SPECIAL REPORT 89-012

(M-CAT) MINOR CALIBER WEAPONS TRAINER MK-19, 40MM MACHINE GUN

JULY 1989

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SPECIAL REPORT 89-012

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Encl: (1) (M-CAT) Minor Caliber Weapons Trainer, Special Report of Jul 1989

1. The Naval Training Systems Center (NAVTRASYSCEN) is pleased to distribute NTSC SR89-012 "(M-CAT) Minor Caliber Weapons Trainer, MK-19 40MM Machine Gun, July 1989 Special Report" at enclosure (1).

2. The purpose of this special report is to summarize the development of a trainer for the MK-19 weapon. The trainer is currently in use by both COMTRALANT and COMTRAPAC. Funds for this effort were provided by the Naval Science Advisory Program, NSAP, and NAVSEA.

3. This research is representative of work conducted by the Advanced Simulation Concepts Division in weapon fire trainers. The next phase will focus on development of a 50 caliber add-on.

4. Your comments and questions are welcomed. For further technical discussions, please contact Mr. Albert H. Marshall (407) 380-4653, or AV 960-4653.

H. C. OKRASKI
Director, Research and
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The M-CAT is a simulator which can be used for both MK-19 and .50 cal machine gun training. It incorporates accurate threat simulation of stationary and moving targets on a large projection screen. The weapon's recoil, sound, tracers, rounds-in-flight and hits are simulated. M-CAT accurately simulates both trajectory and lead for correct scoring. No ammunition or special ranges are required making it safe and economical. Two M-CAT's were fielded for evaluation and have been accepted for use as permanent trainers.

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Mechanical Fabrication of the device was done by the Laboratory Services Division under the Supervision of Joe Porthouse. Paul Grimmer (retired) did the mechanical design.

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SPECIAL REPORT 89-012

EXECUTIVE SUMMARY

PROBLEM

MINOR Caliber Weapons are installed on naval ships for close-in ship defense against high speed boats and aircraft. These weapons lack a fire control system and must be manually aimed at the threat target. The gunner must be trained in range estimation and how to lead maneuvering, high speed targets. This report describes a trainer developed under joint NSAP and NAVSEA sponsorship to safely train these gunner skills.

OBJECTIVE

Develop a trainer that will accomplish the following:

- MK-19 machine gun training (upgradeable to .50 cal)
- Accurate threat simulation of stationary and moving target displayed on a large screen
- Tracer and round-in-flight simulation
- Accurate trajectory and lead simulation
- Safe Training
- No ammunition required
- No special range
- Reliable
- Low Maintenance
- Recoil Simulation
- Eliminates weather delays

Use of target drones and live rounds is extremely expensive and limits training. Training with live rounds is also a major safety concern. M-CAT is designed to overcome these difficulties.

APPROACH

Two systems were developed and delivered to COMTRALANT and COMTRAPAC. The simulator shows a moving target, the rounds in flight as well as the rounds impacting on water or the target. The display is a 72 inch projection TV. The system uses computer graphics and video disk technology to simulate the rounds in flight as well as the explosions of rounds hitting the water or target. Target areas are stored on video disc and can represent various sea states and lighting conditions. Explosions, rounds in flight etc., are inserted by a frame buffer on the video scene. The computer is an Intel 386 single board computer with a 387 math coprocessor. A de-militarized MK-19 is located in front of the projection TV. When the gunner fires the weapon, he experiences recoil and hears the weapon noise. The weapon elevation and azimuth are determined by reading potentiometers located on a MK 64 Mod 4 gun cradle. Flight equations for the rounds have been determined using a fourth order series approximation of the trajectory. This gun mount, with its adaptors, can be used to mount other weapons for future expansion of the system to other similar minor caliber weapons (i.e., M-2, .50 cal, M-60, 7.62 mm, M-249 SAW 5.56 mm).

CONCLUSIONS

The COMTRAPAC system was delivered in March 1989 and COMTRALANT system was delivered in January 1989.

The M-CAT equipment has been well accepted by the gunners who have made valuable suggestions to improve the feedback presented to the trainee.

The combination of video and graphics was preferred by subject matter experts over a purely graphics based system. A high level of scene realism is achieved with these techniques for a relatively low cost.

Using the M-CAT system, the gunners were observed by subject matter experts to rapidly improve their gunnery skills. Trainees time on the trainer is not limited by ammunition range and target availability or weather conditions.

The use of this trainer eliminates the safety problem of training with live rounds. Live rounds cost about $12.00 each and limit live firing affordability.

COMTRAPAC and COMTRALANT have used the MK-19 training system for eight months without equipment failures. They have requested a COG 2.0 designation of the equipment and have requested a .50 cal upgrade or add-on be developed.

A proposal has been submitted to expand the M-CAT to include the .50 cal machine gun.

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INTRODUCTION

MINOR Caliber Weapons are installed on Naval Ships for close-in ship defense against high speed boats and aircraft. These weapons lack a fire control system and must be manually aimed at the threat target. The gunner must be trained in range estimation and how to lead maneuvering, high speed targets. This report describes a trainer developed to safely train these gunner skills.

Minor Caliber Weapons Trainer, M-CAT, features include:

- o MK-19 machine gun training (upgradeable to .50 cal)
- o Accurate threat simulation of stationary and moving targets displayed on a large screen
- o Tracer and round-in-flight simulation
- o Accurate trajectory and lead simulation
- o Safe Training
- o No ammunition required
- o No special ranges
- o Reliable
- o Low Maintenance
- o Recoil Simulation
- o Eliminates weather delays

Use of target drones and live rounds is extremely expensive and limits training. Training with live rounds is also a major safety concern. M-CAT is designed to overcome these difficulties.

Two systems were developed and delivered directly to COMTRALANT and COMTRAPAC. The COMTRAPAC system was delivered in March 1989 and the COMTRALANT system was delivered in January 1989. Funds for this effort were provided by NSAP and NAVSEA. The systems have been reliable to date. Figures 1 thru 4 show the M-CAT System.

Figure 1. Projection screen (72 inch diagonal).

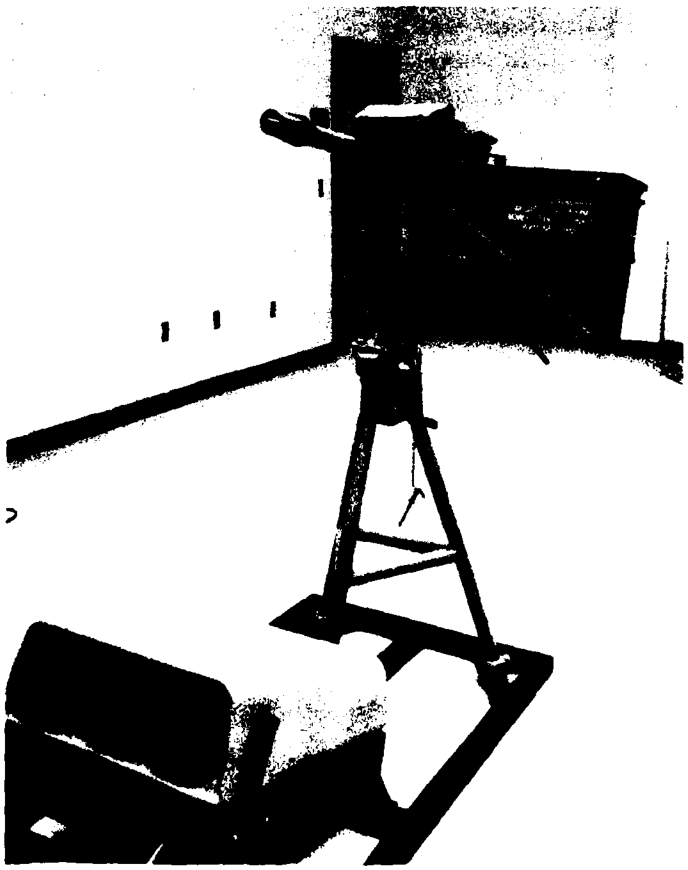

Figure 2. MK-19 weapon and video projector.

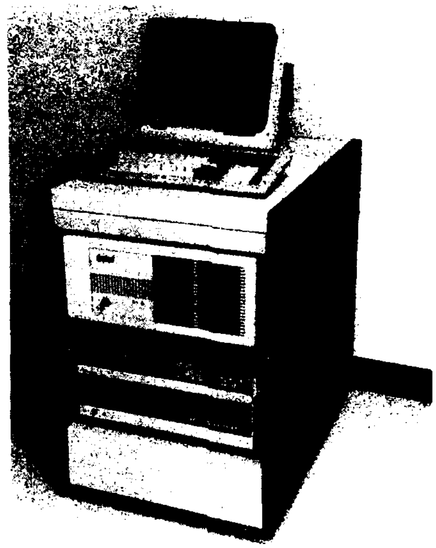

Figure 3. Computer and video disk systems.

Figure 4. M-CAT in use at COMTRAPAC

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GENERAL CAPABILITIES

The MK-19 is a 40 mm machine gun that fires grenades at the rate of 375 rounds per minute. This weapon can penetrate up to two inches of armor and can saturate an area with lethal fragments. The effective range of the weapon is 1500 meters. The gunner can see the round during part of its trajectory and at maximum ranges the time of flight of the round can be 10 seconds, with the round achieving a maximum elevation of 100 meters. The gunner has to derive the fire control solution mentally using the location of the falling rounds as well as the visible part of the rounds trajectory. To train the gunner effectively, the simulator shows the rounds in flight as well as the rounds impacting on the water or target.

The display for the system is a 72 inch SONY projection TV. The system uses computer graphics and video disk technology to simulate the rounds in flight as well as the explosions of rounds hitting the water or target. Target areas are stored on video disc and can represent various sea states and lighting conditions. Explosions, rounds in flight etc. are inserted by a frame buffer on the video scene. The computer is an Intel 386 single board computer with a 387 math coprocessor. A de-militarized MK-19 is located in front of the projection TV. When the gunner fires the weapon he experiences recoil and hears the weapon noise. The weapon elevation and azimuth are determined by reading potentiometers located on a MK 64 Mod 4 gun cradle. Flight equations for the rounds have been determined using a fourth order series approximation of the trajectory. This gun mount, with its adaptors, can be used to mount other weapons for future expansion of the system to other similar minor caliber weapons (i.e., M-2, .50Cal, M-60 7.62 mm, M-249 SAW 5.56 mm).

The system is easily disassembled so that any part can be transported by two men. The system can be transported by either air or truck. The system is intended for use in a classroom environment. It is capable of operation in temperatures from 32 degrees F to 95 degrees F with humidities of 90 percent non-condensing or less. The computer equipment and video projector operate on 120 VAC 15A and the electric air compressor operates on 120 VAC 20A.

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EQUIPMENT DESCRIPTION

The M-CAT system (Figure 5) consists of the following major assemblies:

TRAINING STATION (MK-19)
COLOR VIDEO PROJECTOR
TV PROJECTION SCREEN
COMPUTER CABINET AND TERMINAL
ELECTRIC AIR COMPRESSOR

The training station contains a demilitarized MK-19. The MK-19 ammo box is used to store some of the system electronics. Recoil is simulated by pneumatically moving the MK-19 handles. The trainee selects a training scenario from an on-screen menu by pressing the weapon trigger. Results of the training scenario are presented to the gunner using text on the screen.

The color video projector is a SONY VPH-1031Q. It has a resolution of 1100 TV lines (RGB inputs) or 650 TV lines (video input). The projector is a direct projection system with 3 picture tubes and 3 lenses. The TV projection screen is a SONY VPS-72HG1 with a 72 inch diagonal dimension.

