AMBUSH

AMBUSH! is bound to rate as the most fascinating, exciting, and addictive space game of the year. It gives visual and sound effects of a space battle, and is loaded with realism. Impress your friends (and enemies) by building this unique and fascinating game.

(Photo by courtesy of 20th Century Fox)

AMBUSH! is a space game par excellence. It represents a space ship (yours) that is about to be attacked by a fleet of suicide craft. The craft can attack you on one of four randomly selected quadrants. The attacks come one at a time, at randomly selected intervals that vary between nought and five seconds. Your ship has a limited store of ammunition, and you can defend the vessel with one of four FIRE buttons. You have to hit the correct one of those buttons to stop the attack: if you hit more than one button at a time, you use up ammunition at an excessive rate.

The game continues until all the attacking craft are destroyed, or until you are wiped out. You can be wiped out by being too slow in hitting a FIRE button, by hitting the wrong FIRE button, or by running out of ammunition through incorrect operation of the FIRE buttons. You can chose to face an attack by either ten (a DEK) or a hundred (a CENT) suicide craft: ammunition storage is automatically selected to suit the type of game chosen. A DEK game typically takes less than one minute to play. A CENT game takes several minutes.

Sound And Light

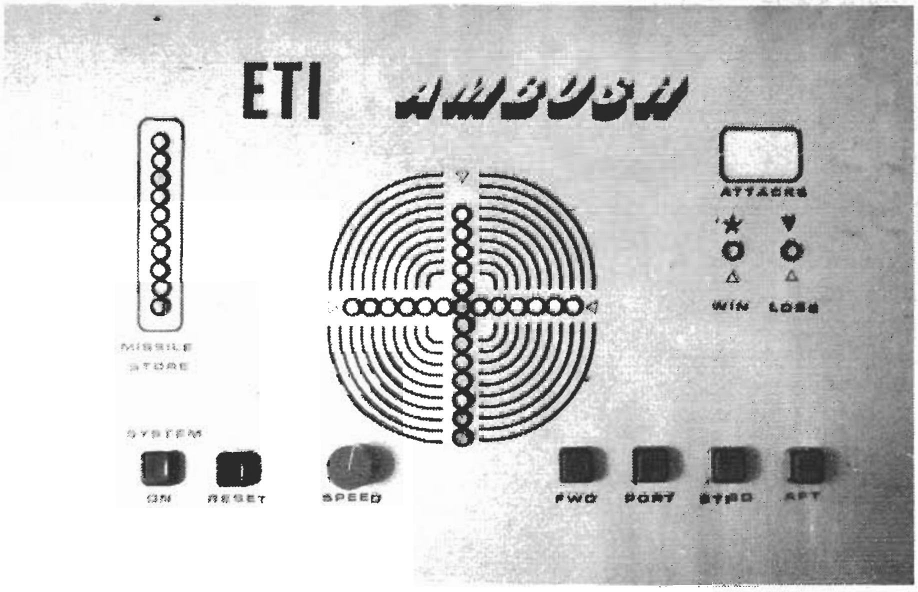
The game is loaded with audio and visual effects. On the sound side, there are individual noises to represent an attack, or the operating of FIRE weapons, and to indicate the winning or losing of a game. The level of the ATTACK sound varies with the quadrant of attack; attacks from the forward quadrant are silent, those from port or starboard are at half volume, and those from aft are at full volume.

The visual effects are also quite impressive. The attacks are shown by an array of LED's, arranged in the form of a cross with arms of varying lengths. The upper arm represents the forward attack quadrant, and comprises five orange LED's. The lower arm represents the aft attack quadrant, and comprises seven green LED's. The port and starboard arms each comprise six yellow LED's. At the centre of the cross is a red LED, representing your own ship.

The game is also provided with an ammunition level indicator, in the form of a three colour column of ten LED's, and with a two digit attack counter with seven-segment LED readouts. There are individual LED's to indicate the GAME WON and GAME LOST states.

Science Project

Ambush! is a CMOS based design of considerable technical interest, and should make an excellent educational project for schools and colleges. It uses seventeen IC's plus a couple of transistors. The IC types range from simple NAND and NOR gates to complete decade counter-decoder chips, and include flip-flops, data latches, 12-stage ripple counters, and multiplexers.



