housing and Mounting

The housing for the laser transmitter is a tubular structure made of die-cast aluminum. The housing and clamp assembly are jig-bored to provide the required alignment accuracy and stability. The transmitter mount is designed to provide a rigid support that will not loosen with heat or vibration. Rotation of the transmitter is prevented by the machined keyway in the rear of the housing.

The electronic components, batteries, laser diodes, and drivers are packaged in machined modules to facilitate permanent alignment and minimize shock damage. The optical module is supported by two rings in the housing for rigidity.

The transmitter is clamped to the slipring at the base of the carrying handle on the M-16. The weight of the transmitter is centered near the pivot point of the weapon; therefore, it does not seriously affect the weapon's balance. The mounted device requires no modifications of the rifle and does not interfere with the weapon's conventional sights.

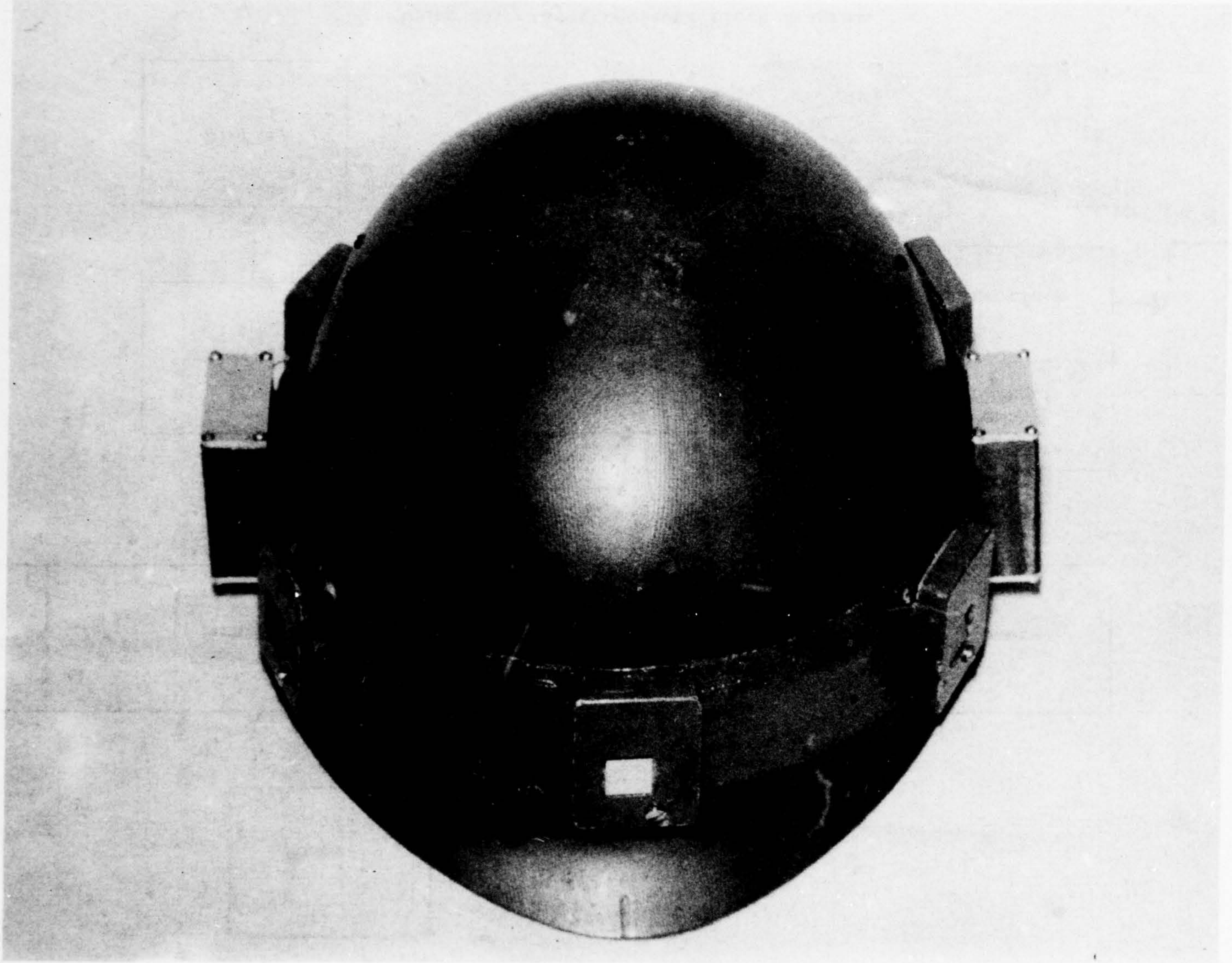


Figure 13. Helmet-mounted sensor/receiver subsystem.

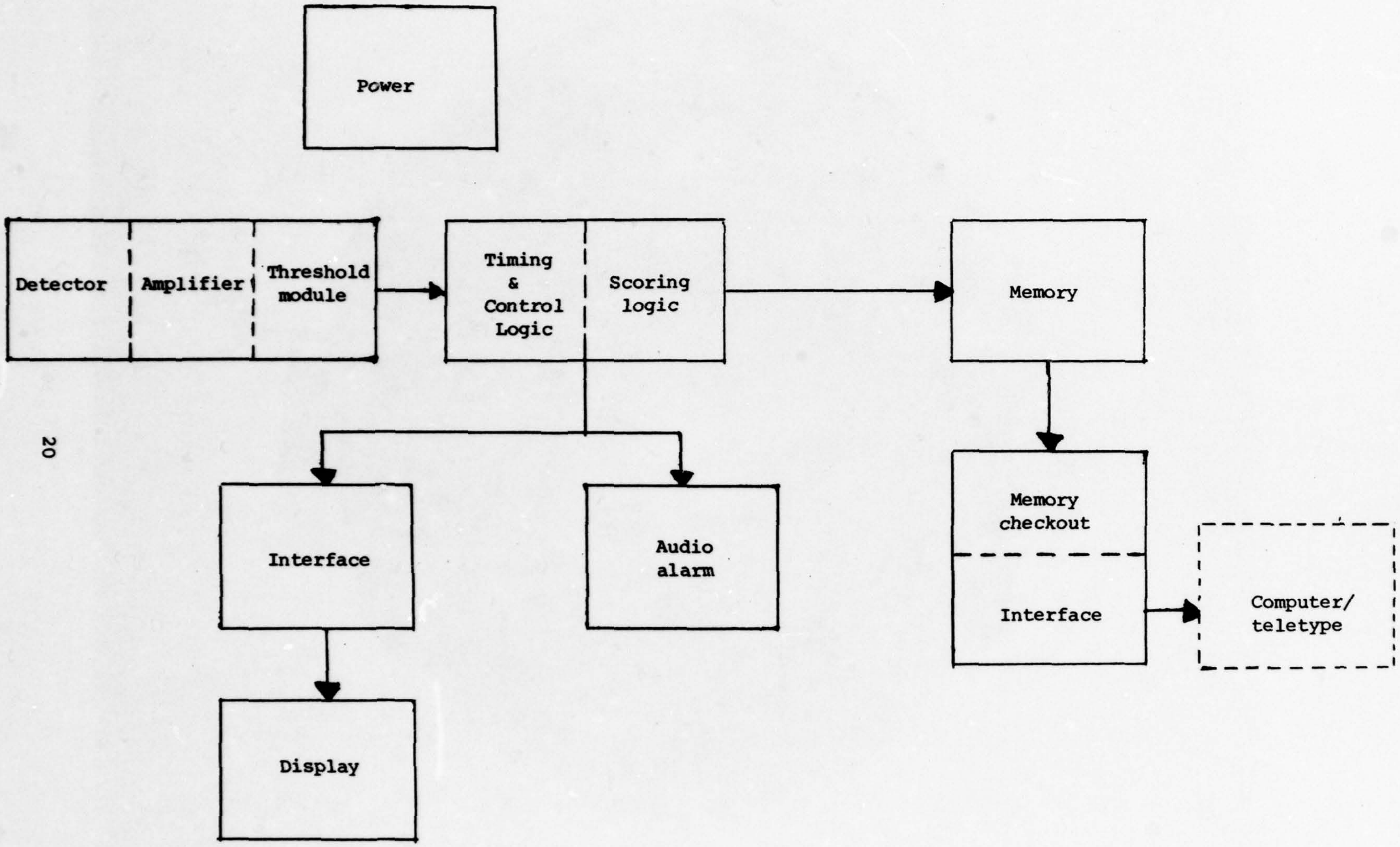


Figure 14. Laser receiver block diagram.

Laser Receiver

The helmet-mounted laser receiver is shown in Figure 13. Sensors and electronics are mounted on or in the helmet so as to equalize weight distribution and eliminate exposed parts or cabling. The helmet receiver package consists of the following:

1. Six detectors are mounted on a band around the circumference of the helmet liner. The wiring is contained in the band and, together, the detectors provide for 360° coverage.

2. The control, scoring, and memory electronics are mounted on a logic board that fits snugly inside the helmet between the webbing and the top of the helmet.

3. Small audio hit indicators are mounted inside the helmet above the right and left ears.

4. The batteries for the power supply are housed in two metal containers on either side of the helmet.

The receiver block diagram is shown in Figure 14. The timing and control logic remains in an idle state until activated by a laser sync pulse. When the detector receives a sync pulse, the threshold module activates the timing and control logic. The timing and control logic in turn enables the scoring logic and, together, they decode the laser message and store the data in memory. In normal operational use, the appropriate audio alarm in the helmet is activated when a hit or a near-miss is scored. If real-time visual display of hits and near-misses is desired, such as in a test situation, external control lines can be connected to the scoring logic for this purpose.

When the total message has been received and stored, the timing and control logic resets itself to the idle state. External control lines are present in the memory section for dumping memory (into a computer or teletype) and for checking the memory circuits for proper operation. The external lines also control the output shift register. This register reads the memory and shifts 32 bits of information to the interface device.

Detector

Figure 15 shows a closeup of a laser detector mounted on the helmet band. The detector/amplifier/threshold housing is made of die-cast aluminum and anodized green. An interference filter attached to the front of the detector/amplifier case limits the wavelength of the ambient light incident on the detector.