The computer cabinet (Figure 6) contains the following equipment:

INTEL SYS-320 COMPUTER
NOVA 620 TIME CORRECTOR
PANASONIC TQ-2024F VIDEO DISK PLAYER

The Intel Sys-320 computer controls the training system. The heart of the computer is an Intel 386 microprocessor chip with an Intel 387 math coprocessor. The Nova 620 is a digital time base corrector. It is used to time base correct the video data coming from the video disk player. Time based correction is necessary because of mechanical problems inherent with the video disk player. The video player disk contains the target scenarios. The player is controlled by the SYS-320 via an RS232C serial interface. The computer system (Figures 7 and 8) contains the following boards:

Parallax Video Graphics Boards (2)
INTEL SBC-214 Disk Controller
INTEL SBC-386/21 Computer Board
INTEL SBC-546 System I/O/ Clock Board
Zendex ZX-564 Mother Board
SBX-350 Parallel I/O
SBX-351 Serial/Timer
DTX-311 Analog Input

The Parallax graphics board implements a bus interface draw processor 2048 x 1024 x 8 bits of image memory, color look up tables and an RGB Output stage. The controller performs over 85 graphics instructions, operating at a basic drawing rate of 12 million pixels per second, The Parallax board generates the round in flight, and hit and miss explosions. The output of the Parallax board goes to the SONY projector.

Potentiometers on the gun cradle are used to determine the weapon azimuth and elevation. Voltages from the potentiometers are filtered by four-pole low-pass filters. These filters are implemented on the horizontal/vertical potentiometer driver circuit located in the ammunition canister. Appendix A provides a functional description and schematic of the circuit. After filtering, the horizontal and vertical position signals are converted to digital values by the Data Translation (DTX-311) analog input board (Figure 4). This board is located on the Zendex ZX-564 Mother Board in the computer.

A mechanical switch activated by the MK-19 trigger is used to control the recoil/pulse generator circuit located in the ammunition canister. This circuit, described in Appendix B, provides both an interrupt signal to the computer and allows control of the weapon's recoil mechanism (Figure 7).

With a video camera located at the same level as on a destroyer deck, target scenarios were recorded on a video disk. A Panasonic video disk player displays these scenarios as controlled via an RS-232 interface from the computer. Each frame of the video disk is individually digitized as to target size, location, and range. The guns azimuth and elevation are determined by reading potentiometers on the gun cradle. The computer calculates the rounds'trajectory and the Parallax graphics generates the rounds in flight and the explosions. The graphics data are then superimposed on the video disk target scene. The results are displayed by the video projector.

A sound system circuit is used to generate sound effects by playing back a digitized recording of the MK-19 muzzle blast along with simulated hit and miss explosions. This circuit, described in Appendix C, is located inside the computer rack. Two microcomputers on this circuit reproduce sounds by transferring data stored in EPROM to digital to analog converters. One processor generates the MK-19 muzzle blast while the other generates miss and hit explosions (Figure 11). Range and sound delay of the explosions are taken into account. These sound effects are mixed to create simultaneous sound effects. An amplifier on the circuit provides output for a headset or an external speaker.

Recoil is caused by moving the weapons handles using a pneumatic cylinder. Compressed air to the cylinder is controlled by using high speed solenoid valves. Figure 12 shows the recoil circuit. The compressed air is generated by a portable air compressor.

SOFTWARE DESCRIPTION

The M-CAT software was written using Intel's PLM-286 complier under the iRMX 286 operating system. This high level language along with the real-time capabilities of the operating system allowed rapid development of this application software.

Simulation of the MK-19 40 mm machine gun required knowledge of the ballistic characteristics of the 40 mm round. From aiming data for the 40 mm HEDP (m430) round, a ballistic model was determined using an iterative mathematical approach. From this model a solution for the projection of the round in flight at the screen distance was calculated. Using this information, graphical rounds and explosions are superimposed over the video disk image giving the gunner a visually correct perspective. Graphical sequences of hit and miss explosions are stored in the display buffer for block image transfer during program execution. These graphical images are loaded from the hard disk during program initialization. The graphics are updated at the frame rate of the video disk player (30Hz) using a double buffer drawing technique.

The information on the video disk can be separated into 35 scenarios, each showing a different range, speed, attitude, or direction of the target boat. The boat used was a 20.5 ft. boat with a 200 HP outboard. Target ranges are varied between 75 and 700 meters with boat speeds from zero to thirty-five miles per hour. Files which describe the outline and range of the target for each frame of a scenario are stored on the hard disk. Before a scenario is played the description file is loaded into memory for fast access by the program. Target hits are determined by comparing current grenade hit locations with the target location for the current frame. Presently six different training sessions are selectable for the on-screen menu. Each of these sessions provide the gunner with a random sequence of targets from a fixed list of video disk scenarios. For example, the lateral moving target session displays in a random order ten different scenarios of the video disk in which the target moves laterally to the gunner.

At the end of the session, a complete gunner assessment is printed on the screen. Gunner performance rating (expert, gunner, assistant gunner, and beginner) is determined based on the average number of rounds to destroy a target over the scenario. A target is destroyed or damaged based on a scoring system which monitors each rounds impact distance to the target. Each round impact within 60, 15, and 5 meters is given a weight, xx points. A sum total of these weights is calculated during each target's presentation in the scenario. A total of 40 points or more destroys a target. If the total is between 20 and 39 points the target is considered damaged. An example of a scenario scoring display follows.

An operator's menu provides flexibility to this scoring system and performance rating through several setup parameters. From this menu the instructor can vary the weight for each round impact distance (5, 15, and 60 meters). Also, the instructor can selectively activate each scoring distance through the skill level parameter. A skill level of 1 activates only the 5 meter impact distance. Skill level 2 activates both 5 and 15 meter impact distances. Similarly, skill level 3 activates 5, 15, and 60 meter impact distances. The basis for performance rating, average number of rounds per target destroyed, can also be varied for each rating classification. Once these parameters are set to the instructors specification they can be saved as the system startup parameters. This enables the instructor to configure the system as he or she desires. A sample scenario is shown below.

SCENARIO 6 (8 Targets)

# targets destroyed	006
# targets damaged	002
# rounds expended	144
#, % rounds within 5 meters	006, 004
#, % rounds within 15 meters	016, 011
#, % rounds within 60 meters	061, 042
average rounds/kill	024

RATING - EXPERT

SAMPLE SCENARIO SCORING DISPLAY

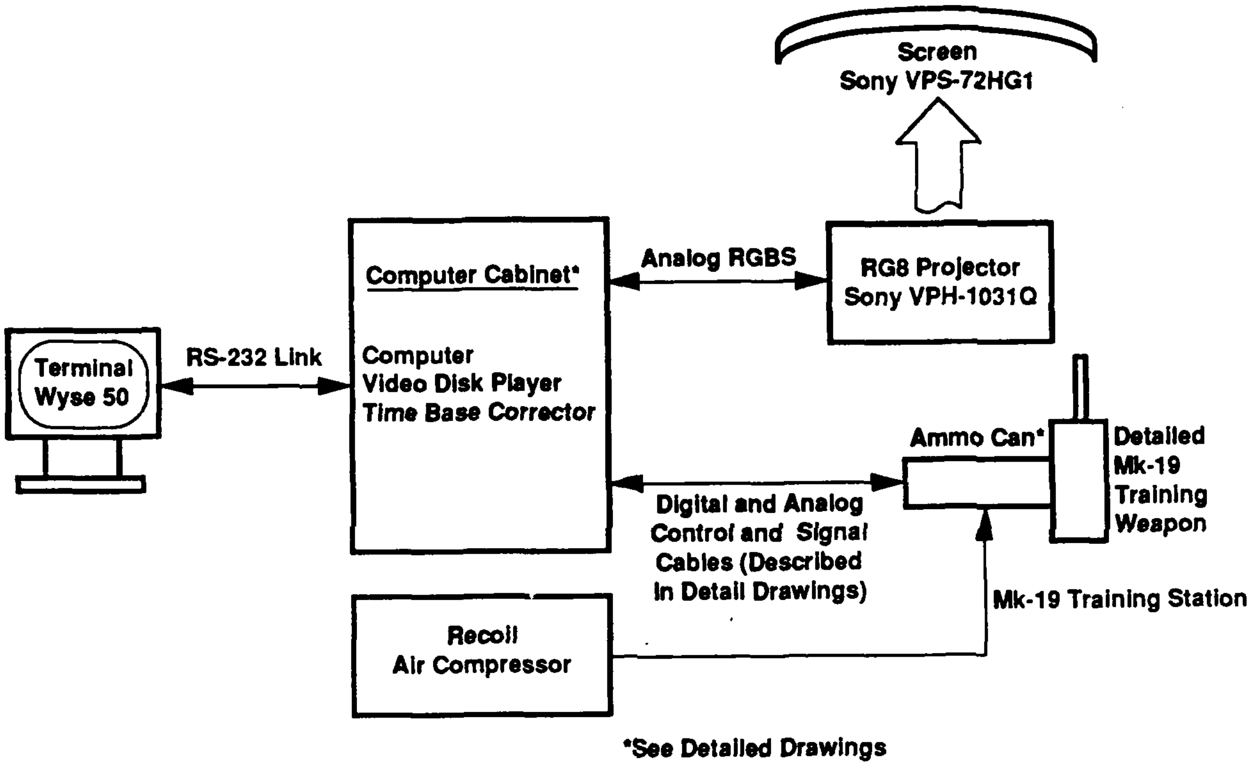

Figure 5. System block diagram.

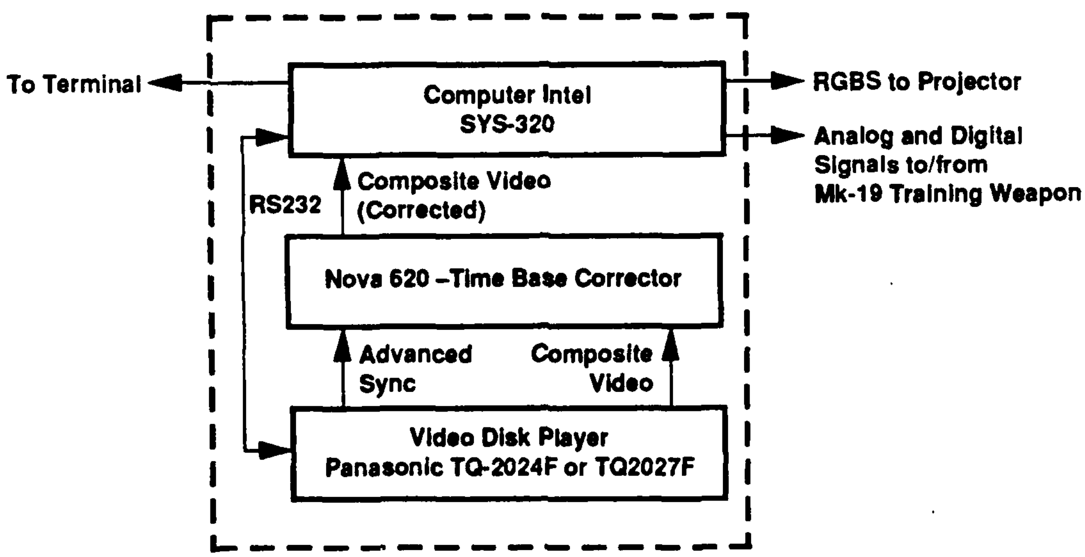

Figure 6. Computer cabinet.