Playing The Game

Game Start. The game starts as soon as power is applied to its circuits. A game can be restarted by pressing the RESET switch.

Attacks:

(1). The game can be set for play against either ten (a DEK) or a hundred (a CENT) attacks.

(2). Attacks come at random intervals, variable between nought and approximately five seconds.

(3). The quadrant of each attack is randomly selected, except for the first attack of the game, which always comes from the aft quadrant.

(4). The speed of attack can be pre-set by the player, to suit skill levels. A 'respectable' attack speed is equal to about 50 mS per LED division on the quadrant attack indicator.

(5). At 'respectable' attack speeds, the player has approximately 250 mS of attack warning on the forward quadrant, 300 mS on the port and starboard quadrants, and 350 mS on the aft quadrant.

(6). Attacks on the aft quadrant are accompanied by a full volume staccato sound. Port and starboard attacks are at reduced volume, and those from the forward quadrant are silent.

(7). The accumulated number of attacks is registered on a 2-digit display throughout the game.

HOW IT WORKS

SIMPLIFIED BLOCK DIAGRAM OF THE AMBUSH GAME

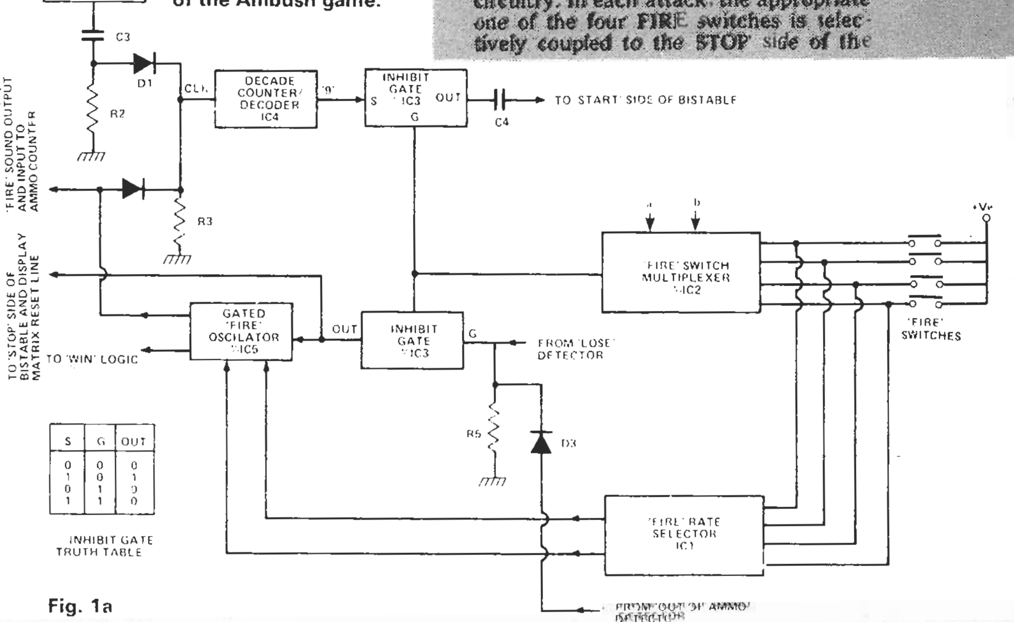
The heart of the unit is the 'Display Matrix Driver and Logic' block, which in reality takes the form of a 4017 decade counter with ten decoded outputs. Outputs 1 to 7 of the counter are fed to the LED display matrix, and outputs 6 to 8 are selectively fed via a multiplexer to the GAME LOST indicator block and to the CLOCK DISABLE pin of the 4017. The input of the 4017 is derived from a clock generator via a gate, which in turn is controlled by a simple START-STOP (Reset-Set) bistable.

The operating sequence of the above six blocks is fairly simple. Initially, the bistable is in the STOP mode, the gate is closed, the 4017 is in the RESET state, and all LED's in the display matrix are off. At some randomly determined time a START pulse is fed to the bistable, the gate opens, clock pulses start to reach the 4017, and LED's are sequentially switched on in one of the arms of the display matrix. If the gate remains open, one of the selectively chosen 6-7-8 outputs of the IC eventually goes high and operates the GAME LOST indicator and disables the clock input line of the 4017.