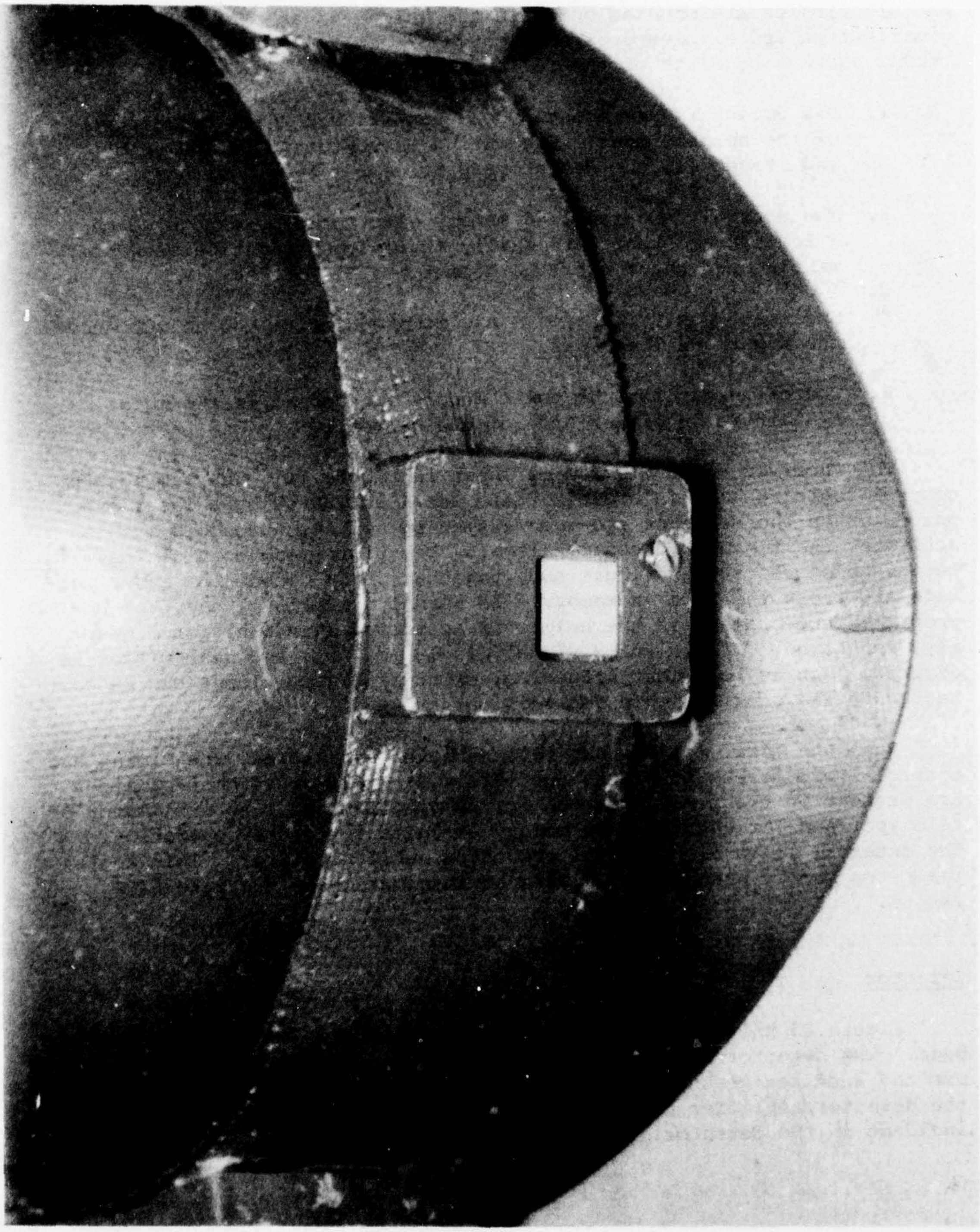


Figure 15. Closeup of laser detector.

Each detector is a silicon photodiode with a field of view of 60°; six detectors are located at equal intervals around the helmet band. Combined, the detectors provide for 360° coverage of the target. The sensitive surface of the detector is 1 square centimeter and the peak sensitivity is at 905 nanometers. Appendix H discusses in detail the signal-to-noise ratio analysis for the filter and detector.

Timing and Control Logic

The timing and control logic contains a crystal clock, divide-down counters, and windowing circuitry for receiving the beams and controlling the memory. The logic circuit is interfaced to the laser detector through a variable-threshold amplifier. The output of the threshold amplifier is tied to the master start portion of the logic circuitry.

When a laser sync pulse is received, the master start enables the windowing circuitry to begin looking for the identification pulse. The windowing circuitry scans all 32 identification timeslots and generates a valid message signal if one and only one identification pulse is received. If no identification pulse is received, the logic interprets the original sync pulse as having been noise. If two or more identification pulses are received, neither one is accepted, because (a) there is either too much noise being externally generated or (b) two conflicting messages are being received.

In any case, if a valid identification pulse is not received, the control logic resets the detector to the idle state and awaits a new sync pulse. If a valid identification pulse is received in one of the 32 timeslots, the identification pulse is latched into a holding register and the beam-pattern decoding circuits are activated.

The beam-pattern pulses that are received are also latched into a holding register. The identification and beam-pattern information is held in the registers until the scoring logic has been activated. The scoring logic decodes the beam pattern in terms of hit and near-miss scores and deposits the score in a memory location along with the identification of the shooter and the time.

The time information comes from a free-running counter that operates off of the crystal clock. The real-time clock can be reset by external control lines. Appendix I shows the logic flow chart for the laser receiver.

Scoring Logic

The scoring logic is activated when a complete laser message has been received and placed into the holding registers. As mentioned earlier, the score is determined by the beams that are detected. If all four beams are detected, the logic scores a hit and activates the audio alarm. If only two beams are received, the scoring logic registers a near-miss and activates the appropriate near-miss alarm.

Table 1

Scoring Logic for Beam Pattern

Beams	Near-miss direction	Hit
A	Low to the right	
A + B	Low	
B	Low to the left	
B + C	Left	
C	High to the left	
C + D	High	
D	High to the right	
A + D	Right	
A + B + C + D		Kill
(A + B + D)		Kill
(A + B + C)		Kill
(B + C + D)		Kill
(A + C + D)		Kill

Refer to Figure 11 and Table 1 to see how various portions of the beam pattern are scored. For reference purposes, the beams from the four laser diodes are designated A, B, C, and D. The letters in each segment of the pattern (Figure 11) show the beams and the beam overlap. Inspection of Table 1 shows that hits as well as near-miss and direction of near-miss can be determined by the beam overlap. Overlap of all four beams is defined as a target hit, and a target hit can occur only if the center square is illuminated. Logically, however, any combination of three beams is also scored as a hit because these combinations cannot occur unless the "bullet" is on the center of the target. The absence of a complete beam pattern in these cases can result only from the loss of one or more beams because of scintillation, partial target obscuration, etc.

As the table shows, direction of a near-miss can be determined easily. For example, if the target is illuminated by beam A alone, the miss is low and to the right. This conclusion may be somewhat confusing because, in the pattern shown in Figure 11, the area illuminated by beam A alone is above and to the left of the hit zone. However, if the target is illuminated in area A only, the bullet is low and to the right of the target, from the point of view of the shooter.

After the beam pattern has been scored, the holding register containing time, identification, and beam-pattern information is strobed into memory to await output through the memory interface into the computer or teletype.

Memory

The target-carried memory provides the capability for recording data whenever an on-line computer interface is not feasible or not desired. The LES memory consists of off-the-shelf large-scale integration (LSI) circuits. These LSI chips were developed for microprocessor use where considerations of high-density storage, reliability, low power, and portability were paramount; a common application is in pocket and desk calculators. In the LES, they are used to provide programmable memory space for recording time-tagged identification and event data. They permit immediate postexperiment data readout by direct interface into a teletypewriter or Teletype lines leading into a computer.

The helmet-mounted memory contains 25,600 bits and can record 1,024 time-tagged messages. The time bits can cover an 8-hour run at 1-second resolution. The memory is wired into shift registers that format the data output into standard ASCII code. This code makes dumping the data easy and makes the data compatible with many devices such as Teletype, Teletype paper punch, telephone modems, ASCII floppy disks, and other computer interfaces. Appendix J discusses the memory interface in detail.

Real-time Display Device

The receiver contains a connector for external control lines that interface with a real-time information display. The receiver is used for laser zeroing and test purposes to provide the firer with immediate feedback of information on hits and directions of near-misses. A visual display panel contains lights that correspond to the beam pattern illuminating the target. In addition, the display contains a sonalert that generates an audible tone appropriate to a hit, near-miss, or miss. Appendix K discusses the LES display device in more detail.

Audio Hit Indicator

A player who has been illuminated by one or more laser pulses is immediately informed whether he/she has been hit or near-missed. Two audio alarms, one mounted on each side of the helmet, provide this information. Each alarm emits a single tone, and the scoring logic gates the appropriate alarm on to indicate a hit or near-miss.

The left alarm is keyed on for 1 second to indicate a near-miss to the left. The right alarm is keyed on for 1 second to indicate a near-miss to the right. Both alarms are keyed on for 1 second to indicate a high or low near-miss. When a hit is recorded, both alarms are keyed on and remain on until they are manually reset by the player.

Receiver Power

Two power sources are required for the receiver--one for the logic and detector amplifier supply, and the other for the detector bias supply. Mallory mercury batteries (TR 115) are used for both purposes. Four batteries are wired in series to supply approximately 28 volts to the detector bias supply. Four other batteries are wired in parallel to supply approximately 7 volts at 50 milliamperes to the logic and detector amplifiers. Further details of the receiver power supply are given in Appendix G.

Receiver Packaging and Mounting

Figure 16 shows how the receiver electronics, detectors, and power supply are mounted in the helmet liner and on the helmet band. The helmet band is made of Fiberglas formed to fit down over the helmet and seat on the base. The detectors are individually housed and placed at equal intervals on the band. The two battery supplies are also individually housed on opposite sides of the band. With the helmet liner on, the batteries are located near the player's ears.

The audio hit indicators are mounted on the inside surface of the helmet, one next to each earphone. The logic board, containing the memory chips and the control and scoring logic, is mounted in the dome on the inside of the helmet (see Figure 17). The logic board is secured in place by a metal plate, and connections to the board are made through a hole in the plate. The receiver components add approximately 2 pounds to the weight of the helmet liner, which is about equal to the weight of the regular steel "pot."

Computer

The prototype LES operating in a stand-alone mode can collect and record 1,024 time-tagged messages. These data, stored in the player-carried memory module, can be read out to either a standard ASCII Teletype or a small, multipurpose computer such as the DEC PDP-8/E. The memory electronics and memory interface module can be programed to buffer and to encode the data so that the data will be compatible with most small computer systems.