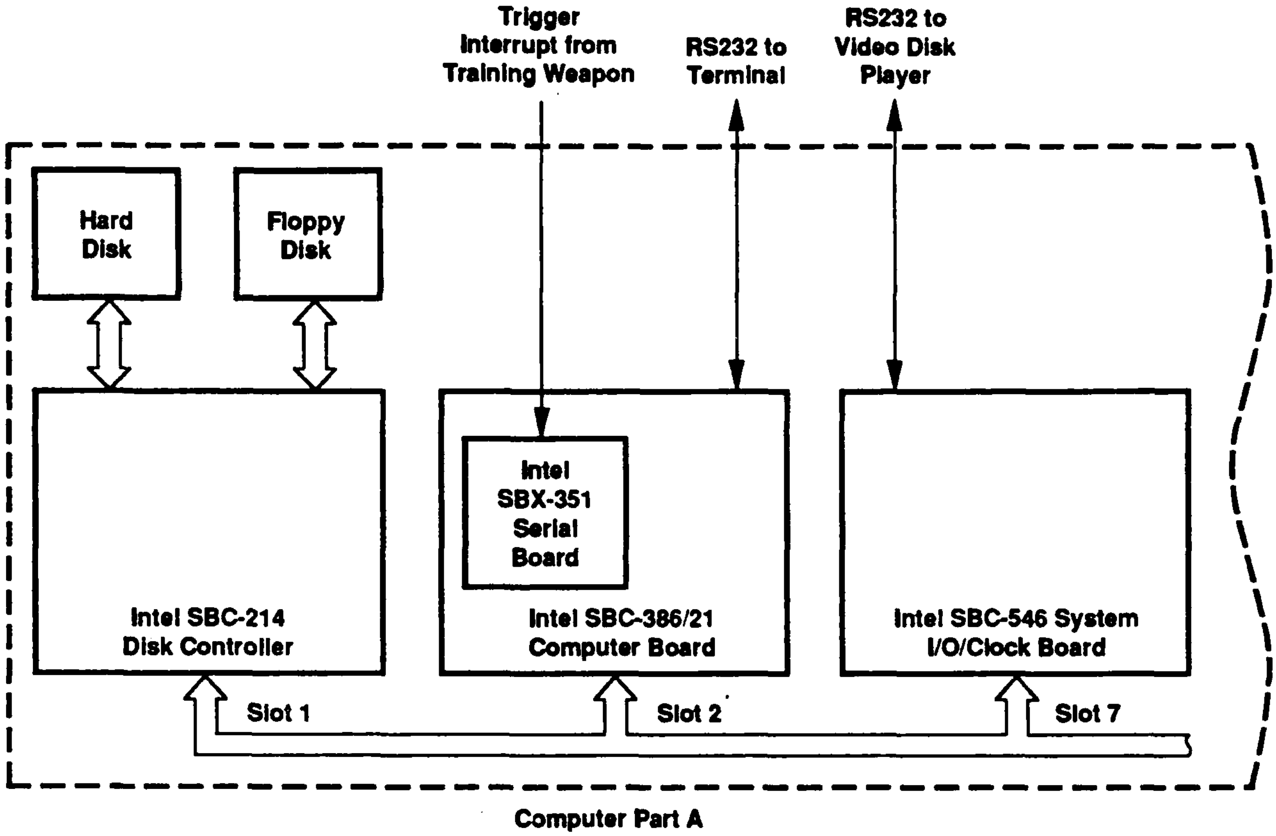

Figure 7. Computer sub-assemblies - 1.

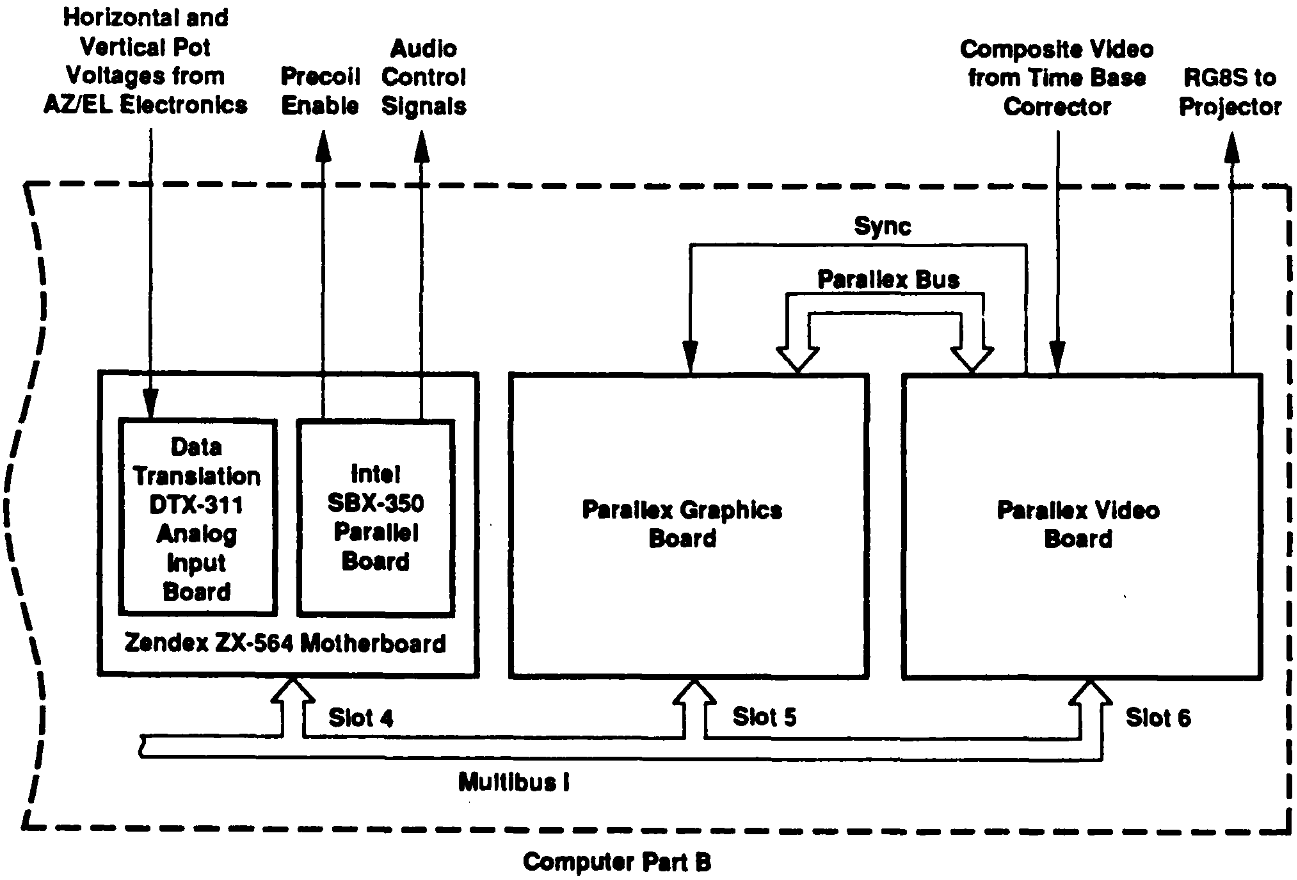

Figure 8. Computer sub-assemblies - 2.

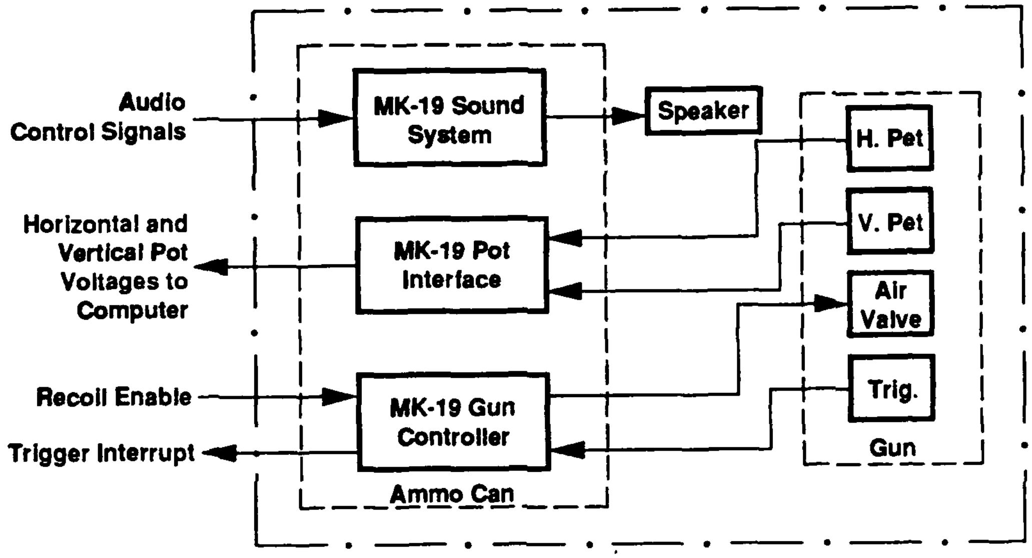

Figure 9. MK-19 training weapon.

Figure 5. MK-19 Training Weapons

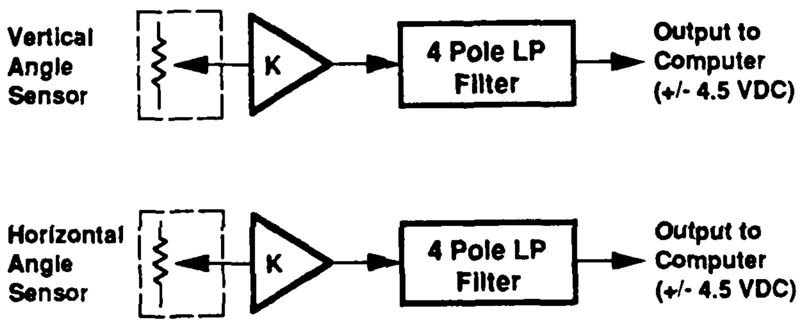

Figure 10. Gun sensor.

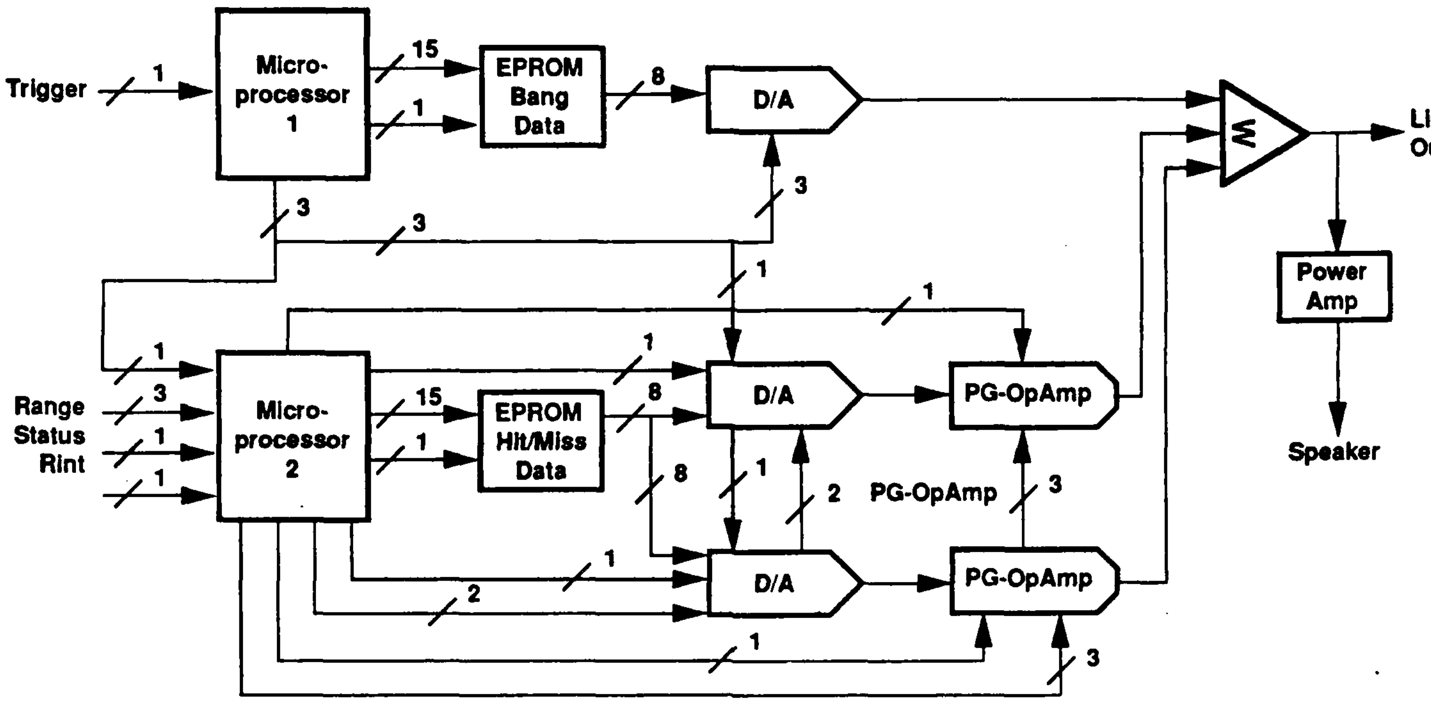

Figure 11. M-CAT sound system.