Alternatively, the bistable can be set to the STOP mode before the game terminates by operating the appropriate FIRE switch. In this case the bistable closes the clock gate, and the 4017 resets to the zero state. A new sequence of operations starts when another random START pulse is fed to the input of the bistable. Note that output 1 of the 4017 is fed to the ATTACK COUNTER, so that the counter advances by one count each time the clock generator gate opens. The game ends shortly after the attack counter reaches its full (at 10 or 100) state, at which point the GAME WON indicator circuits come into operation.

The START signal to the bistable is derived from the random delay generator, which is integral with the FIRE switch circuitry. In each attack, the appropriate one of the four FIRE switches is selectively coupled to the STOP side of the

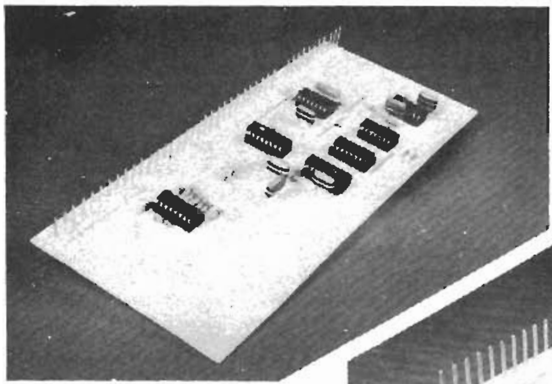
Figs. 1a and b. Simplified block diagram of the Ambush game.



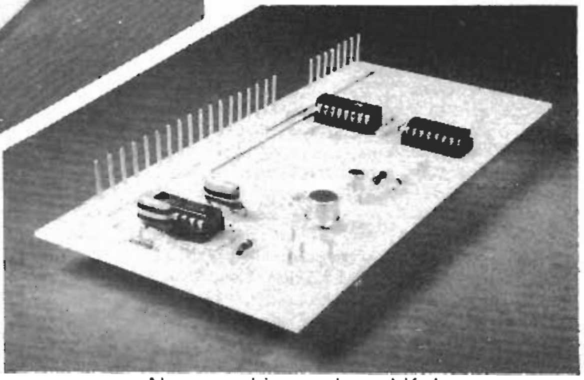
S	G	OUT
0	0	0
1	0	1
0	1	0
1	1	0

INHIBIT GATE TRUTH TABLE

Fig. 1a



(left) ICs 2 and 6-11 mounted on an Ambush PCB.



(right) This board carries LED display matrix drivers, multiplexers and logic, plus audio and power connections.

Defence

(a). The player has four FIRE buttons for defence. The buttons are marked F (forward), P (port), S (starboard), and A (aft). To stop an attack, the player must press the FIRE button appropriate to the prevailing attack quadrant, before the attacking vessel reaches its target (the red LED at the centre of the display). A correct firing is accompanied by a rasping sound. No sound is produced if the wrong button is pressed.

(b). The ship has sufficient ammunition to fight off attacks only if each FIRE duration is limited to about 100 mS or less. Thus, there is sufficient ammunition for about one second of continuous fire in the DEK game, and ten seconds of fire in the CENT game. The ammunition state is shown on a register throughout the game.

(c). When the correct FIRE button is pressed, the rate of ammunition usage is directly proportional to the total number of FIRE buttons that are pressed at that time. Thus, if all the fire buttons are pressed at once, the ammunition supply will exhaust in 0.25 seconds in the DEK game or 2.5 seconds in the CENT game. The audio frequency of the FIRE sound is proportional to the rate of ammunition usage. When the ammunition store is exhausted, the player has no defence, and loses the game after the next attack.

Game Lost. The player loses the game by having his starship hit by an attacking suicide craft. When the game is lost the red LED at the centre of the attack quadrant indicator turns off, and simultaneously a loud droning noise is generated and a red GAME LOST LED flashes on the control panel.

Game Won. The player wins the game by defeating all attacks. At GAME WON a green LED illuminates on the control panel, and a coarse beating or throbbing sound is generated. ▶

bistable via a multiplexer, and a simulated 'fire' sound is generated if the operator activates the correct switch; the frequency of the 'fire' sound is determined by the FIRE RATE SELECTOR circuit, and is proportional to the total number of FIRE switches pressed at any given moment.