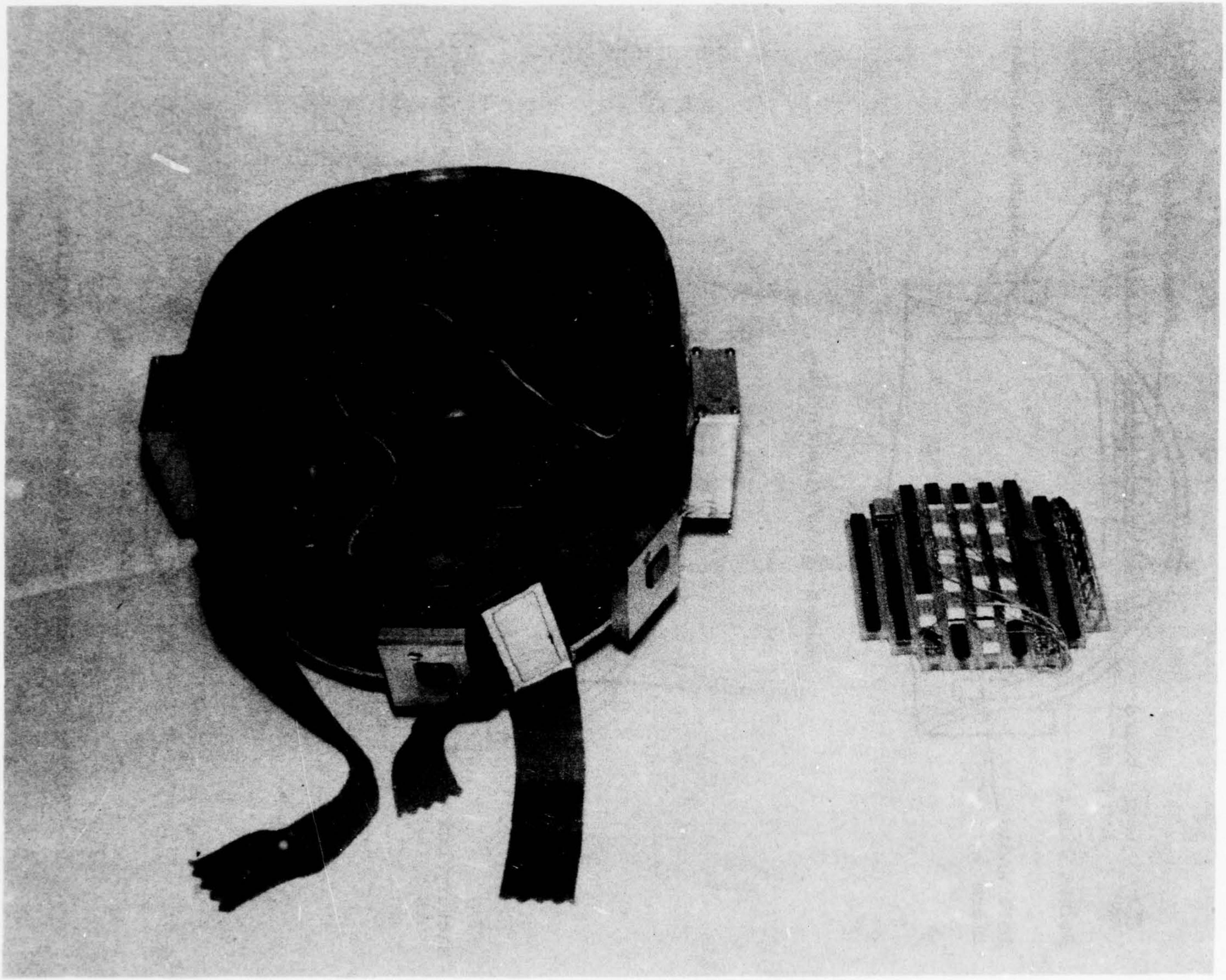
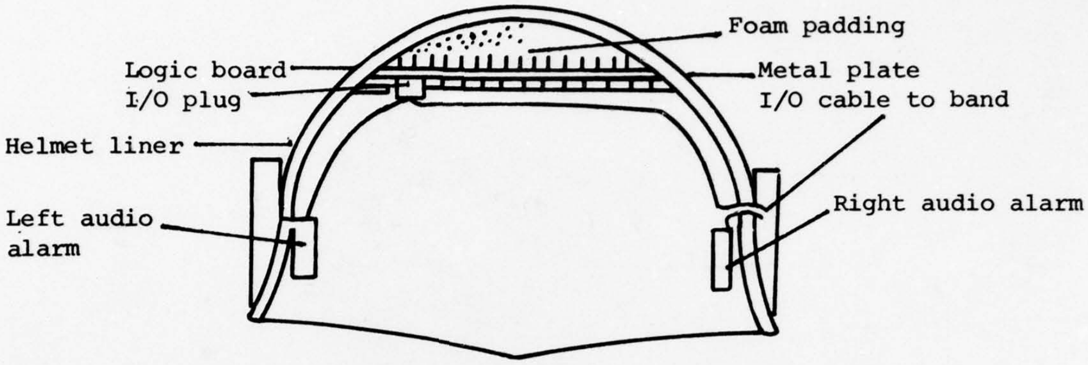
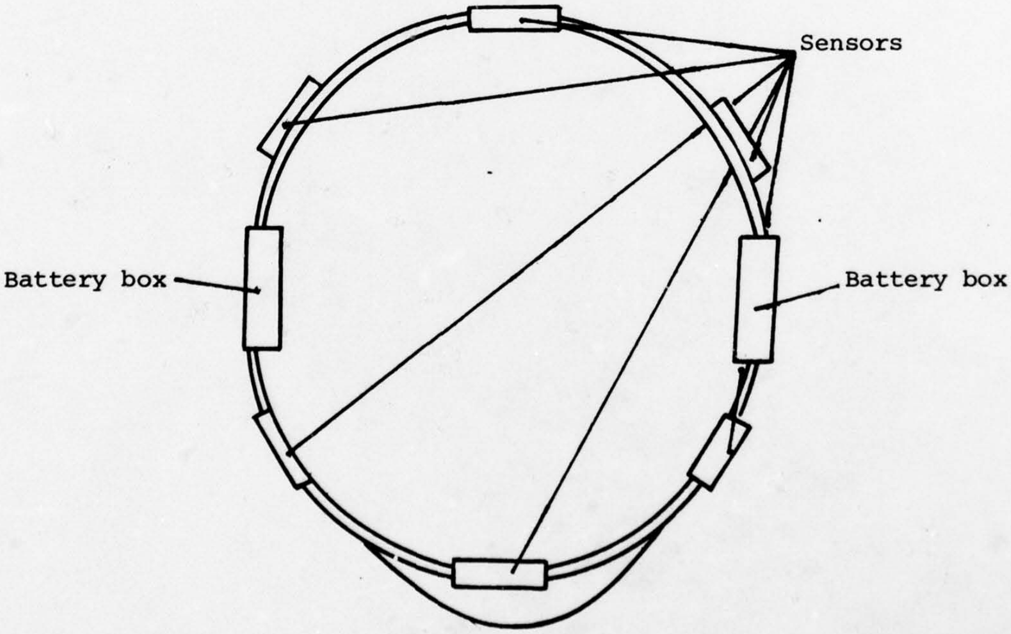


Figure 16. Receiver electronics.



Helmet front view cutaway



Helmet top view

Figure 17. Receiver electronics configuration.

With this capability, a multigun system could be developed to collect and record real-time casualty assessment data, including target/shooter identification, during two-sided, simulated combat exercises. After an exercise, the data from all the memory modules could be read into an onsite computer system for data reduction and analysis, or the data could be recorded on magnetic or paper tape for later reduction and analysis.

APPENDIX A

LES SPECIFICATIONS

Performance Characteristics

Firing modes	Semiautomatic, fully automatic
Firing rate	Exceeds cyclic rate of fire of all automatic weapons
Trigger mechanism	Acoustical transducer actuated by blank round triggers laser
Maximum effective range	350 meters
Onboard memory	25,000 bits of memory; total of 1,024 messages
Player identification	32 identification slots

Electronic and Optical Parameters

Laser source	GaAs laser diode
Peak power output	7 watts
Peak emission wavelength	905 nanometers
Peak forward current	30 amperes
Pulse width	100 nanoseconds
Message repetition frequency	12.5 hertz
Beam divergence	5 milliradians
Output format	Time-modulated pulse code
Detector type	PIN photodiode
Detector field of view	60° inclusive
Solar background rejection	Operates in full sunlight

Physical Parameters

Transmitter	
Length	6.5 inches
Diameter	2 inches
Weight	2 pounds
Detector-helmet band assembly	
Diameter	9 inches
Weight	1 pound
Helmet, logic, memory assembly	
Fits inside helmet	
Weight	1 pound

APPENDIX B

LASER SAFETY

The use of any laser device presents the possibility that personnel may be exposed to potentially hazardous radiation from these devices. The radiation hazard is in the form of ocular damage that can occur from staring into the laser transmitter. Laser energy entering the eye can be focused by the lens to an extremely high energy density. The resultant temperature can be great enough to cause a permanent burn spot on the retina which can lead to partial or total blindness.

The following information on the eye safety of the LES system is based on engineering estimates. The LES will be submitted to the U.S. Army Environmental Hygiene Agency for a formal radiation protection study to determine if the system meets the eye safety standards set by the Surgeon General (given in Army Regulation AR 40-46, "Control of Health Hazards from Lasers and Other High Intensity Optical Sources") and the Environmental Hygiene Agency (given in Army Technical Bulletin TB MED 279, "Control of Hazards to Health from Laser Radiation," May 30, 1975).

The emitted laser beam is divergent outside the exit aperture; therefore, the greatest radiant exposure occurs at the exit aperture. The calculations that follow will assume this worst-case eye position (at the exit aperture) and long-term focusing directly into the laser device.

The calculations, nomenclature, and symbols will follow the Department of the Army TB MED 279. The maximum firing rate for the LES is 750 rounds per minute or 12.5 rounds per second. A 20-shot burst in 1.6 seconds is the maximum continuous firing interval, assuming a standard M-16 magazine. There are six laser pulses emitted for each round expended (see Figure B-1).

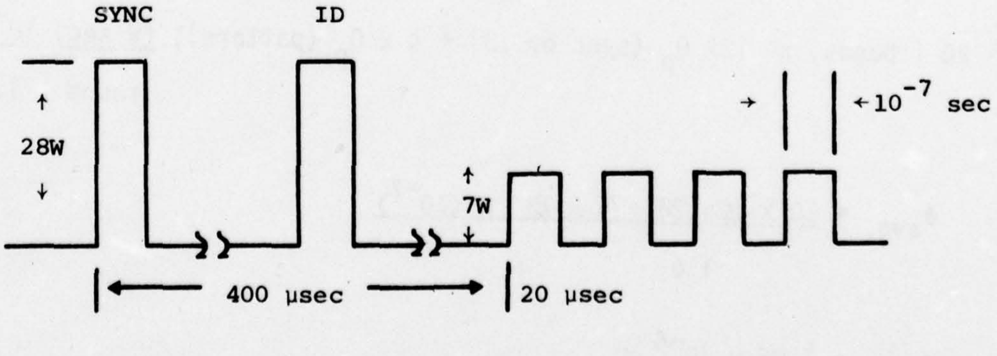


Figure B-1. Single-round pulse output diagram.

The first two pulses are a synchronization (sync) and an identification (ID) pulse consisting of the simultaneous firing of all four diodes and having 28 watts of power each. The last four pulses are the pattern pulses of 7 watts each. All pulses are 10^{-7} seconds in width (Tp). The maximum power available from each diode is 7 watts, but the LES is operated at a lower operating point and the measured diode output is 5 watts. However, for safety calculations the 7-watt value is used.

The radiant energy, Qp, in the sync and ID pulse is

$$Q_p = \Phi_p \times T_p \quad \text{where} \quad \Phi_p = 28 \text{ Watts}$$

$$\text{and} \quad T_p = 10^{-7} \text{ sec.}$$

$$Q_p = 28\text{W} \times 10^{-7} \text{ Sec}$$

$$= 28 \times 10^{-7} \text{ J.}$$

The radiant energy in a pattern pulse is

$$Q_p \text{ (pattern)} = \Phi_p \times T_p \quad \text{where} \quad \Phi_p = 7 \text{ Watts}$$

$$T_p = 10^{-7} \text{ sec.}$$

$$Q_p \text{ (pattern)} = 7\text{W} \times 10^{-7} \text{ sec}$$

$$= 7 \times 10^{-7} \text{ J.}$$

The time-averaged radiant power over the 20-round burst is

$$\Phi_{\text{avg.}} = 20 \text{ (rounds)} \times [2\times Q_p \text{ (sync or ID)} + 4 \times Q_p \text{ (pattern)}] \; \frac{\text{(W sec)}}{\text{round}} \; \frac{10^{-7}}{1.6 \text{ sec}}$$

$$\Phi_{\text{avg.}} = \frac{20 \times [(2\times 28) + (4 \times 7)] \;\; \text{W } (10^{-7})}{1.6}$$

$$\Phi_{\text{avg.}} = 1.05 \times 10^{-4} \text{ W.}$$

The exit aperture is 51mm in diameter, which provides an exit area, A, of 20.25 cm^2. The time-averaged beam-power density over the exit aperture gives a power average,

$$\overline{E}_{avg.} = \Phi_{avg.}/A$$

$$= \frac{1.05 \times 10^{-4}\ W}{20.25\ cm^2}$$

$$= 5.2 \times 10^{-6}\ {}^{W}/_{cm^2}\ .$$

The averaged peak radiant exposure is

$$\overline{H}_{avg.} = Q_p\ (\text{sync or ID})_{/A}$$

$$= \frac{28 \times 10^{-7}\ J}{20.25\ cm^2}$$

$$= 1.4 \times 10^{-7} J/_{cm^2}\ .$$

The three areas to evaluate in laser safety are (a) single-pulse radiant exposure, (b) average radiant exposure, and (c) exposure limit reduction as a result of the pulse repetition frequency.