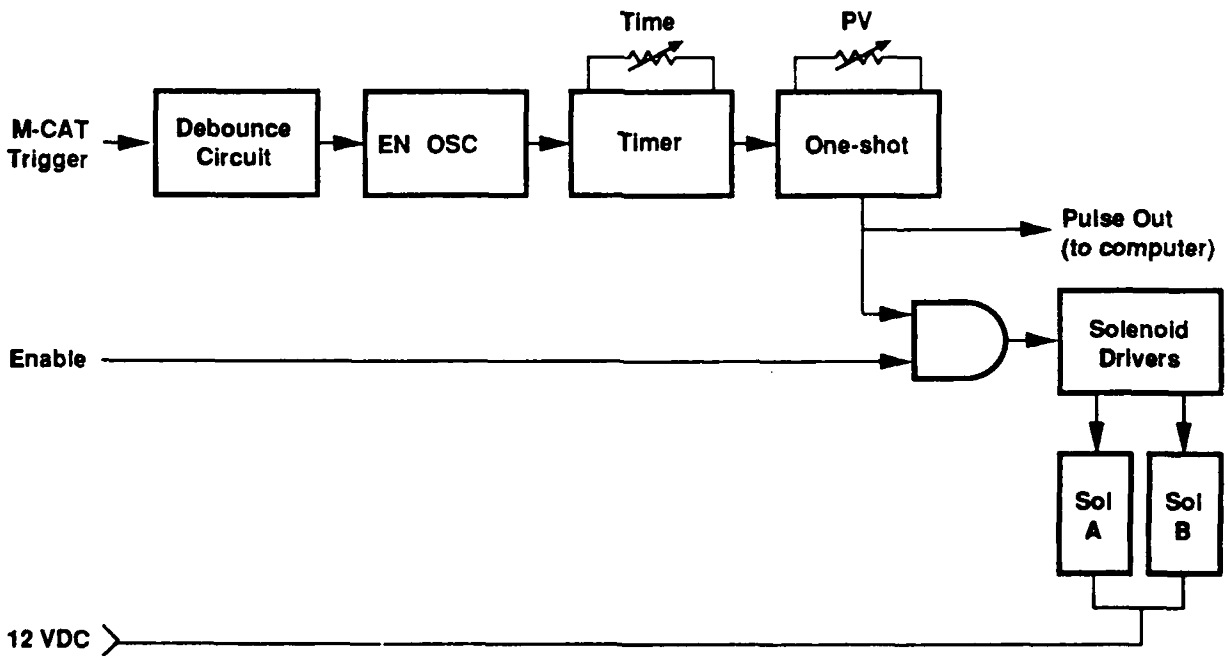

Figure 12. Recoil circuit.

CONCLUSIONS

The M-CAT equipment has been well accepted by the gunners who have made valuable suggestions to improve the feedback presented to the trainee.

The combination of video and graphics was preferred by subject matter experts over a purely graphics based system. A high level of scene realism is achieved using these techniques for a relatively low cost.

Using the M-CAT system the gunners were observed by subject matter experts to rapidly improve their gunnery skills. Trainees time on the trainer is not limited by ammunition, range and target availability or weather conditions.

The use of this trainer is very cost effective and eliminates the safety problem of training with live rounds. Live rounds cost about $12.00 each and limit live firing affordability.

COMTRAPAC and COMTRALANT have used the MK-19 training system for eight months without equipment failures. They have requested a COG 2.0 designation of the equipment and have requested a .50 cal upgrade or add-on be developed.

A proposal has been submitted to expand the M-CAT to include the 50 cal machine gun.

APPENDIX A

HORIZONTAL/VERTICAL POTENTIOMENTER DRIVER CIRCUIT

The horizontal/vertical potentiometer driver circuit (1a) was designed to supply two independent analog signals (varying from + 5vdc to - 5vdc) to the M-CAT system computer. The analog signals correspond to the vertical (ver) and horizontal (hor) position of the weapon. The hor and ver potentiometers (pots) are physically located on the M-CAT. The circuit consists of two identical channels. For simplicity only the horizontal channel will be described. The hor pot is wired between the 12 vdc bipolar supply. Resistors R16 and R18 are in series with the hor pot to act as a voltage divider. The hor pot will travel approximately 270 degrees for a full horizontal movement of the weapon . The voltage at the wiper of the pot is applied to IC1. IC1 acts as a buffer and a voltage scaler. R2 is adjusted so that the output of the hor channel will swing a maximum of +/- 5vdc. The output of IC1 is then filtered by a LP 4-pole Butterworth filter (fc=600hz). This cut off frequency was selected to minimize phase delay to a negligible value before being sent to the MCAT system computer.

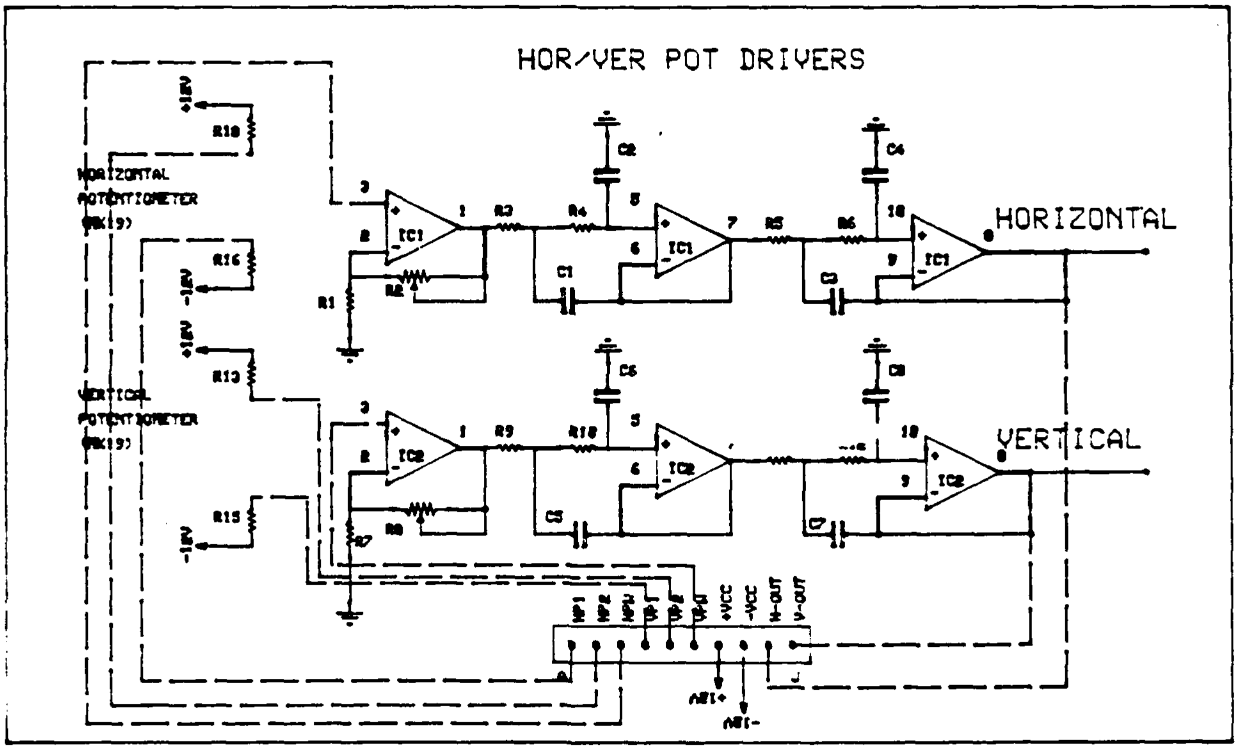

Figure A-1. Hor/Vert pot drivers.

APPENDIX B

M-CAT RECOIL/PULSE GENERATOR

The M-CAT Recoil/Pulse Generator Circuit (Figure 2A) was designed to generate the recoil and interrupt signal to the M-CAT system computer upon trigger pull. As the trigger is held down the circuit will generate a continuous pulse train for both the recoil drivers and the M-CAT system computer. IC1a is configured as a monostable multivibrator designed to oscillate at 262 hz. The trigger switch on the M-CAT is debounced and then used to control the start and stop of IC1a. IC1a is configured as a one shot astable multivibrator. IC1b effectively divides the output from IC1a to produce the 6 hz (167ms) rate required by the M-CAT system computer and the recoil drivers. Potentiometer R1 controls the divider rate of ICib. IC2 is also configured as a one shot astable multivibrator. IC2 is used to control the pulse width of the signal being supplied to the solenoid drivers. Potentiometer R2 controls the pulse width (25 msec) of the output of IC2. An enable signal is generated by the M-CAT system computer to disable the recoil signal via IC4. However, the M-CAT system computer will continue to receive the interrupt signal as the trigger is held down. The enable signal is also applied to the sound system to indicate the status of the ammunition can.

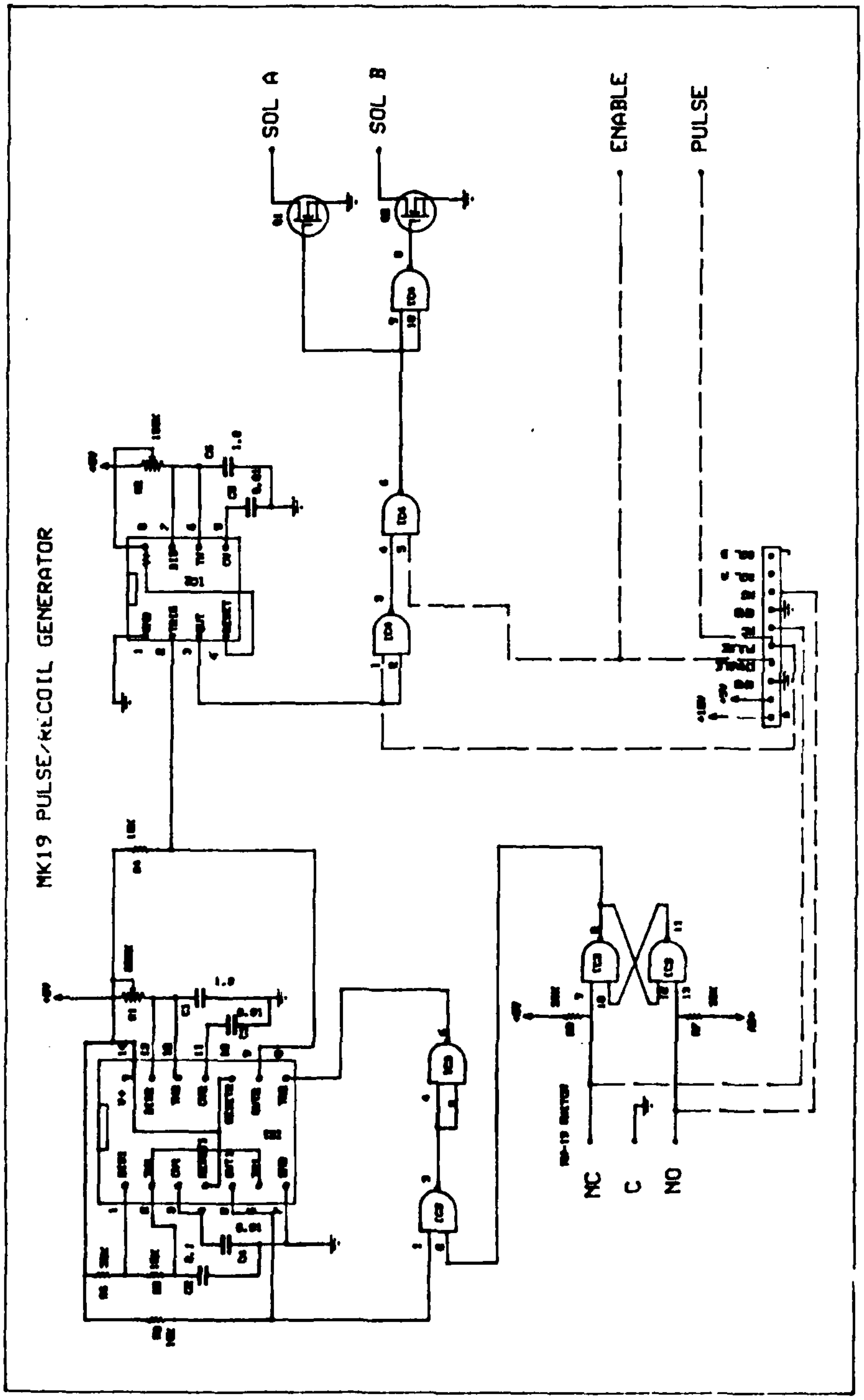

Figure B-1. MK-19 Pulse/Recoil generator.