The output of the fire sound generator is used to drive the ammunition register, which counts and gives a visual readout of the total number of cycles generated. The sound is also used to generate a latched random 'select' code for the four multiplexers that are used in the game. These multiplexers are used for FIRE switch selection, for LED Display Matrix line and line length selection, and to determine the audio levels of the ATTACK sounds.

The ATTACK, FIRE, WIN and LOSE sound signals are all fed to a simple two-transistor audio amplifier, which drives a 40 ohm output speaker.

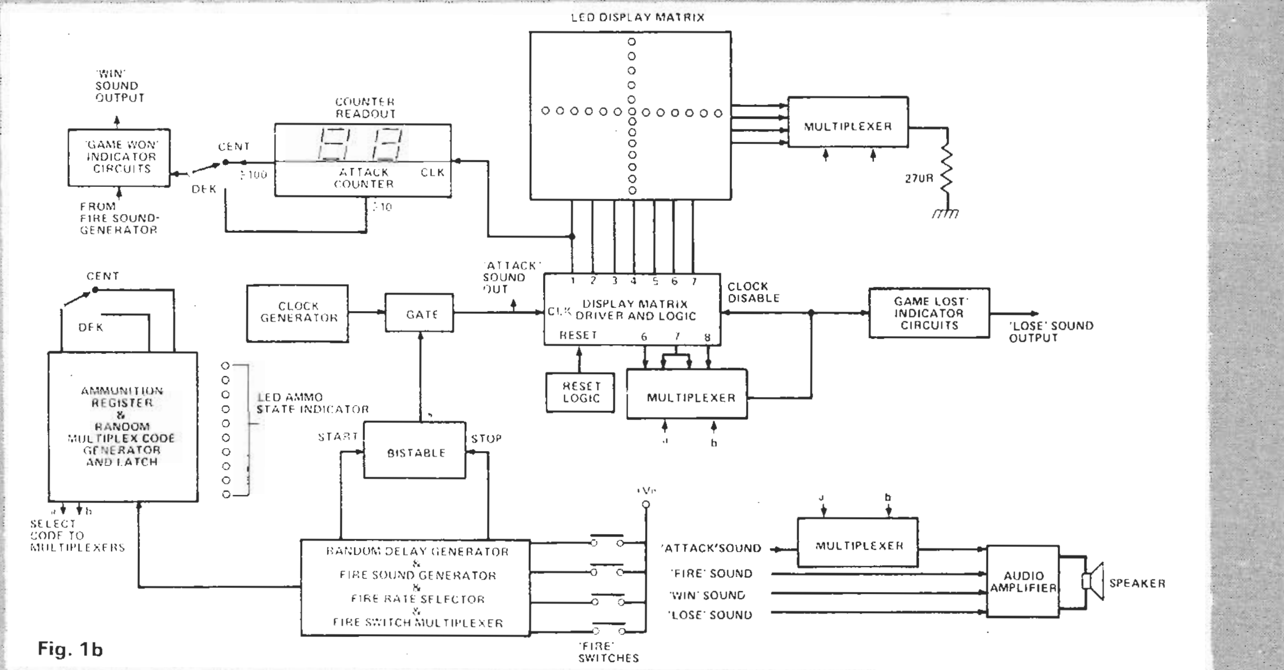


Fig. 1b

HOW IT WORKS

RANDOM DELAY and 'FIRE' SOUND GENERATOR, plus 'FIRE' RATE SELECTOR and FIRE SWITCH MULTIPLEXER

THIS IS probably the most complex 'block' in the entire game, because most of its individual sections are interdependent. Fig. 2 shows the circuit diagram of this major 'block'.

THE 'FIRE' SOUND GENERATOR

Let's deal first with the 'FIRE' SOUND GENERATOR. IC2 is one half of a 4052 dual 4-channel multiplexer. This connects a selected one of its four inputs to its output, depending on the 'a — b' binary code signal that is fed to its 'select' (pins 9 and 10) terminals. Thus, when the appropriate one of the four FIRE switches is pressed, a logic-1 signal appears at output pin-3 of the multiplexer. This signal is 'debounced' by R6-C6 and R7, and is passed to the signal input of the INHIBIT GATE formed by IC3/3 and IC3/4.