Single-Pulse Radiant Exposure

$$\overline{H}_{standard}\ (\text{single pulse}) = 1.25 \times 10^{-6}\ J/_{cm^2}$$

$$\text{LES}\ \overline{H}_{avg.} = 1.4 \times 10^{-7}\ J/_{cm^2}$$

$$\text{Safety Margin} = \frac{1.25 \times 10^{-6}\ J/cm^2}{1.4 \times 10^{-7}\ J/_{cm^2}}$$

$$= 8.9\ .$$

Average Radiant Exposure

$$\overline{E}_{\text{standard}} = 2.5 \times 10^{-3}\ {}^{W}/_{cm^2}$$

$$\text{LES}\ \ \overline{E}_{\text{avg.}} = 5.2 \times 10^{-6}\ {}^{W}/_{cm^2}$$

$$\text{Safety Margin} = \frac{2.5 \times 10^{-3}\ {}^{W}/_{cm^2}}{5.2 \times 10\text{-}^{6}\ {}^{W}/_{cm^2}}$$

$$= 481.$$

Exposure Limit Reduction as a Result of the Pulse Repetition Frequency (PRF)

The safety reduction factor resulting from PRF is .06. Therefore,

$$\text{Safety Margin} = .06\ \frac{(H_{\text{standard}})}{\overline{H}_{\text{avg.}}\ \text{LES}}$$

$$= .06\ \frac{(1.25 \times 10^{-6})}{1.4 \times 10^{-7}} = .534.$$

The safety margin of .534 is not eye safe. However, the figures assume that all the repetitive pulses are of the same amplitude as the sync and ID pulses. The pattern pulses are actually only one fourth that value. By averaging the peak power and then calculating, the safety margin is as follows:

$$\text{Peak power average} = \frac{(2 \times 28 \times 10^{-7}) + (4 \times 7 \times 10^{-7})}{6\ \ \ (20.25)}\ \frac{J}{cm^2}$$

$$= 7 \times 10^{-8}\ {}^{J}/_{cm^2}\ .$$

$$\text{Safety margin} = .06\ \frac{(1.25 \times 10^{-6})}{7 \times 10^{-8}}$$

$$= 1.1.$$

The 1.1 margin is eye safe.

The conclusions that can be drawn are that the LES system will be eye safe at any range beyond 3 m from the exit aperture and probably will be eye safe between the exit aperture and a range of 3 m.

APPENDIX C

ACOUSTICAL TRANSDUCER

The laser transmitter uses a small dynamic earphone made by Allied Radio (No. 33174) as an acoustic transducer to detect when a live or blank round is fired by the weapon. The transducer is mounted in a small insulated compartment in the transmitter clamp assembly (Figure C-1) and is surrounded on all sides by a thin layer of foam insulation. This insulation helps isolate the transducer from the weapon, thus reducing the possibility of false triggering because of mechanical vibrations when a round is chambered.

An audio transducer is used because it has some advantages over a pressure transducer. The frequency response of the audio transducer is in the low range; therefore, it attenuates the high-frequency signals from the bolt returning in the chamber and ensures a better signal-to-noise ratio. The audio transducer also does not saturate on the mechanical vibrations or gas pressure. Since the transducer does not go into saturation, any amplitude difference between the blank firing signal and the bolt returning can be better discriminated. Finally, the audio transducer moves in only one plane. It is mounted for movement in the vertical plane, thus eliminating the stronger shocks that occur in the longitudinal and transverse planes.

In normal operation, the laser transmitter is clamped to the slipring on the M-16 in such a way that the coupling chamber and transducer compartment are close to a gas port near the base of the carrying handle. This gas port is actually a star-shaped hole through which the gas tube enters the cylinder (Figure C-2). Inside the cylinder, the gas tube is coupled with the bolt carrier key; when the weapon is fired, the pressurized gas in the tube causes the bolt carrier to move to the rear. The star hole allows a small portion of the gas used to push the bolt carrier to escape out over the slipring. When the laser transmitter is clamped to the slipring, the coupling chamber forms a tight fit around the star hole. Thus the pressure wave emerging from the star hole is forced into the coupling chamber, where it is detected by the acoustic transducer.

The signal generated by the transducer is fed to an impedance matching transformer. A fixed resistance of 3.3 ohms is shunted across the transducer to provide a uniform fixed load for the impedance matching transformer. The output of the transformer is interfaced to the transmitter logic module by a single transistor.

Measurements made of the output signals from the transducer produced when a blank round was fired and when the bolt was allowed to slam home on an empty chamber showed a signal-to-noise ratio of 4:1. The signal level produced by a blank round was 2 volts peak to peak and .5 volt bolt peak to peak for the bolt return only.

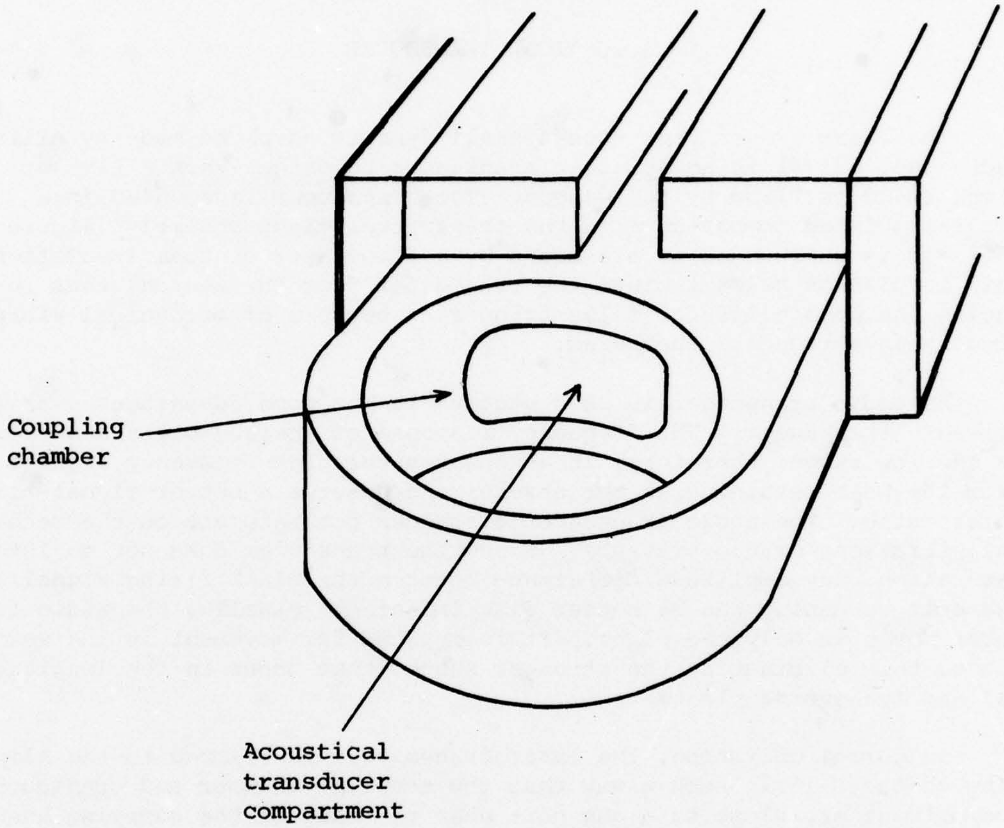


Figure C-1. View of coupling chamber.

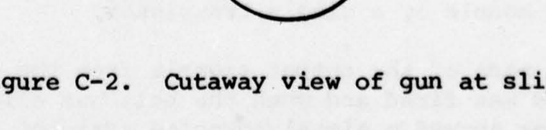


Figure C-2. Cutaway view of gun at slipring.

APPENDIX D

LASER TRANSMITTER LOGIC FLOW CHART

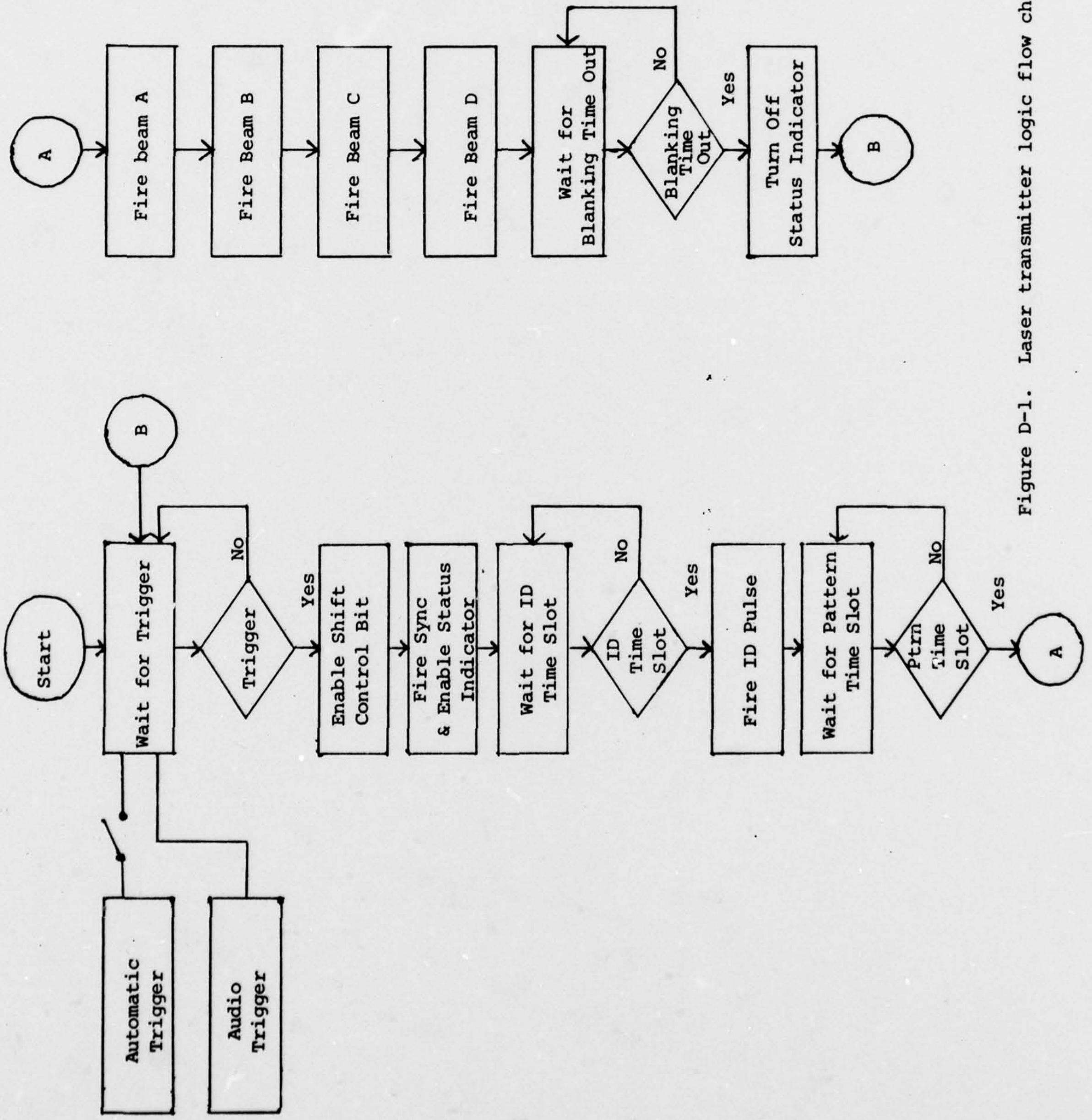


Figure D-1. Laser transmitter logic flow chart.

APPENDIX E

LASER PACKAGE

Laser and Fiber Optic Package Assembly

The laser package must fulfill several requirements. Basically, it must hold lasers rigidly in a radio frequency (RF) shielded enclosure, allow for efficient low-impedance electrical input, permit good heat conduction from the laser chips to the outside heat sink, and provide optical coupling from the lasers to the source exit aperture. So that the light out of the fibers will be uniform over this cross section, the fibers must be long enough for optical integration to occur.

The LES laser transmitter uses four laser diodes assembled in dual laser packages. Each of the dual packs is a thin, rectangular, metal package with pins along each of the long sides. All pins are grounded to the case for shielding purposes except the two central pins attached to the p-sides of the lasers. The laser diodes themselves are mounted on copper blocks that have a step machined across the face to allow attachment of the fiber optic.

The fibers are made by drawing conventional glass fibers. Special high-index optical glass is first machined and then drawn into a thin thread of glass with a .010-inch-square cross section. The fiber sections selected for use are the same size within 100 millionths of an inch. The fibers are scribed and broken to 1-inch lengths. One end of each fiber segment is ground flat and polished.