APPENDIX C

M-CAT SOUND SYSTEM CIRCUIT DESCRIPTION

The sound system circuit (Figure C-1) was designed to generate up to three simultaneous digitized sound affects. The circuit can be broken into two sections. Section one consists of IC1, IC3, IC5, IC8, and IC9. This section is used to generate the digitized gunshot sound affect and can work independently of section two. Section two consist of IC2, IC4, IC6, IC7, IC8, IC9, IC10, and IC11. This section is used to generate the digitized misses and hits with digital volume control and sound delay. Section two cannot work independently of section one. Section one supplies both an interrupt signal and the digital to analog transfer pulse required by section two. The digitized gunshot is stored in an eprom (IC3). IC1 (uP1) contains the software to control the sampling of the data contained in IC3 and to control the digital to analog converter (IC5). IC1 also generates the xfer signal used to interrupt IC2 (uP2) and latch the digital to analog converters IC6 and IC7. The digitized miss and hit sound effects are also stored in an eprom (IC4). IC2 contains the software to control sampling of the data stored in IC4 and to control the digital to analog converters (IC6 and IC7). The volume is controlled by two programmable operational amplifiers (IC10 and IC11) under software control. All three digitized signals are fed into a simple summer network. The summed signals are then fed into a power amplifier designed to drive a pair of headphones or speaker. A line out signal is also available for an external amplifier and speaker if so desired.

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GENERAL CAPABILITIES

The MK-19 is a 40 mm machine gun that fires grenades at the rate of 375 rounds per minute. This weapon can penetrate up to two inches of armor and can saturate an area with lethal fragments. The effective range of the weapon is 1500 meters. The gunner can see the round during part of its trajectory and at maximum ranges the time of flight of the round can be 10 seconds, with the round achieving a maximum elevation of 100 meters. The gunner has to derive the fire control solution mentally using the location of the falling rounds as well as the visible part of the rounds trajectory. To train the gunner effectively, the simulator shows the rounds in flight as well as the rounds impacting on the water or target.

The display for the system is a 72 inch SONY projection TV. The system uses computer graphics and video disk technology to simulate the rounds in flight as well as the explosions of rounds hitting the water or target. Target areas are stored on video disc and can represent various sea states and lighting conditions. Explosions, rounds in flight etc. are inserted by a frame buffer on the video scene. The computer is an Intel 386 single board computer with a 387 math coprocessor. A de-militarized MK-19 is located in front of the projection TV. When the gunner fires the weapon he experiences recoil and hears the weapon noise. The weapon elevation and azimuth are determined by reading potentiometers located on a MK 64 Mod 4 gun cradle. Flight equations for the rounds have been determined using a fourth order series approximation of the trajectory. This gun mount, with its adaptors, can be used to mount other weapons for future expansion of the system to other similar minor caliber weapons (i.e., M-2, .50Cal, M-60 7.62 mm, M-249 SAW 5.56 mm).

The system is easily disassembled so that any part can be transported by two men. The system can be transported by either air or truck. The system is intended for use in a classroom environment. It is capable of operation in temperatures from 32 degrees F to 95 degrees F with humidities of 90 percent non-condensing or less. The computer equipment and video projector operate on 120 VAC 15A and the electric air compressor operates on 120 VAC 20A.

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EQUIPMENT DESCRIPTION

The M-CAT system (Figure 5) consists of the following major assemblies:

TRAINING STATION (MK-19)
COLOR VIDEO PROJECTOR
TV PROJECTION SCREEN
COMPUTER CABINET AND TERMINAL
ELECTRIC AIR COMPRESSOR

The training station contains a demilitarized MK-19. The MK-19 ammo box is used to store some of the system electronics. Recoil is simulated by pneumatically moving the MK-19 handles. The trainee selects a training scenario from an on-screen menu by pressing the weapon trigger. Results of the training scenario are presented to the gunner using text on the screen.

The color video projector is a SONY VPH-1031Q. It has a resolution of 1100 TV lines (RGB inputs) or 650 TV lines (video input). The projector is a direct projection system with 3 picture tubes and 3 lenses. The TV projection screen is a SONY VPS-72HG1 with a 72 inch diagonal dimension.

The computer cabinet (Figure 6) contains the following equipment:

INTEL SYS-320 COMPUTER
NOVA 620 TIME CORRECTOR
PANASONIC TQ-2024F VIDEO DISK PLAYER

The Intel Sys-320 computer controls the training system. The heart of the computer is an Intel 386 microprocessor chip with an Intel 387 math coprocessor. The Nova 620 is a digital time base corrector. It is used to time base correct the video data coming from the video disk player. Time based correction is necessary because of mechanical problems inherent with the video disk player. The video player disk contains the target scenarios. The player is controlled by the SYS-320 via an RS232C serial interface. The computer system (Figures 7 and 8) contains the following boards:

Parallax Video Graphics Boards (2)
INTEL SBC-214 Disk Controller
INTEL SBC-386/21 Computer Board
INTEL SBC-546 System I/O/ Clock Board
Zendex ZX-564 Mother Board
SBX-350 Parallel I/O
SBX-351 Serial/Timer
DTX-311 Analog Input

The Parallax graphics board implements a bus interface draw processor 2048 x 1024 x 8 bits of image memory, color look up tables and an RGB Output stage. The controller performs over 85 graphics instructions, operating at a basic drawing rate of 12 million pixels per second. The Parallax board generates the round in flight, and hit and miss explosions. The output of the Parallax board goes to the SONY projector.

Potentiometers on the gun cradle are used to determine the weapon azimuth and elevation. Voltages from the potentiometers are filtered by four-pole low-pass filters. These filters are implemented on the horizontal/vertical potentiometer driver circuit located in the ammunition canister. Appendix A provides a functional description and schematic of the circuit. After filtering, the horizontal and vertical position signals are converted to digital values by the Data Translation (DTX-311) analog input board (Figure 4). This board is located on the Zendex ZX-564 Mother Board in the computer.

A mechanical switch activated by the MK-19 trigger is used to control the recoil/pulse generator circuit located in the ammunition canister. This circuit, described in Appendix B, provides both an interrupt signal to the computer and allows control of the weapon's recoil mechanism (Figure 7).

With a video camera located at the same level as on a destroyer deck, target scenarios were recorded on a video disk. A Panasonic video disk player displays these scenarios as controlled via an RS-232 interface from the computer. Each frame of the video disk is individually digitized as to target size, location, and range. The guns azimuth and elevation are determined by reading potentiometers on the gun cradle. The computer calculates the rounds'trajectory and the Parallax graphics generates the rounds in flight and the explosions. The graphics data are then superimposed on the video disk target scene. The results are displayed by the video projector.

A sound system circuit is used to generate sound effects by playing back a digitized recording of the MK-19 muzzle blast along with simulated hit and miss explosions. This circuit, described in Appendix C, is located inside the computer rack. Two microcomputers on this circuit reproduce sounds by transferring data stored in EPROM to digital to analog converters. One processor generates the MK-19 muzzle blast while the other generates miss and hit explosions (Figure 11). Range and sound delay of the explosions are taken into account. These sound effects are mixed to create simultaneous sound effects. An amplifier on the circuit provides output for a headset or an external speaker.

Recoil is caused by moving the weapons handles using a pneumatic cylinder. Compressed air to the cylinder is controlled by using high speed solenoid valves. Figure 12 shows the recoil circuit. The compressed air is generated by a portable air compressor.

SOFTWARE DESCRIPTION

The M-CAT software was written using Intel's PLM-286 complier under the iRMX 286 operating system. This high level language along with the real-time capabilities of the operating system allowed rapid development of this application software.

Simulation of the MK-19 40 mm machine gun required knowledge of the ballistic characteristics of the 40 mm round. From aiming data for the 40 mm HEDP (m430) round, a ballistic model was determined using an iterative mathematical approach. From this model a solution for the projection of the round in flight at the screen distance was calculated. Using this information, graphical rounds and explosions are superimposed over the video disk image giving the gunner a visually correct perspective. Graphical sequences of hit and miss explosions are stored in the display buffer for block image transfer during program execution. These graphical images are loaded from the hard disk during program initialization. The graphics are updated at the frame rate of the video disk player (30Hz) using a double buffer drawing technique.

The information on the video disk can be separated into 35 scenarios, each showing a different range, speed, attitude, or direction of the target boat. The boat used was a 20.5 ft. boat with a 200 HP outboard. Target ranges are varied between 75 and 700 meters with boat speeds from zero to thirty-five miles per hour. Files which describe the outline and range of the target for each frame of a scenario are stored on the hard disk. Before a scenario is played the description file is loaded into memory for fast access by the program. Target hits are determined by comparing current grenade hit locations with the target location for the current frame. Presently six different training sessions are selectable for the on-screen menu. Each of these sessions provide the gunner with a random sequence of targets from a fixed list of video disk scenarios. For example, the lateral moving target session displays in a random order ten different scenarios of the video disk in which the target moves laterally to the gunner.

At the end of the session, a complete gunner assessment is printed on the screen. Gunner performance rating (expert, gunner, assistant gunner, and beginner) is determined based on the average number of rounds to destroy a target over the scenario. A target is destroyed or damaged based on a scoring system which monitors each rounds impact distance to the target. Each round impact within 60, 15, and 5 meters is given a weight, xx points. A sum total of these weights is calculated during each target's presentation in the scenario. A total of 40 points or more destroys a target. If the total is between 20 and 39 points the target is considered damaged. An example of a scenario scoring display follows.

An operator's menu provides flexibility to this scoring system and performance rating through several setup parameters. From this menu the instructor can vary the weight for each round impact distance (5, 15, and 60 meters). Also, the instructor can selectively activate each scoring distance through the skill level parameter. A skill level of 1 activates only the 5 meter impact distance. Skill level 2 activates both 5 and 15 meter impact distances. Similarly, skill level 3 activates 5, 15, and 60 meter impact distances. The basis for performance rating, average number of rounds per target destroyed, can also be varied for each rating classification. Once these parameters are set to the instructors specification they can be saved as the system startup parameters. This enables the instructor to configure the system as he or she desires. A sample scenario is shown below.