It passes signals only when its GATE input is at logic-0: pin-1 is the 'G' terminal of this particular gate, and is tied to ground via R5, but can be driven high by the outputs of the LOSE and OUT OF AMMO detectors. The gate thus passes on the FIRE switch signals only when the game is not lost and the ammunition store is not exhausted.

The output of the inhibit gate is used to activate a gated 'FIRE' sound oscillator designed around IC5/3 and IC5/4. The main timing components of this oscillator are C2 and R12 to R15. These timing resistors are connected via IC1, which is a 4016 quad bilateral switch, which has each of its four internal 'switches' activated by one of the four FIRE switches: these internal switches are normally open, and close when their appropriate FIRE switch is closed.

Thus, the complete action of the 'FIRE' sound generator is such that a sound is produced only when the 'correct' FIRE switch is pressed, and only when the game is not lost or the ammunition exhausted. The frequency of the sound is proportional to the total number of FIRE switches pressed and varies from about 800 Hz for one switch, to about 320 Hz for four switches.

The pin-4 output of the 'FIRE' oscillator is low in the normal quiescent state, and its signals are passed to the input of an audio amplifier for sound effects, and also to the inputs of the ammunition register and the Random Delay generator. An inverted output (normally high) is also taken from the pin 3 output of the oscillator and is fed to the WIN LOGIC circuitry. Note that the gate input signal of the oscillator is also fed to the STOP side of the bistable and to the RESET pin of the display matrix driver, so that IC12 is reset each time the correct FIRE switch is pressed.

THE RANDOM DELAY GENERATOR

The heart of the random delay generator is IC4, a 4017 decade counter with ten decoded outputs (numbered 0 to 9): the '9' output of the counter is coupled to the START side of the bistable via a normally-ON inhibit gate. The clock input to the counter is derived from a slow (about 2 Hz) oscillator (IC5/1 and IC5/2) and from the 'FIRE' oscillator output via an OR gate formed by D1-D2 and R3.

Whenever the correct FIRE button is pressed during an attack a logic-1 signal is fed to the 'G' (pin 13) terminal of the inhibit gate, which turns off and blocks the signals from the 4017 counter. Simultaneously, fast clock signals are fed into the counter from the 'FIRE' sound generator. Consequently, when the FIRE switch is released and the inhibit gate returns to the ON state the counter is an unknown or random number of steps from the '9' count (which is the one that provides the START signal to the bistable). Clock signals are then fed to the counter from the slow oscillator only until, after a delay that is infinitely variable from zero to about five seconds, the counter reaches the '9' state and feeds a START command to the bistable.