The previously formed fibers are held in a special fixture that has precision adjustments in 6 degrees of freedom, and the fibers are positioned in the laser package under a microscope. The polished end is butted against the laser diode. The shaft of the fiber is positioned in the same plane as the top cover of the laser package and is offset to one side of the top cover's longitudinal center line. A small amount of adhesive is placed at the fiber-laser interface and cured. A second fiber is attached similarly. A properly slotted cover is placed on the package and a separation of proper thickness is placed between the fibers. The fibers are held in precise position and epoxied in place. The excess fibers are scribed and broken off. The fiber ends are then ground flush with the package end and polished.

These packages form an extremely rugged optical source. Mounted in the laser transmitter, they have undergone hundreds of blank firings on the M-16 rifle. No failures because of shock or normal operation in the laser gun have been experienced to date.

Laser Diode Specifications[1]

The laser diodes used in the LES transmitter are LD-33 GaAs injection diodes that emit coherent infrared radiation. The diode is built in a heterojunction structure consisting of three distinct layers: N-type GaAs, P-type GaAs, and P-type GaAlAs. Recombination occurs in the immediate vicinity of the GaAs P-type region. The heterojunction formed at the interface of the P-type GaAs and P-type GaAlAs confines the injected carriers and also reduces reabsorption. As a result of this, threshold is reduced and power efficiency correspondingly increased. The radiant power output is proportional to the forward current and the spectrum is in the region of the peak sensitivity of the S-1 photocathode surface and of silicon photodetectors.

The device is capped with a nonabsorbing plastic making it mechanically rugged. The package includes a 4-40 screw stud that is the negative terminal of the diode and can be used for mounting to a grounded heat sink. The positive terminal is a lead parallel to the plane of the header. The output radiation is emitted along the axis of the stud.

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[1] Technical specifications provided by Laser Diode Laboratories, Inc., Metuchen, N.J. 08840.

APPENDIX F

LENS OPTICS

The LES uses an optics system consisting of a condensing doublet lens that acts like a simple projector lens. The quad laser stack is placed inside the focal point and the lens projects a blurred pattern down the field. The emitting radiation is collimated but never is focused; therefore, the beam is always diverging (see Figure F-1). The divergence is given by the radiating source size over the focal length:

$$\theta_b = \frac{Ds}{F.L.}$$ where Ds is a source size of .020 inch and F.L. = 2 inches.

$$= \frac{.02}{2}$$

$$= .010$$ or 10 millirads.

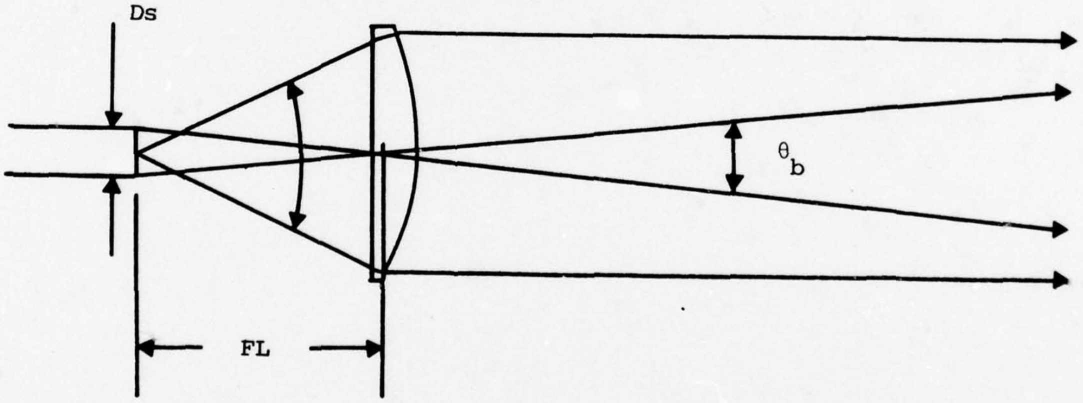


Figure F-1. Beam geometry.

The overlap areas in the beam pattern are created because of the physical proximity of the four fiber sources and the defocusing of the lens. The blurring effect makes each source appear larger than it is, resulting in an overlap of the beams in the pattern projected downrange. As the pattern increases in size as a function of range, the hit zone, or area of overlap, remains relatively constant in size because the power distribution at the edges of each beam drops below sensor threshold. Thus, as the beam diverges, the power distribution at the edges decreases sufficiently to keep the effective overlap area relatively constant in size.

APPENDIX G

POWER

Laser Transmitter

The LES system laser transmitter requires a small lightweight power source capable of furnishing enough power for 8 hours of continuous operation and at least 10,000 rounds of blank firing. In addition, the power source must be portable. The only solution to the above requirement is batteries.

The present laser transmitter mechanical design includes a location for batteries at the rear of the main tube assembly (see Figure G-1). Approximately 4.5 cubic inches of space are available. A simple, easily removable end cap is utilized for ease of battery replacement. Spring tension provided by the end cap assures good electrical contact with the batteries.

Battery Specifications

There are two different types of batteries used in the LES laser transmitter. One type of battery supplies power to the logic module. The other type of battery supplies the high voltage (67.5 volts DC) to the laser module assembly.

Logic Module Battery

One Mallory TR 118 mercury Duracel battery is used to power the logic module. The terminal voltage of the battery is 11.2 volts DC with a service capability of 250 milliampere hours. The suggested load current range is 0-50 milliamperes. The battery weight is 1.15 ounces and requires .60 cubic inch space.

Laser Module Assembly Battery

Three Eveready 505 carbon zinc batteries are used to power the laser module assembly. The terminal voltage of the battery is 22.5 volts. Three of these batteries are connected in series to supply 67.5 volts DC to the laser module assembly. The suggested load current range is 0-1.5 milliamperes. The battery weight is .8 ounces. The volume is .74 cubic inch.

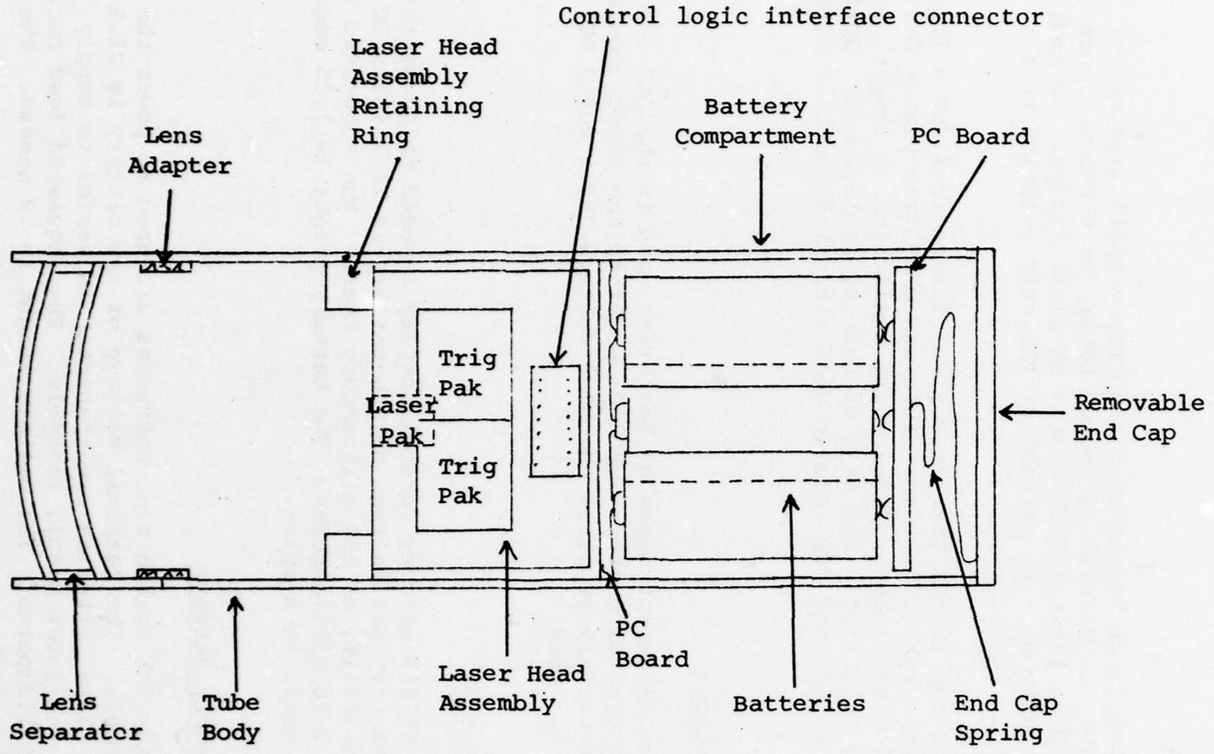


Figure G-1. Mechanical cutaway side view laser transmitter (LES system).

Battery Life

Extensive field testing has been done using the above specified batteries. Test data indicate these batteries will power the system in excess of 8 hours and provide at least 30,000 rounds of blank firing.

Laser Receiver

The LES system laser receiver requires a small lightweight power source capable of supplying enough power for at least 8 hours of continuous operation. The power source must be portable and compatible with the voltage and current requirements of the laser detectors and logic module.

The present helmet configuration is in the form of an electronics band assembly. The band assembly fits over the helmet liner and contains space for six laser sensors and two separate battery boxes. Each battery box will accept four batteries. The top covers of the battery box are removable for easy battery replacement. The battery boxes are made of aluminum and are 3-1/8 inches long, 1-1/2 inches high, and 3/4 inch thick.

Battery Specifications

One type of battery satisfies all of the power requirements of the helmet receiver. The battery used is a Mallory Duracel mercury battery type TR 115R. The terminal voltage of the battery is 6.75 volts with a service capacity of 250 milliampere hours. The suggested load current range is 0-20 milliamperes. The battery weighs .73 ounce and requires approximately .44 cubic inch of space. The battery is 1.32 inches long and .660 inch in diameter.

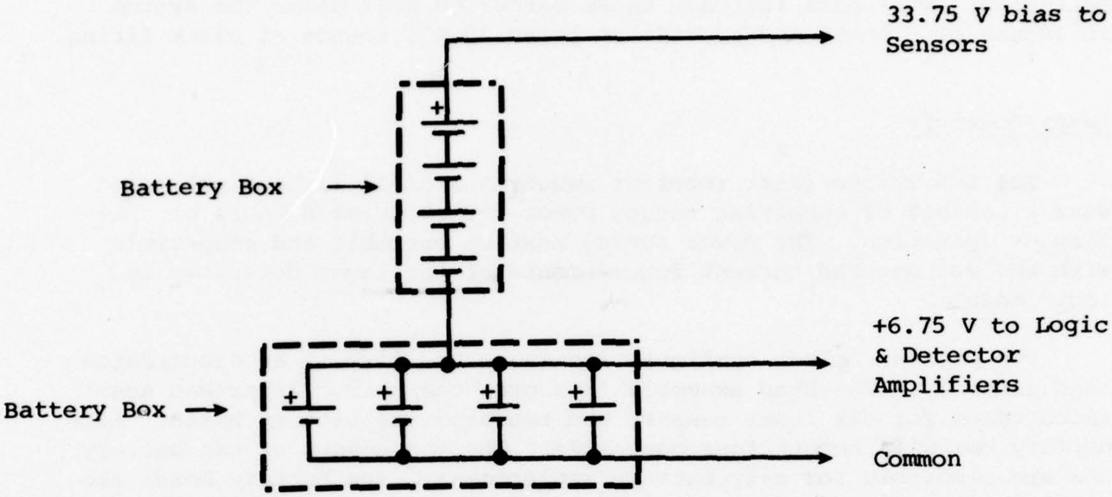
Eight of these batteries are used to supply power to the receiver. One battery pack contains four batteries wired in series to supply the high voltage bias required by the laser detectors. The other battery pack contains four batteries wired in parallel. The parallel combination is required to supply the current requirements of the detector amplifiers and the logic module.

Figure G-2 shows the battery schematic.

Battery Life

Extensive field testing has been done using the above specific battery. Test data indicate that the batteries used to supply power to the detector amplifiers and logic module will last for at least 12 hours of continuous operation.

The batteries used to supply bias voltage for the sensors will last several days. The current drain required from these batteries is very low, resulting in longer life.