SCENARIO 6 (8 Targets)

# targets destroyed	006
# targets damaged	002
# rounds expended	144
#, % rounds within 5 meters	006, 004
#, % rounds within 15 meters	016, 011
#, % rounds within 60 meters	061, 042
average rounds/kill	024

RATING - EXPERT

SAMPLE SCENARIO SCORING DISPLAY

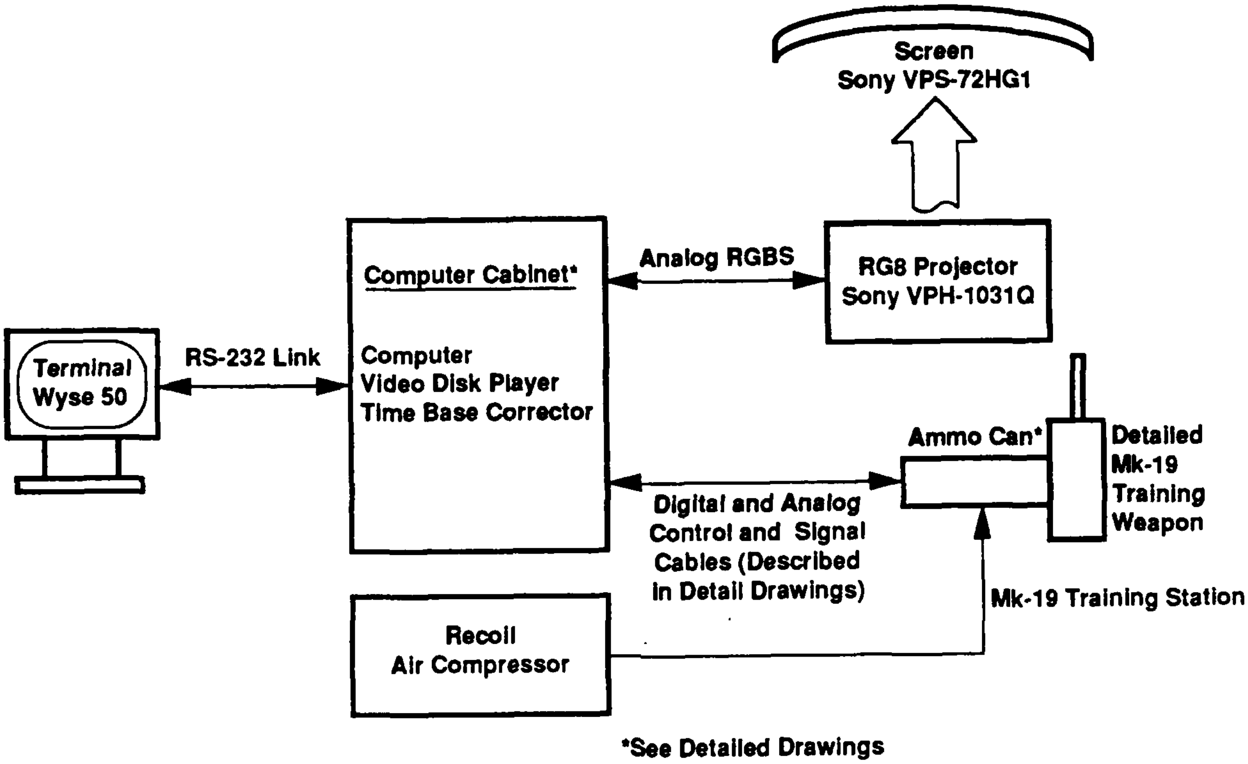

Figure 5. System block diagram.

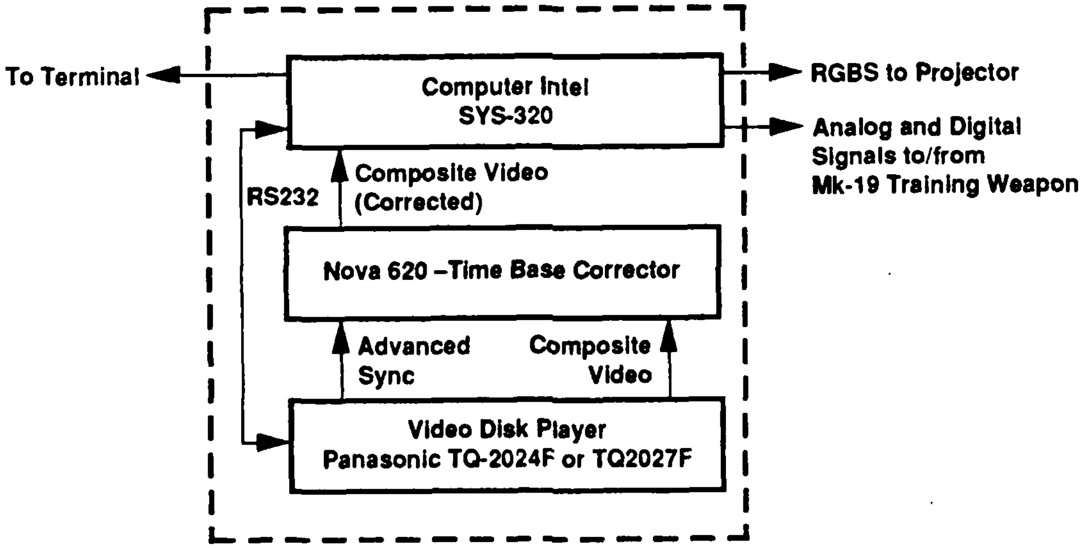

Figure 6. Computer cabinet.

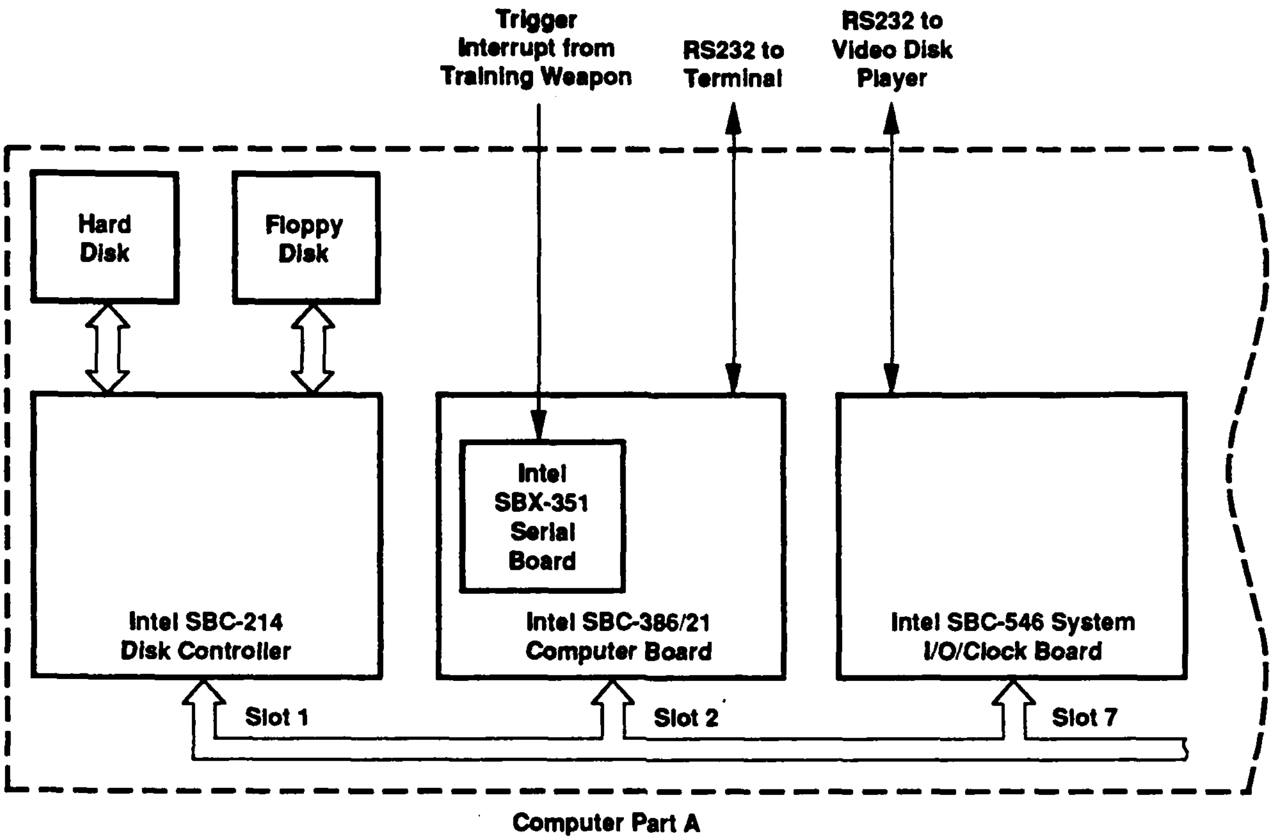

Figure 7. Computer sub-assemblies - 1.

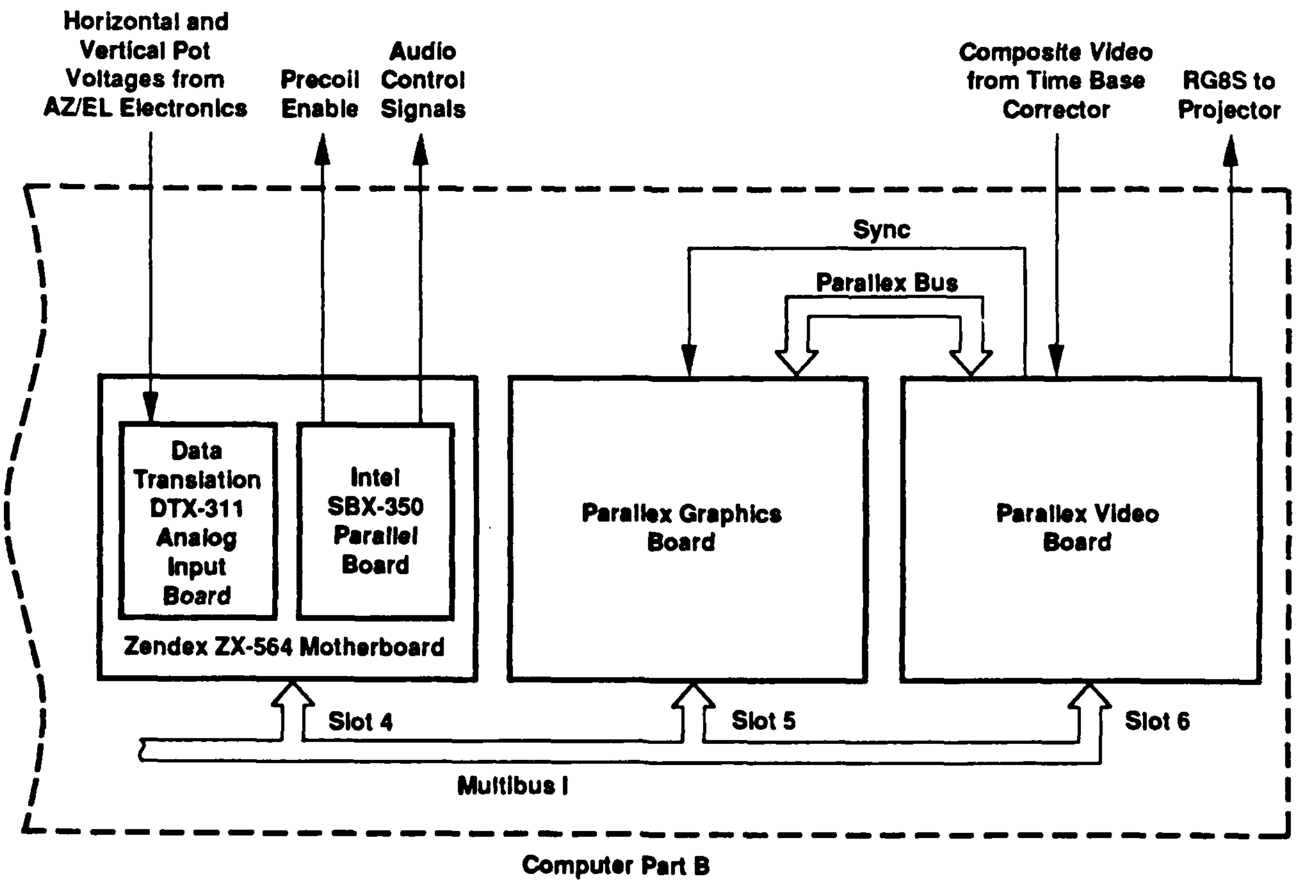

Figure 8. Computer sub-assemblies - 2.