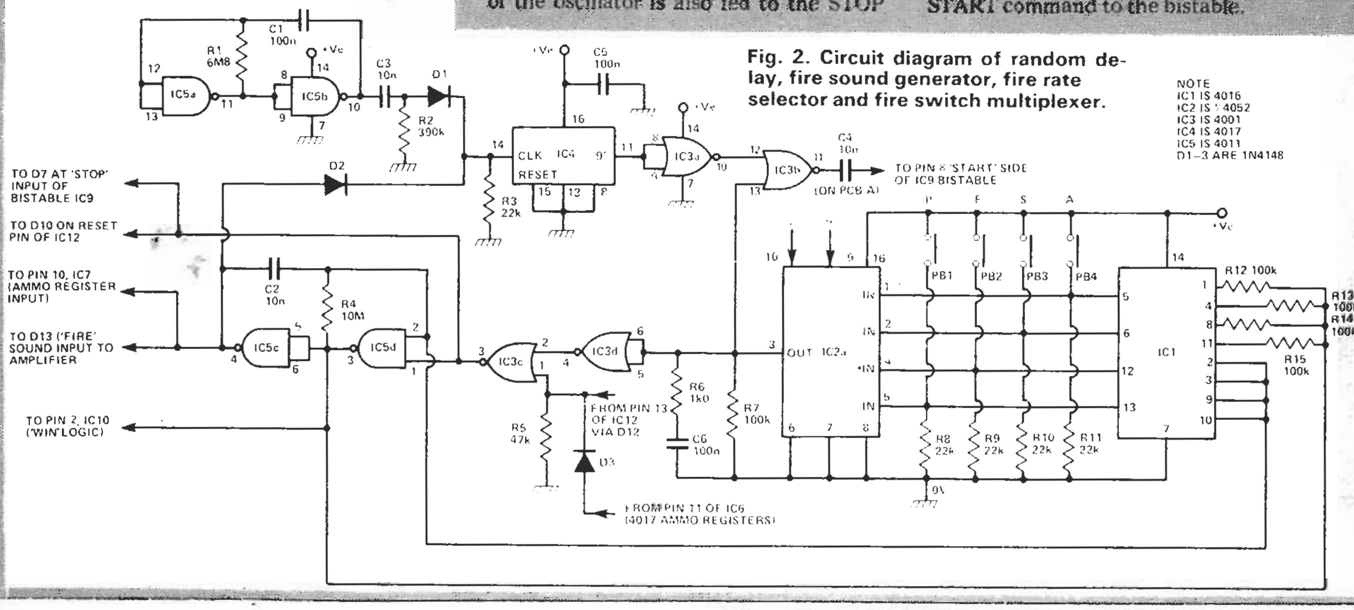


Fig. 2. Circuit diagram of random delay, fire sound generator, fire rate selector and fire switch multiplexer.

HOW IT WORKS

THE BISTABLE, CLOCK GENERATOR, 'ATTACK' SOUND MULTIPLEXER, AND 'GAME LOST' INDICATORS

THE BISTABLE is a simple R-S type, made from a pair of NOR gates (IC9/1 and IC9/2). Its 'START' input is derived from the random delay generator via C4, and 'STOP' inputs are obtained from the 'FIRE' logic or the 'GAME LOST' detector circuitry via the D6-D7-R30 diode OR gate. The pin-1 output of the bistable is normally high, but goes low in the "START" mode, and is fed to one input of the IC10/3 NOR gate, which provides the clock input signal to IC12 (the display matrix counter-driver). The other input of the NOR gate is obtained from the variable-speed CLOCK GENERATOR (IC10/1 and IC10/2) or from the WIN DETECTOR circuitry via the D4-D5-R28 diode OR gate.

Thus, input pin-6 of the NOR gate is normally high, and its output is locked low, so it is unable to pass clock signals. When a 'START' signal is fed to the bistable from the random delay generator, input pin-6 of the gate is driven low, and it does pass clock signals. The gate is turned off again when a 'STOP' signal is fed to the bistable from the 'FIRE' logic circuitry. Note that the gate gets locked into the off state if a logic-1 signal is fed to its pin-5 input from the 'WIN' detector (via D4), or if a logic-1 'GAME LOST' signal is fed to the 'STOP' side of the bistable via D6.

The IC10/1 and IC10/2 clock generator determines the speed of any attack, and its frequency is variable via RV1. The clock signal appearing at the pin-11 output of the IC10/3 NOR gate provides the basic 'ATTACK' sound of the game. The amplitude of this sound is determined by multiplexer IC2/2 and resistors R31 and R32. Attacks from the aft quadrant are at full volume, those from port or starboard are at reduced volume, and those from the forward quadrant are silent.

The 'GAME LOST' indicators use four NAND and one NOR gates: their basic input signals are obtained from pin-13 of IC12, which is normally low but goes high under the game lost condition. IC9/3 is wired as a simple inverter, and drives the