Note. All batteries are Mallory TR 115R, 6.75 volts.

Figure G-2. Power supply schematic.

APPENDIX H

SYSTEM EQUATION AND SIGNAL-TO-NOISE RATIO ANALYSIS

A physical model of the system is shown in Figure H-1. From Figure H-1, the power density (I_o) is a function of the initial power (P_o), the solid angle (θ_b'), and the transmission of the collimating lens (T_t).

$$I_o = \frac{P_o T_t}{\theta_b'}$$

Where θ_b' is in sterads

$(\theta_b \text{ radian})^2 = \theta_b'$ sterads.

The received laser power (I_r) is a function of the detector area (A_r), the range (R), the optical efficiency of the atmosphere (α), and the transmission of the laser filter (T_r).

$$I_r = I_o \frac{A_r}{R^2} e^{-\alpha R} T_r .$$

Substituting $\dfrac{P_o T_t}{\theta_b'}$ for I_o gives

$$I_r = \frac{P_o}{\theta_b'} \frac{A_r}{R^2} e^{-\alpha R} T_r T_t .$$

The maximum theoretical power of the laser diodes is 7 watts. However, only 5 watts have been measured. Therefore, the 5-watt value (P_o) will be used to calculate the signal at 300 m (R).

The laser transmitter optics losses are estimated at 20% loss or 80% transmitted (T_t).

The receiver interference filter passes approximately 70% (T_r).

The beam spread is 10 milliradians (θ_b) or the solid angle of the beam is 10^{-4} sterads (θ_b').

The laser receiver's active detection area is 1 cm^2 (A_r).

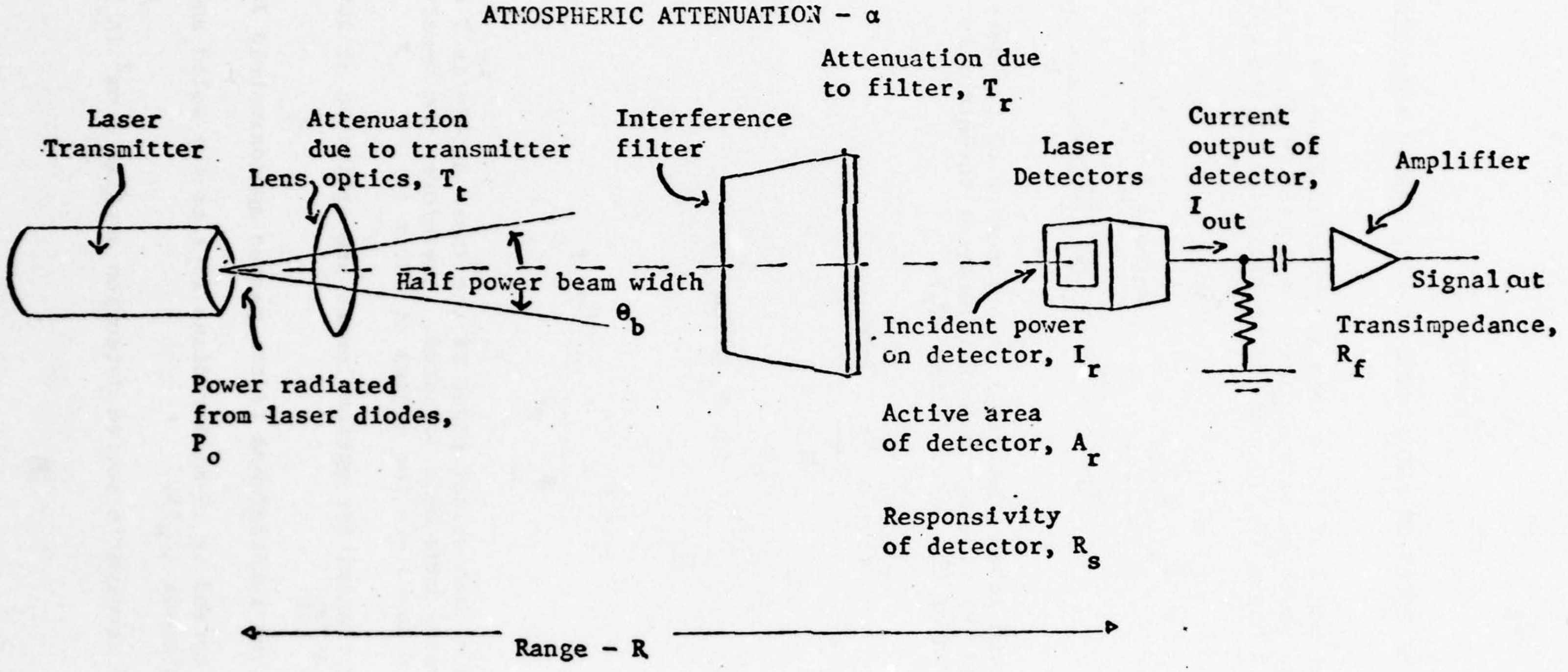


Figure H-1. System physical model.

The atmospheric attenuation coefficient (α) is dependent on two variables, which are the scattering coefficient (σ) and the absorption coefficient (K). The equation for attenuation, assuming monochromatic radiation, is

$$\alpha = \sigma + K.$$

The scattering and absorption coefficients depend on molecular actions (subscripted m) and aerosols (smoke, fog, mist--subscripted a). Therefore,

$$\sigma = \sigma_m + \sigma_a$$

$$K = K_m + K_a$$

and

$$\alpha = \sigma_m + \sigma_a + K_m + K_a.$$

Data for σ_m, σ_a, K_m, and K_a at a sea level horizontal path (worst case) for the GaAs wavelength are shown in Tables H-1 and H-2.

Therefore,

$$\alpha_{\text{very hazy}} = 2.09 \times 10^{-3} + 2.5 + 1 \times 10^{-6} + .38$$

$$= 2.88.$$

Therefore, the incident power on the active surface at 300 m is:

$$I_r = \frac{P_o A_r e^{-\alpha R} T_r T_t}{\theta_b' R^2}$$

$$= \frac{5w\ (10^{-4})\ e^{-(2.88)(.3)} (.7)(.8)}{10^{-4}\ 300^2}$$

$$= 1.31 \times 10^{-5} w$$

$P_o = 5w$

$A_r = 1\ cm^2 = 10^{-4} m$

$\alpha = 2.88$

$T_r = .7$

$T_t = .8$

$\theta_b' = 10^{-4}$

$R = 300m.$

Table H-1

Coefficient molecular km^{-1}	Climatic zone			
	Tropical	Mid-latitude summer	Mid-latitude winter	Subarctic winter
σ_m	1.89×10^{-3}	1.93×10^{-3}	2.09×10^{-3}	2.21×10^{-3}
K_m	$<10^{-6}$	$<10^{-6}$	$<10^{-6}$	10^{-6}

Table H-2

Coefficient K_m^{-1}	Aerosol coefficients		
	Clear 23 Km visibility	Hazy 5 Km visibility	Very hazy 1 Km visibility
σ_a	9×10^{-2}	4.4×10^{-1}	2.5
K_a	1.52×10^{-2}	7.43×10^{-2}	.38

The current output (I_{out}) of the detector is equal to the incident power (I_r) x the responsivity of the detector (R_s).

$$I_{out} = I_r \times R_s \qquad R_s = .5 \text{ amp/watt.}$$

$$= (1.31 \times 10^{-5} \text{w}) \ (.5 \text{ amp/watt})$$

$$= 6.55 \times 10^{-6} \text{ amps}$$

The output signal (S_{out}) from the amplifier is given by the input current (I_{out}) x the transimpedance of the amplifier (R_f).

$$S_{out} = I_{out} \times R_f \qquad R_f = 30 \times 10^3 \text{ ohms.}$$

$$= 6.55 \times 10^{-6} \text{ amp} \times 30 \times 10^3 \text{ ohms}$$

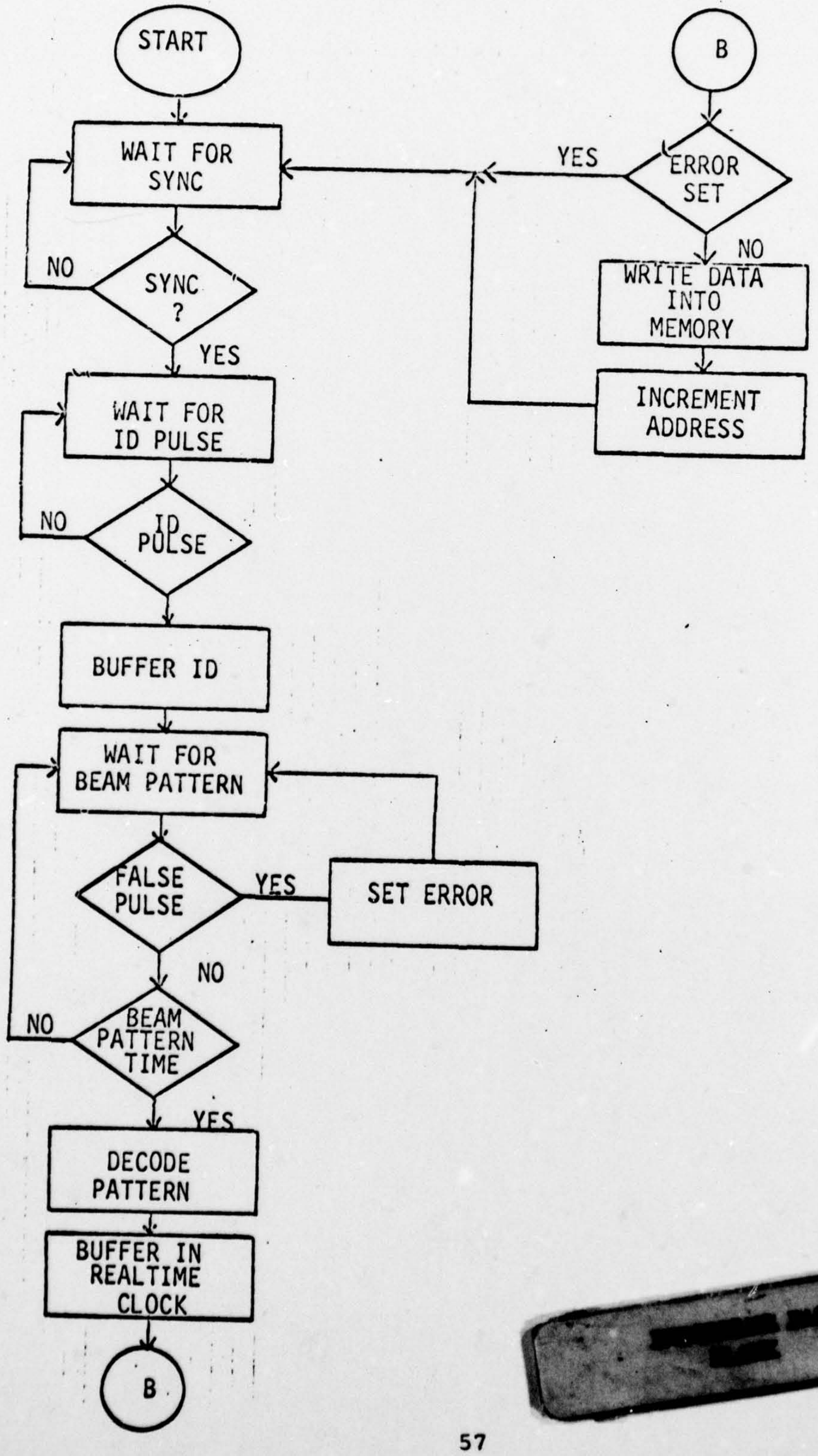
$$= 196 \times 10^{-3} \text{ volts}$$

The measured noise in full sunlight is $\approx 100 \times 10^{-3}$ volts. Therefore, at 300 m the signal-to-noise ratio is

$$\frac{\text{Signal}}{\text{Noise}} = \frac{196}{100} \simeq 2.$$

APPENDIX I

LASER RECEIVER FLOW CHART



APPENDIX J

MEMORY INTERFACE DEVICE

The memory interface device serves the following functions:

1. Before the start of an exercise, it checks out the receiver memory chips for proper operation,
2. It zeroes the memory registers and puts them in a start mode, thus resetting the internal clock and synchronizing all of the receivers being used, and
3. After the operation, the device reads out the memory, formats the data, and outputs the data to a computer, teletype, or other display device.