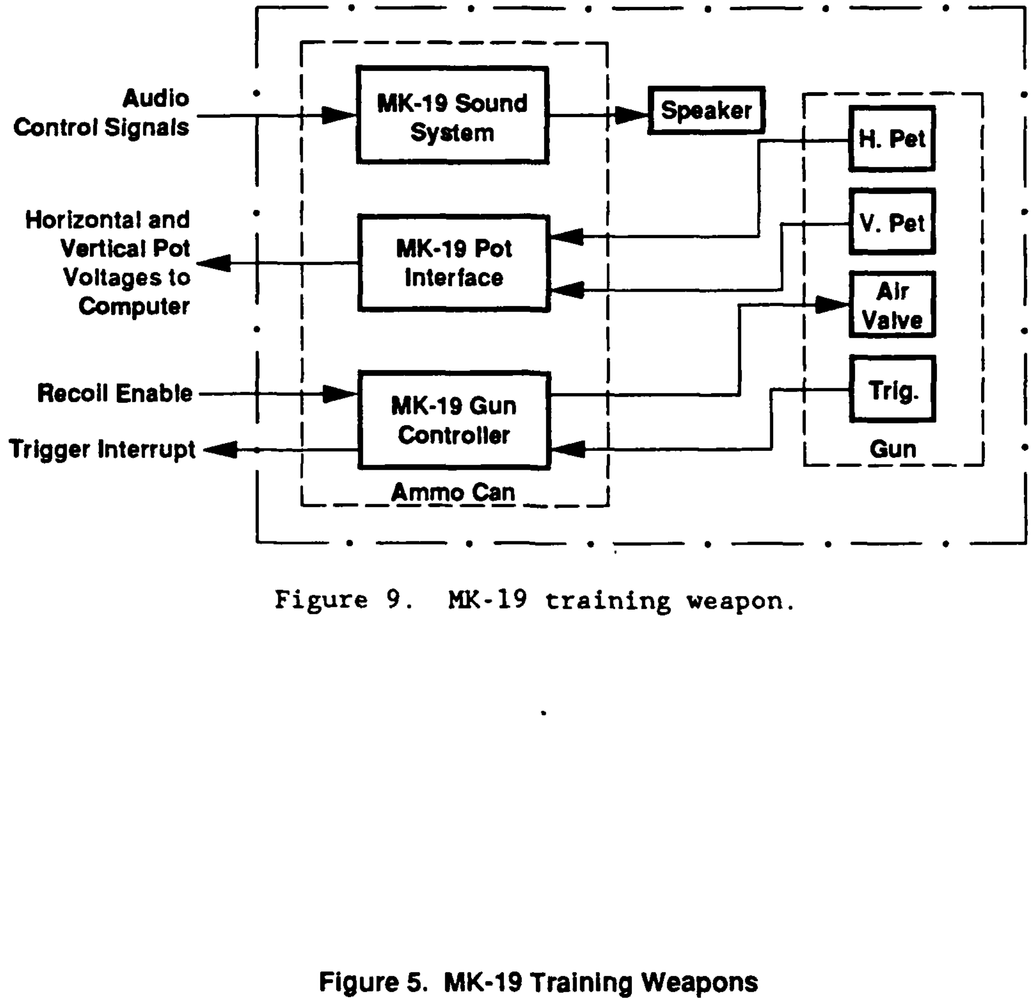

Figure 9. MK-19 training weapon.

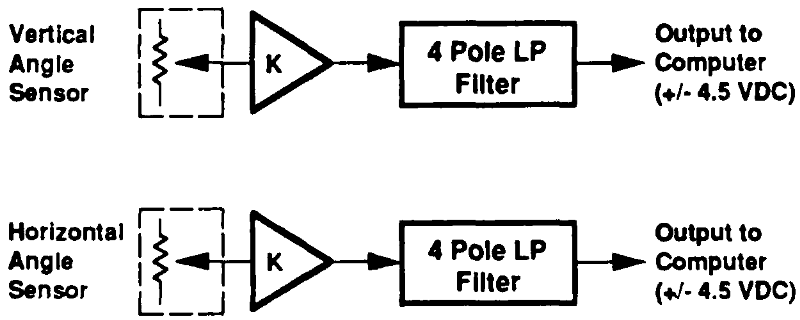

Figure 10. Gun sensor.

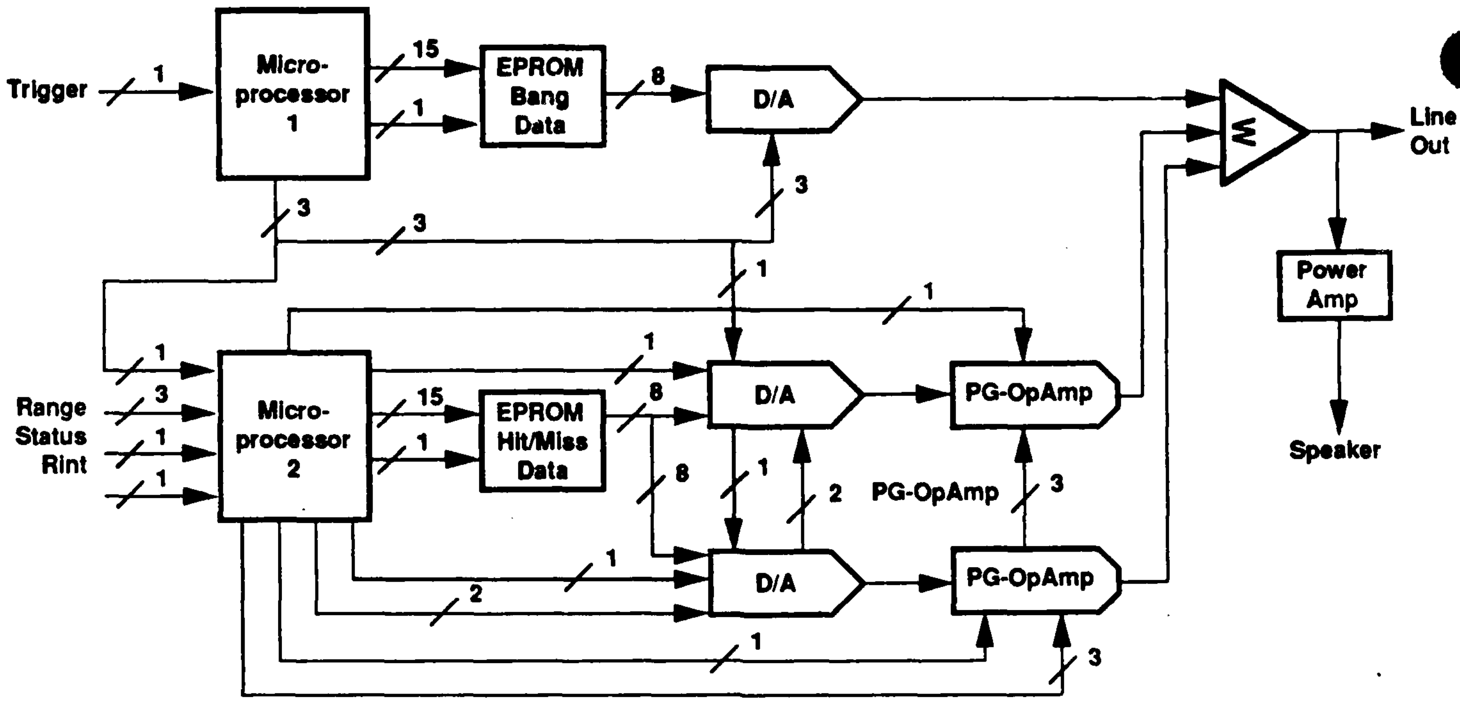

Figure 11. M-CAT sound system.

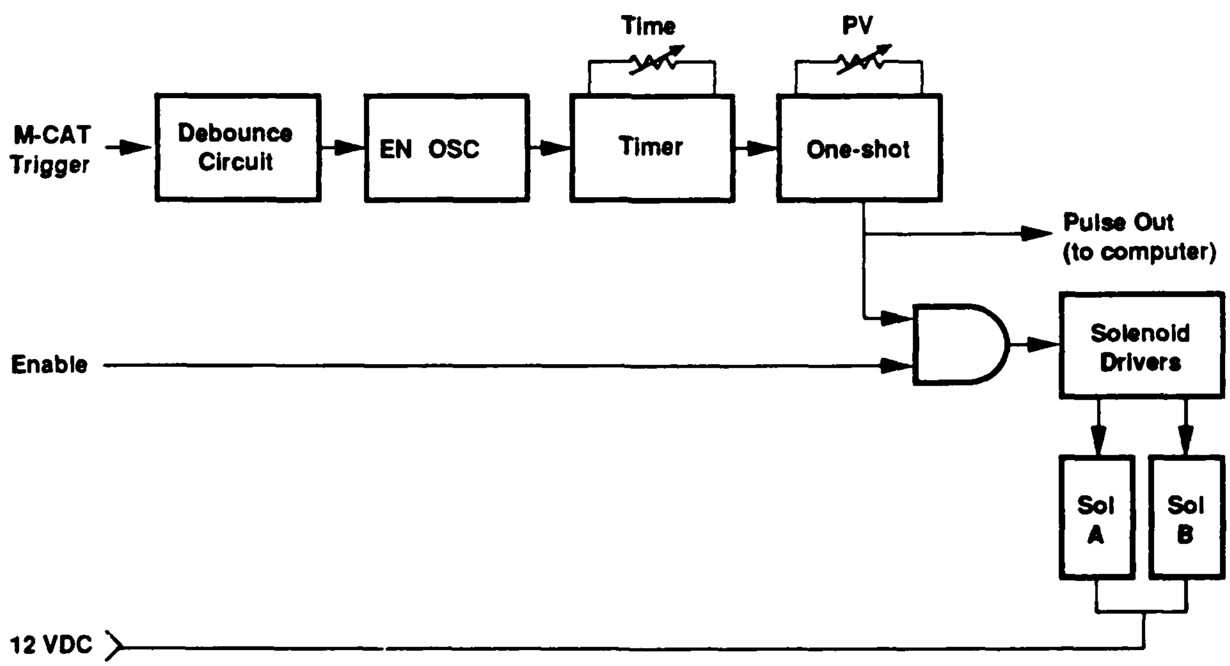

Figure 12. Recoil circuit.

CONCLUSIONS

The M-CAT equipment has been well accepted by the gunners who have made valuable suggestions to improve the feedback presented to the trainee.

The combination of video and graphics was preferred by subject matter experts over a purely graphics based system. A high level of scene realism is achieved using these techniques for a relatively low cost.

Using the M-CAT system the gunners were observed by subject matter experts to rapidly improve their gunnery skills. Trainees time on the trainer is not limited by ammunition, range and target availability or weather conditions.

The use of this trainer is very cost effective and eliminates the safety problem of training with live rounds. Live rounds cost about $12.00 each and limit live firing affordability.

COMTRAPAC and COMTRALANT have used the MK-19 training system for eight months without equipment failures. They have requested a COG 2.0 designation of the equipment and have requested a .50 cal upgrade or add-on be developed.

A proposal has been submitted to expand the M-CAT to include the 50 cal machine gun.

APPENDIX A

HORIZONTAL/VERTICAL POTENTIOMENTER DRIVER CIRCUIT

The horizontal/vertical potentiometer driver circuit (1a) was designed to supply two independent analog signals (varying from + 5vdc to - 5vdc) to the M-CAT system computer. The analog signals correspond to the vertical (ver) and horizontal (hor) position of the weapon. The hor and ver potentiometers (pots) are physically located on the M-CAT. The circuit consists of two identical channels. For simplicity only the horizontal channel will be described. The hor pot is wired between the 12 vdc bipolar supply. Resistors R16 and R18 are in series with the hor pot to act as a voltage divider. The hor pot will travel approximately 270 degrees for a full horizontal movement of the weapon . The voltage at the wiper of the pot is applied to IC1. IC1 acts as a buffer and a voltage scaler. R2 is adjusted so that the output of the hor channel will swing a maximum of +/- 5vdc. The output of IC1 is then filtered by a LP 4-pole Butterworth filter (fc=600hz). This cut off frequency was selected to minimize phase delay to a negligible value before being sent to the MCAT system computer.