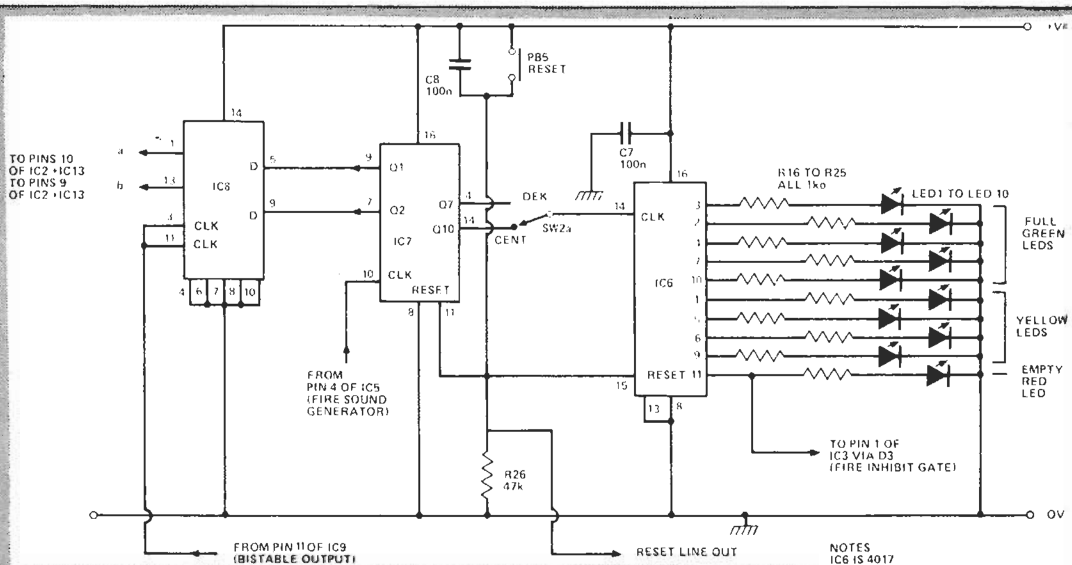


Fig. 3. Circuit diagram of ammo register, random multiplex code generator and latch with the reset line control.

HOW IT WORKS

THE AMMO REGISTER, RANDOM MULTIPLEX CODE GENERATOR AND LATCH, AND RESET LINE CONTROL

THIS BLOCK is relatively simple in its theory of operation. IC7 is a 4040 12-stage ripple counter, and takes its clock input from the output of the 'FIRE' sound generator. IC8 is a 4013 dual D flip-flop, which is wired as a dual data latch with its clock signal taken from the output of the bistable and its data taken from the Q1 (÷ 2) and Q2 (÷4) outputs of IC7. Thus, whenever a FIRE button is pressed and then released IC7 sets randomly determined states on the data inputs of IC8: the next time that the output of the bistable goes high (as an attack begins, on receipt of the bistable START command) these states are latched into the 4013 and are pressed on to the games multiplexers as a 2-bit binary code.

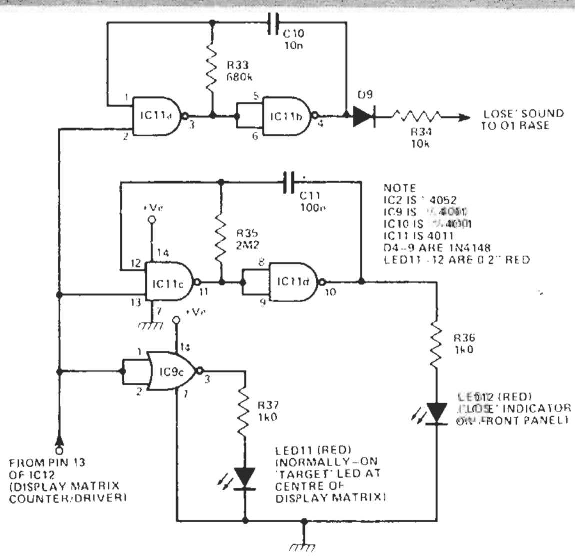
IC6 is yet another 4017 decade counter with ten decoded outputs. It has its outputs fed to a vertical line of ten LED's, which act as the ammunition register. The '0' output of the 4017 goes to the top (FULL level) of the line, and the '9' output goes to the bottom (EMPTY level) of the line. The '9' output also goes to the inhibit gate controlling the 'FIRE' oscillator, preventing the oscillator from working under the 'ammo exhausted' condition. At the start of each game the counter is reset to zero, so that the line of LED's indicate the FULL state.

The clock input of the counter is taken from one of the outputs of the IC7 ripple counter via SW2a. When SW2 is set for a DEK (ten attack) game the Q7 (÷ 128) output is fed to the clock input of IC6, giving a clock signal of about 6.2 Hz when a single FIRE button is operated, and thus causing the register to empty in about 1.5 seconds. When SW2 is set for a CENT (hundred attack) game the Q10 (÷ 1024) output is fed to IC6, giving a clock frequency of about 0.8 Hz from a single FIRE button, and causing the register to empty in about 11.2 seconds. Thus, to win a DEK game the average FIRE duration must be limited below 150 mS in each attack, and in the CENT game it must be limited below 112 mS.