Figure J-1 shows the block diagram for the interface device and Figure J-2 shows the flow chart for the logic operations. The operator selects one of three function modes--memory checkout, zero and start, or read memory. The timing and control circuit scans the operator function switches, activates the appropriate function, provides timing, and makes the basic go/no-go decisions on the memory checkout routine.

All data flow through the input register and are displayed on the operator's display. The data are also duplicated, split, and sent to the memory checkout or the TTY formatter depending on the function selected. In the memory checkout routine, each of the memory chips is exercised by placing successively a 0 and 1 into the bit registers to determine that the electronics are functioning properly (see Figure J-2). If there is a malfunction in the memory, a no-go signal is displayed on the panel and the routine is stopped.

In the readout mode, the timing and control logic places the data directly into the TTY formatter, thus bypassing the checkout circuitry. The formatter changes the data into ASC II code and outputs the data to a 20-mA loop for Teletype display or computer processing.

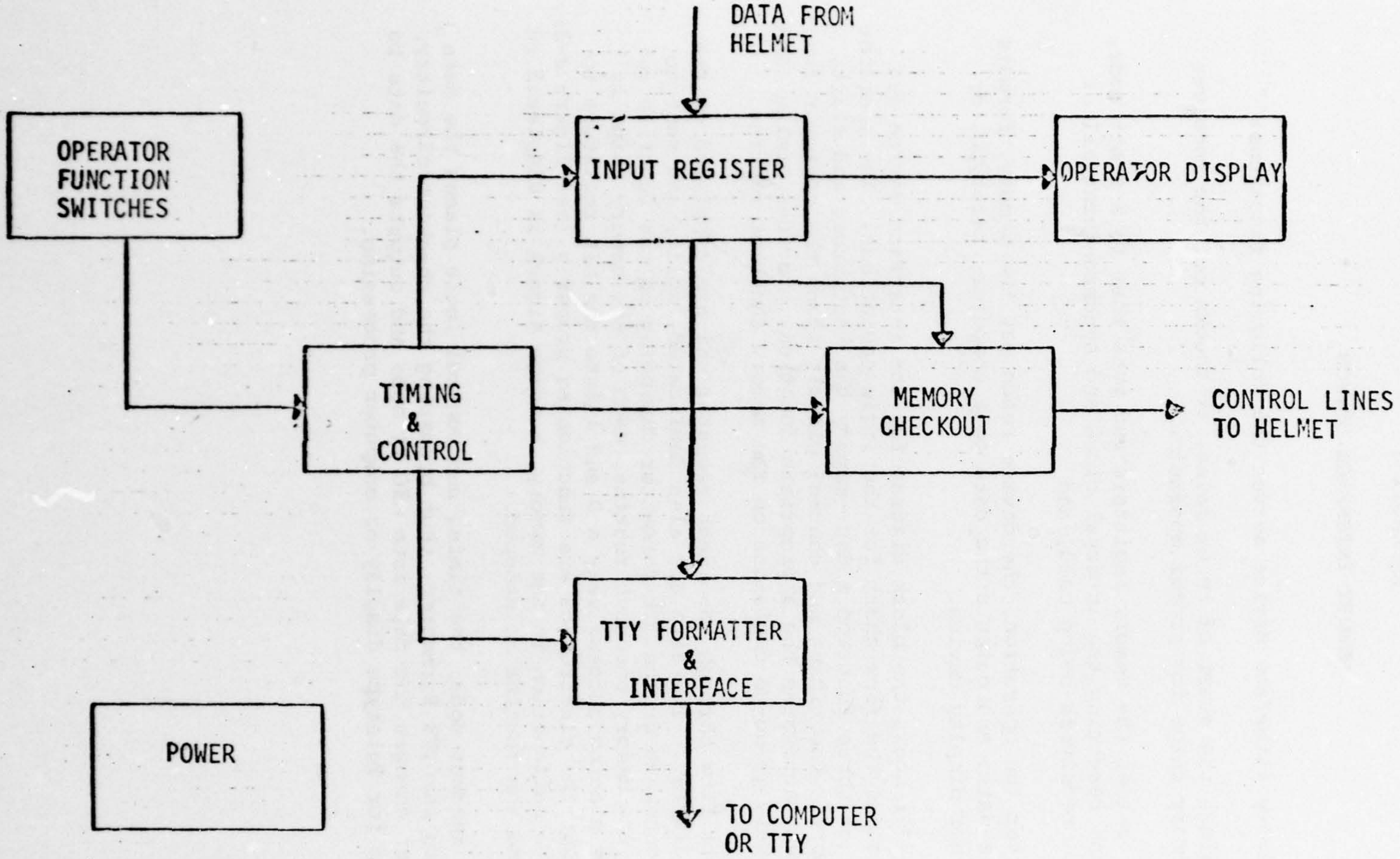


Figure J-1. Interface device block diagram (LES receiver).

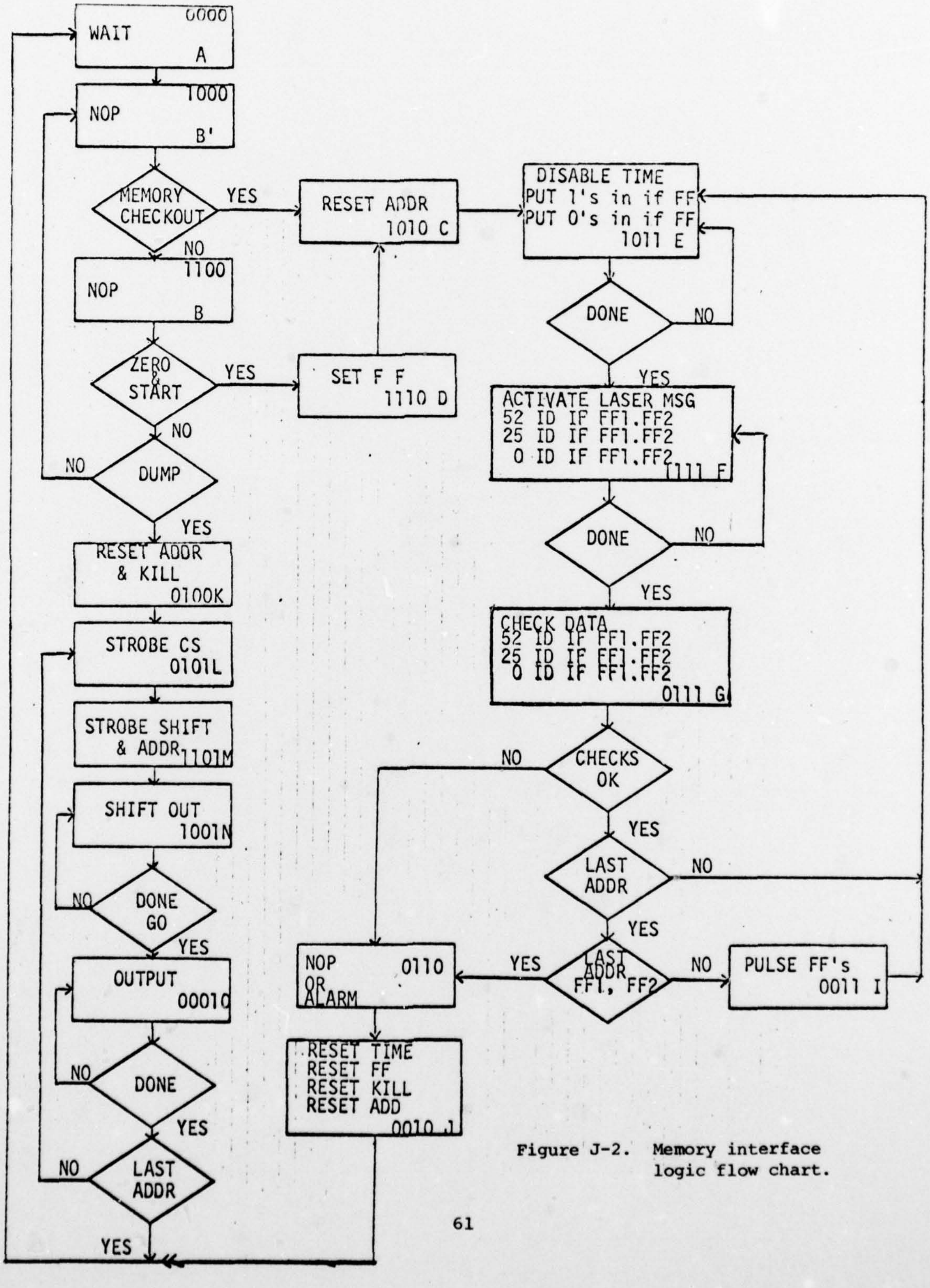


Figure J-2. Memory interface logic flow chart.

APPENDIX K

LES DISPLAY DEVICE

Purpose

The purpose of the LES system display is to provide the firer with real-time information concerning hit and near-miss data generated by the target electronics module.

In addition to providing visual indication of hit and near-miss data, the display contains a sonalert that generates an audible tone upon receipt of hit, near-miss (beam pattern), or far-miss (no beam pattern) data.

The display contains a mode switch for selection of either a three-beam or four-beam kill. (See Figure K-1.)

Functional Description

Input Circuitry. The input circuit to the display is designed to operate over a long distance--several kilometers if necessary--by means of a single run of two conductor cables. The circuit is compatible with a standard 20-milliampere Teletype loop and contains a 20-mA loop source.

The input interface element is a Monsanto MCT2E optical isolator. The optical isolator provides isolation between the decoding logic and the incoming line, reducing the possibility of false data caused by a noisy environment.

TTY Decoder. The data format used by the display is the standard ASCII (American Standard Code for Information Interchange) seven-level code. Data received by the display are in serial form and must be converted to a parallel format before decoding. (See Figures K-2 and K-3 for the display device block diagram and flow chart.)

Serial-to-parallel conversion is accomplished by a single, universal, asynchronous receiver-transmitter (UART) logic chip. The UART accepts asynchronous serial data consisting of a sync bit, up to eight data bits, an optional parity bit, and two stop bits. Bit weight is a function of baud rate and is equal to 9 milliseconds in the present system. The baud rate could be increased for faster data transfer if necessary. A master reset switch is used to reset the display to zero.