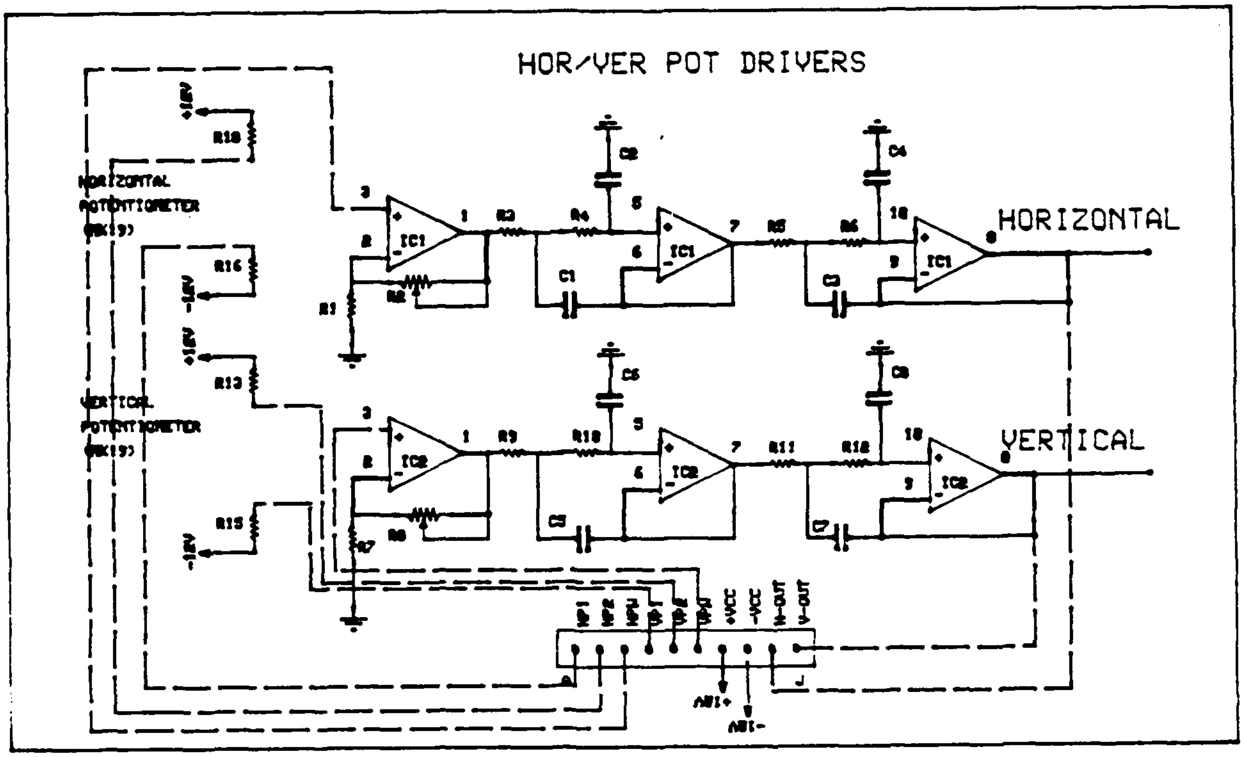

Figure A-1. Hor/Vert pot drivers.

APPENDIX B

M-CAT RECOIL/PULSE GENERATOR

The M-CAT Recoil/Pulse Generator Circuit (Figure 2A) was designed to generate the recoil and interrupt signal to the M-CAT system computer upon trigger pull. As the trigger is held down the circuit will generate a continuous pulse train for both the recoil drivers and the M-CAT system computer. IC1a is configured as a monostable multivibrator designed to oscillate at 262 hz. The trigger switch on the M-CAT is debounced and then used to control the start and stop of IC1a. IC1a is configured as a one shot astable multivibrator. IC1b effectively divides the output from IC1a to produce the 6 hz (167ms) rate required by the M-CAT system computer and the recoil drivers. Potentiometer R1 controls the divider rate of ICib. IC2 is also configured as a one shot astable multivibrator. IC2 is used to control the pulse width of the signal being supplied to the solenoid drivers. Potentiometer R2 controls the pulse width (25 msec) of the output of IC2. An enable signal is generated by the M-CAT system computer to disable the recoil signal via IC4. However, the M-CAT system computer will continue to receive the interrupt signal as the trigger is held down. The enable signal is also applied to the sound system to indicate the status of the ammunition can.

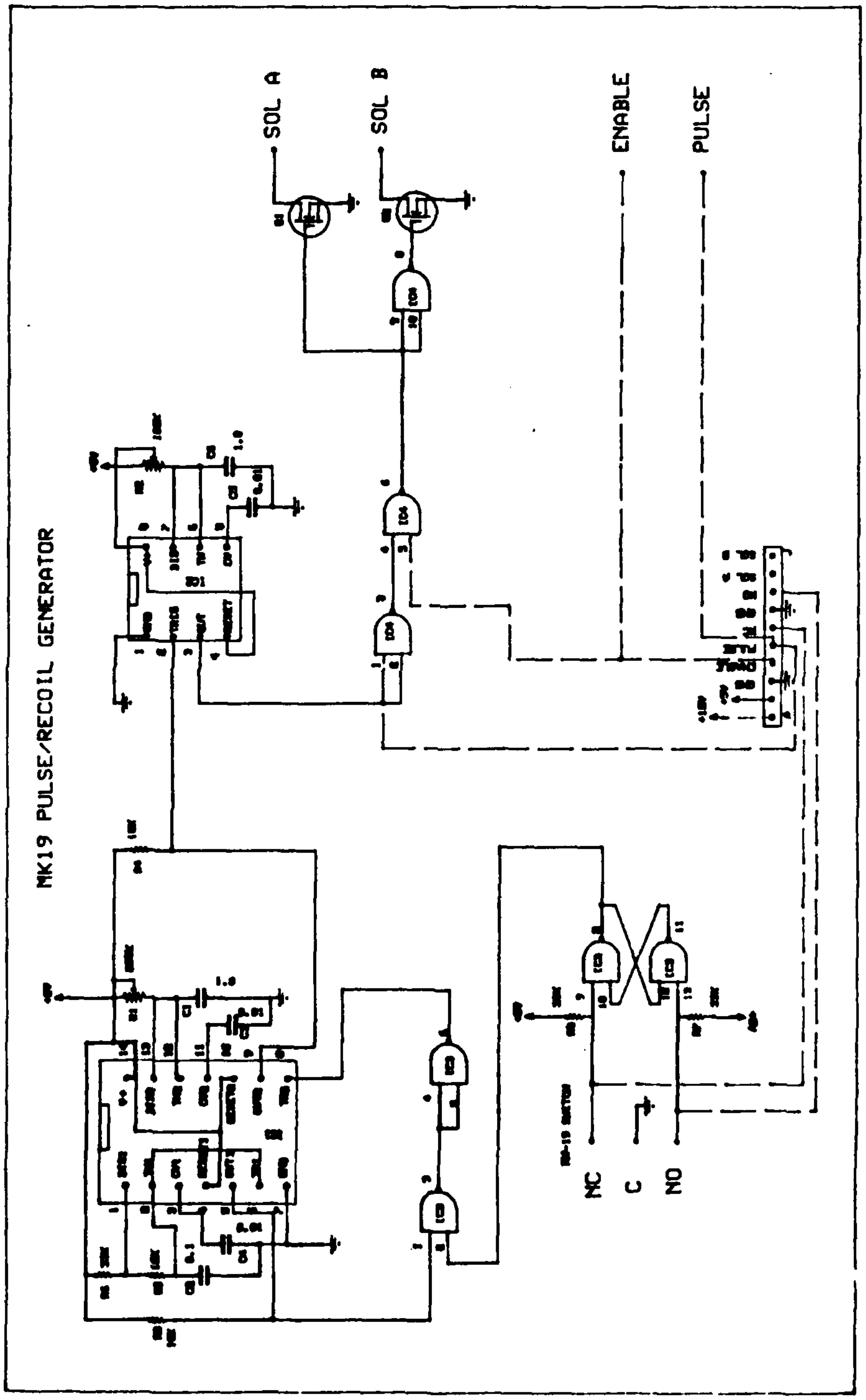

Figure B-1. MK-19 Pulse/Recoil generator.

APPENDIX C

M-CAT SOUND SYSTEM CIRCUIT DESCRIPTION

The sound system circuit (Figure C-1) was designed to generate up to three simultaneous digitized sound affects. The circuit can be broken into two sections. Section one consists of IC1, IC3, IC5, IC8, and IC9. This section is used to generate the digitized gunshot sound affect and can work independently of section two. Section two consist of IC2, IC4, IC6, IC7, IC8, IC9, IC10, and IC11. This section is used to generate the digitized misses and hits with digital volume control and sound delay. Section two cannot work independently of section one. Section one supplies both an interrupt signal and the digital to analog transfer pulse required by section two. The digitized gunshot is stored in an eprom (IC3). IC1 (uP1) contains the software to control the sampling of the data contained in IC3 and to control the digital to analog converter (IC5). IC1 also generates the xfer signal used to interrupt IC2 (uP2) and latch the digital to analog converters IC6 and IC7. The digitized miss and hit sound effects are also stored in an eprom (IC4). IC2 contains the software to control sampling of the data stored in IC4 and to control the digital to analog converters (IC6 and IC7). The volume is controlled by two programmable operational amplifiers (IC10 and IC11) under software control. All three digitized signals are fed into a simple summer network. The summed signals are then fed into a power amplifier designed to drive a pair of headphones or speaker. A line out signal is also available for an external amplifier and speaker if so desired.

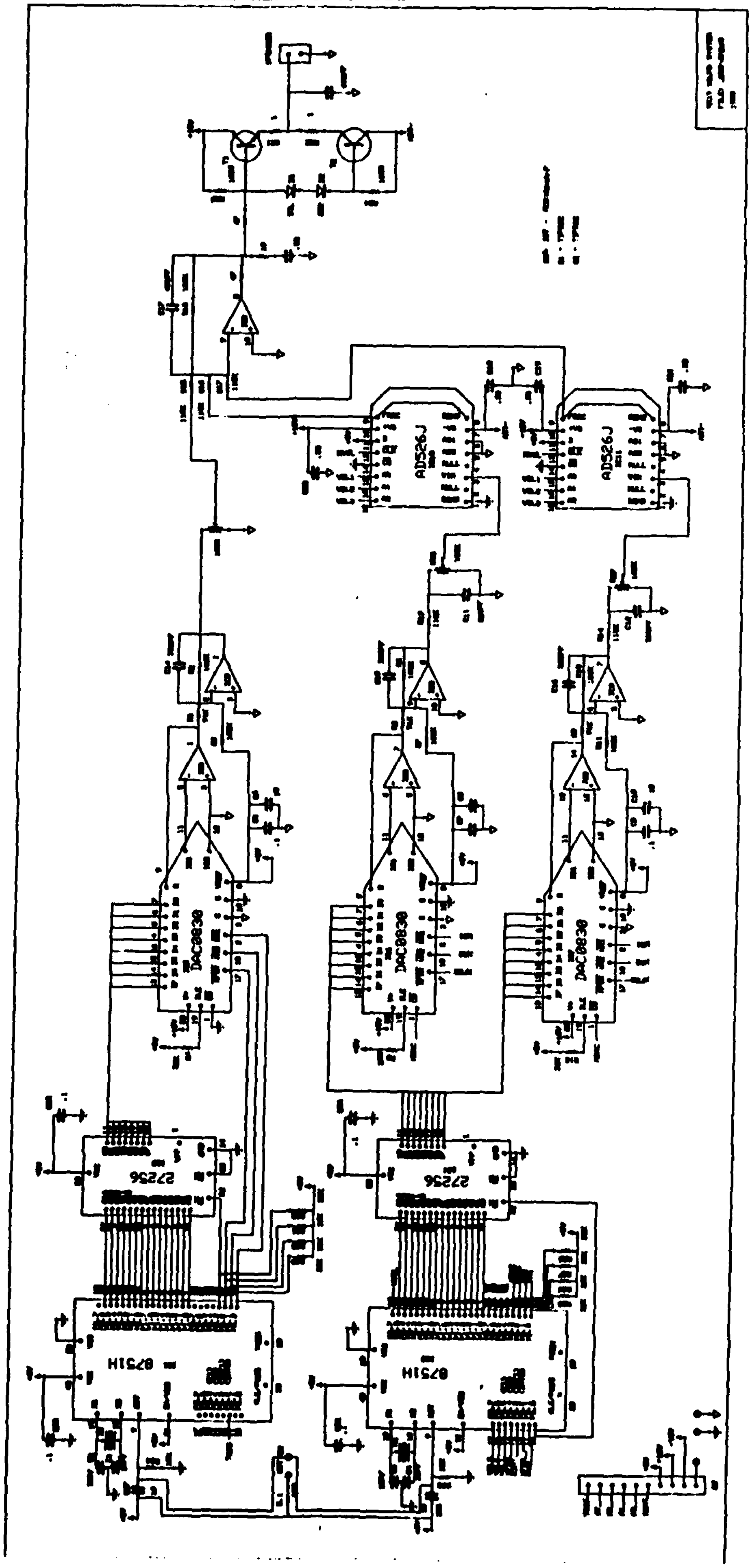

Figure C-1. MK-19 Multi-Sound Generator

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