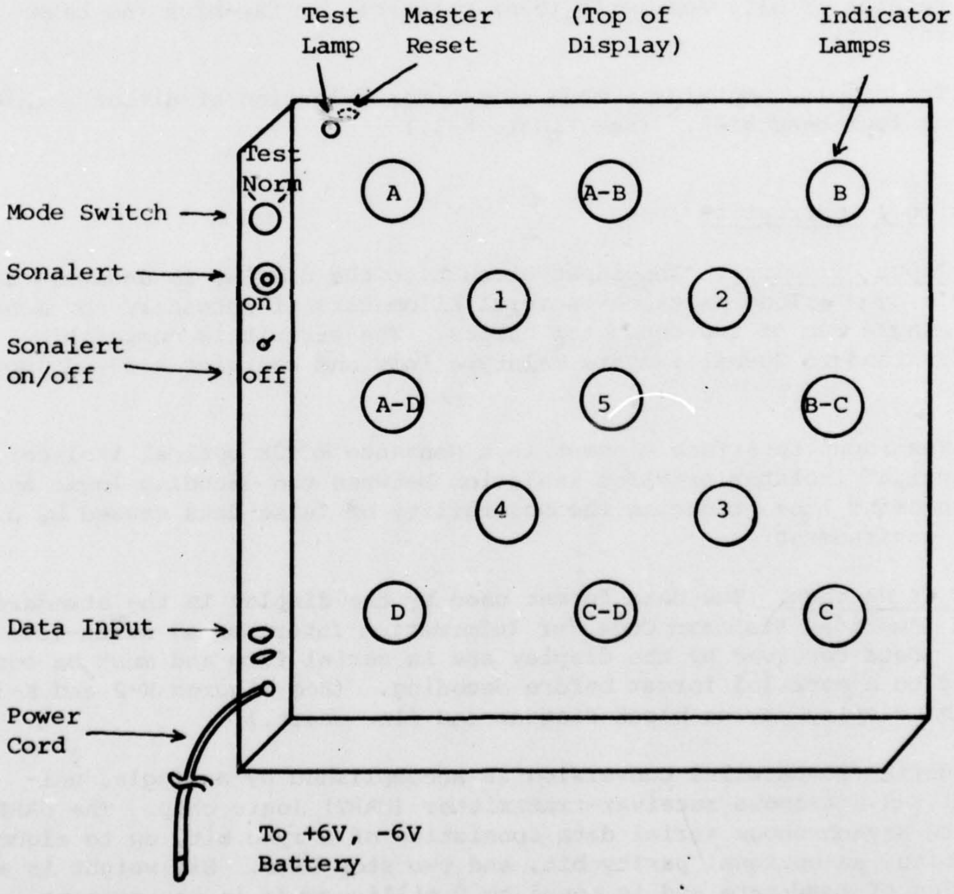


Figure K-1. Display device.

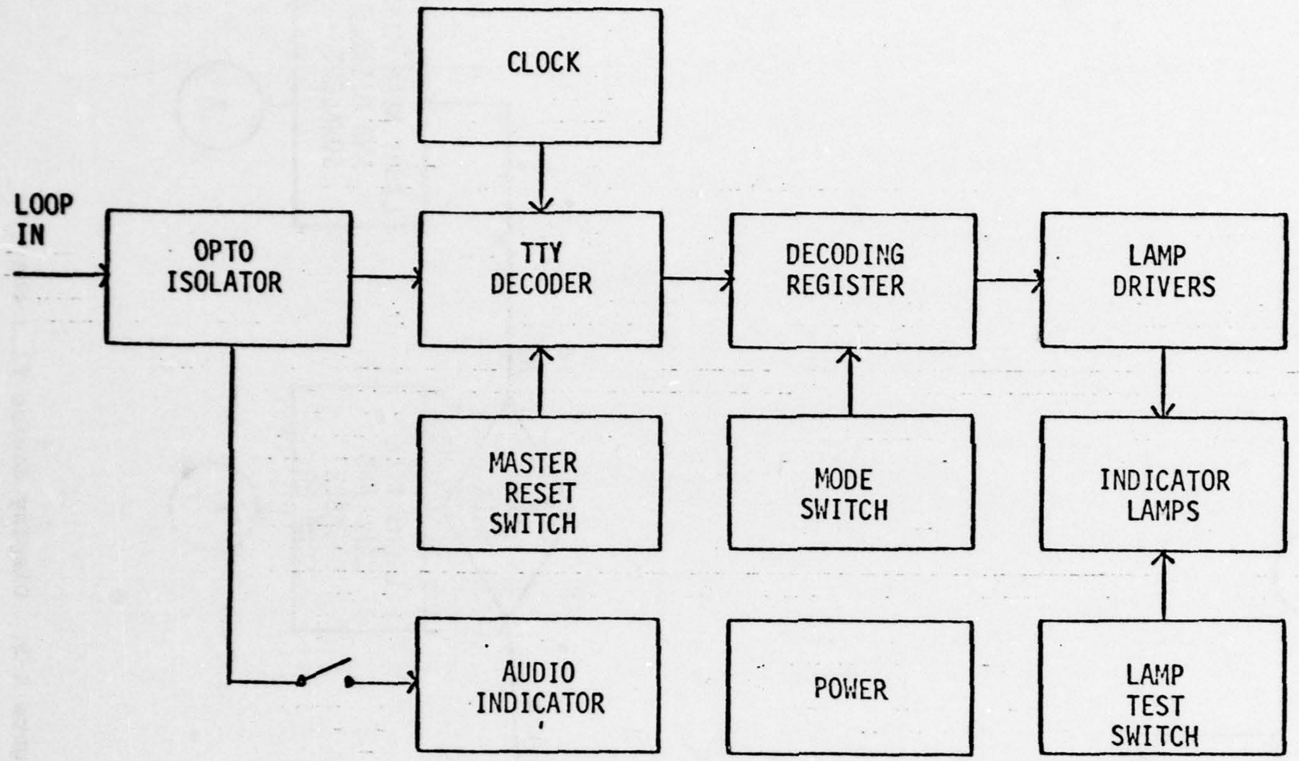


Figure K-2. Display device block diagram.

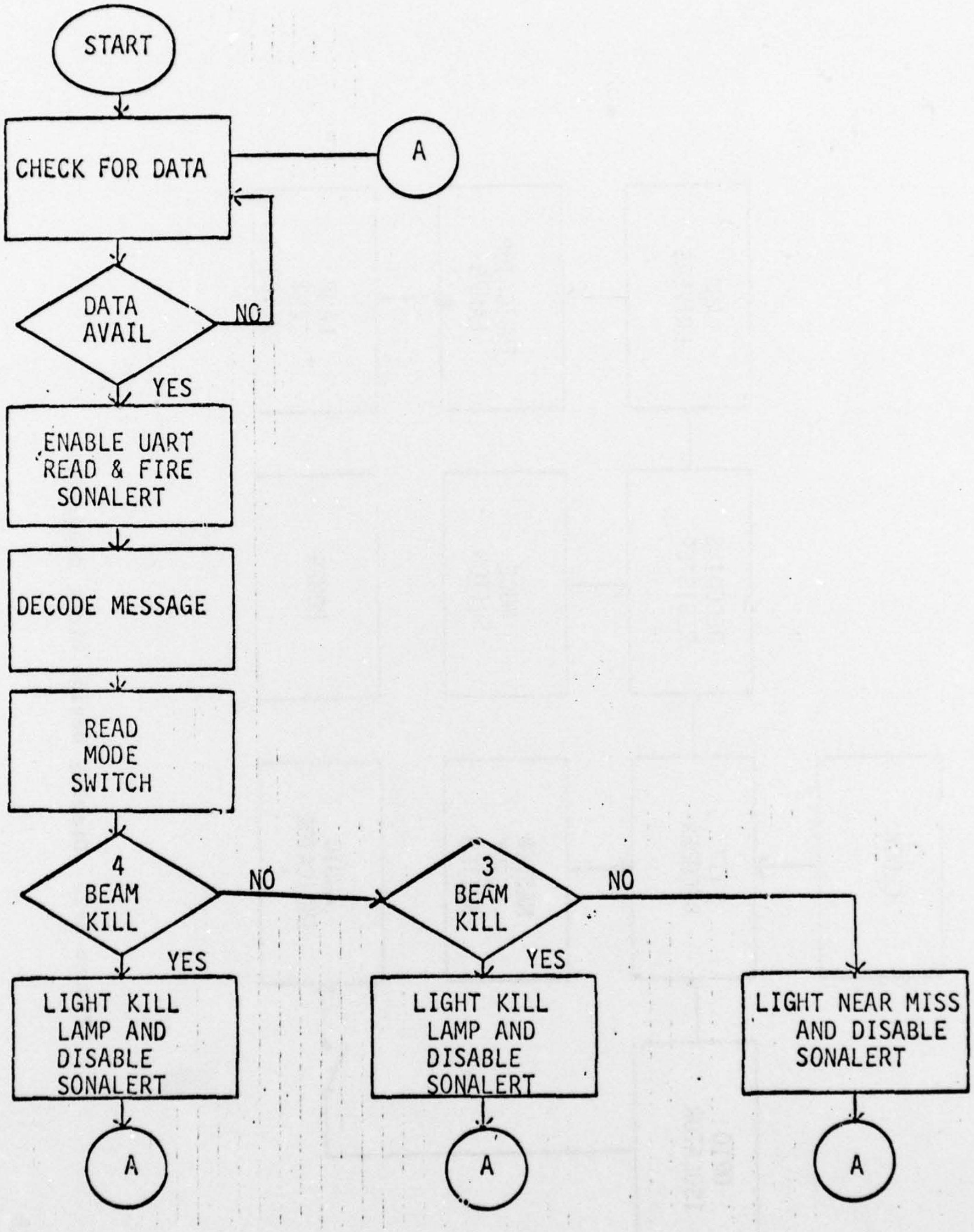


Figure K-3. Display device flow chart.

Data Decoder. The output of the UART consists of four parallel data lines. These data must be decoded into the proper format to drive the hit-near-miss visible indicators. Decoding is accomplished by two BCD to decimal decoder logic chips. The output of the BCD decoder is fed to the mode switch.

Mode Select Switches. The display contains a single, two-position rotary switch that enables the display to be used in "normal" or "test" mode.

With the switch in the normal position, any three-beam combination, the presence of all four beams, or the presence of any two diagonal beams will cause the center kill lamp to illuminate.

When the mode switch is placed in the test position, all four beams must be present before the center kill lamp will illuminate.

In addition, when the switch is in the test mode, any two diagonal beams received will illuminate their respective lamps. This is the only condition that will cause two indicator lamps to illuminate simultaneously.

Indicator Lamps. After the incoming data have been decoded properly, they must be displayed to present a visual readout to the player. Incandescent lamps are used as the display medium. Lamps with a high degree of brightness were selected so the display could be utilized in bright sunlight. To supply the current required by the lamp, a transistor driver is required for each lamp. In addition, a test switch is available to ensure all lamps are operating. When the test switch is depressed, all lamps illuminate to indicate operating status.

Audible Indicator. Any time a command is received from the logic module in the helmet, a sonalert in the display is keyed on for .5 second. This audible tone alerts the player that a message has been received by the display. In addition, if the data line between the helmet and the display becomes open for any reason, the sonalert will give a continuous indication to alert the player that a problem exists. The sonalert can be switched in and out of the circuit by means of a toggle switch located on the side of the display chassis.

Power. Power for the display is supplied by a single, rechargeable, Nicad battery pack. Power requirements are +6 volts DC and -6 volts DC. Current required varies as a function of the number of lamps illuminated at any one time. When the lamp test switch is depressed, all lamps illuminate at one time and the current required is 6.5 amperes. The logic board draws 100 milliamperes at +6 volts DC and 15 milliamperes at -6 volts DC. Each indicator lamp draws .5 ampere at +6 volts DC.

Display Format. The display contains 13 indicator lamps arranged in a square pattern (see Figure K-1). Individual lamps indicate which beam or combination of beams illuminated the laser detector.

For example, if lamp A illuminates, this indicates only beam A hit the detector and that a near-miss in the upper left-hand corner was recorded. See Table K-1 for the complete display format.

Table K-1

Display Logic Format

Beams detected	Mode switch	Lamp illuminated	Shot location
A	*	A	High left
A + B	*	A - B	Overhead
B	*	B	High right
B + C	*	B - C	Right
C	*	C	Low right
C + D	*	C - D	Low
D	*	D	Low left
A + D	*	A - D	Left
A + C	Test	1 + 3	Kill
B + D	Test	2 + 4	Kill
A + B + D	Test	1	Mid-high left
A + B + C	Test	2	Mid-high right
B + C + D	Test	3	Mid-low right
A + C + D	Test	4	Mid-low left
A + B + C + D	Test	5	Kill
A + C	Normal	5	Kill
B + D	Normal	5	Kill
A + B + D	Normal	5	Kill
A + B + C	Normal	5	Kill
B + C + D	Normal	5	Kill
A + C + D	Normal	5	Kill
A + B + C + D	Normal	5	Kill

Construction

The display is constructed on an off-the-shelf Bud Chassis No. AC1431. The chassis dimensions are 17 x 17 x 4 inches. All of the decoding logic and lamp drivers are mounted on a small board inside the chassis box. A stand is permanently attached to maintain the display in an upright position.

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