The games main reset line is activated automatically at switch-on via C8. The line can be operated manually at any time via RESET button PB5.

red LED at the centre of the games main display matrix. This LED is normally on, but goes off when the game is lost.

IC11/1 and IC11/2 are wired as a medium-speed gated astable, which provides the 'GAME LOST' sound output via D9 and R34, and IC11/3 and IC11/4 are wired as a low-speed gated astable, which drives a red 'GAME LOST' LED. Both astables are normally off, with their outputs low. Under the 'GAME LOST' condition both astables operate, the 'LOSE' sound is generated and the 'LOSE' LED flashes on and off.



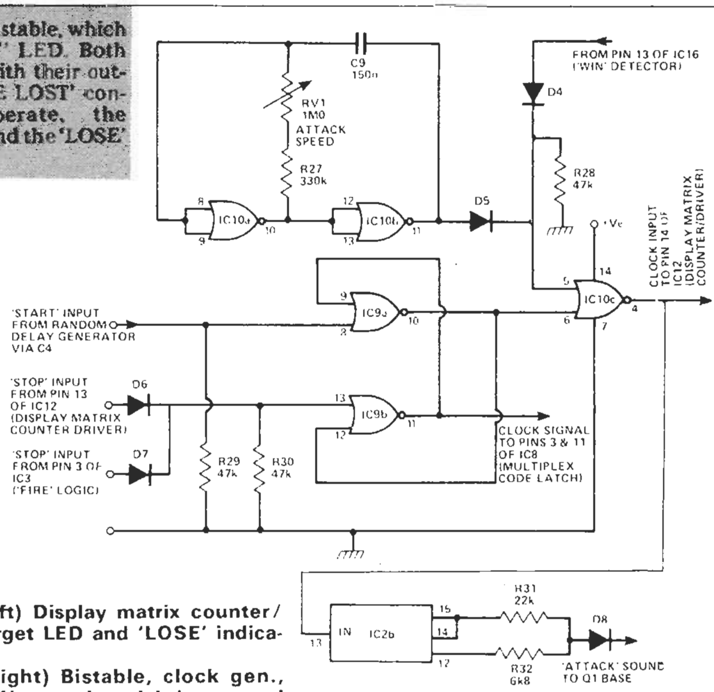


Fig. 4 (left) Display matrix counter/driver, target LED and 'LOSE' indicator.
Fig. 5. (right) Bistable, clock gen., 'ATTACK' sound multiplexer and 'GAME LOST' indicators.

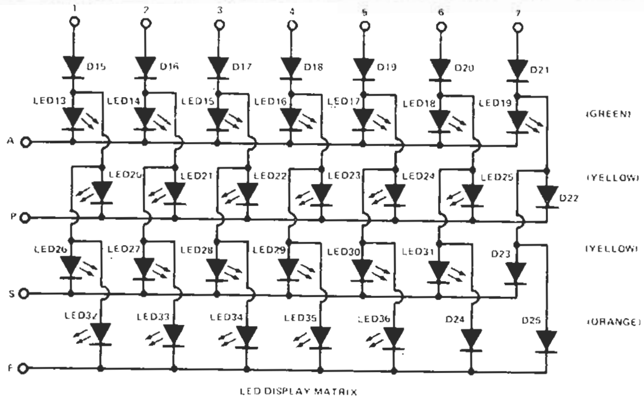


Fig. 6a. LED display matrix.

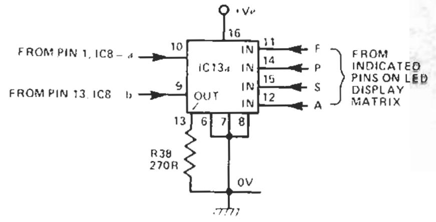


Fig. 6b. Line selection.

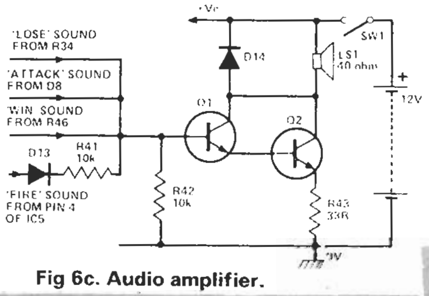


Fig 6c. Audio amplifier.

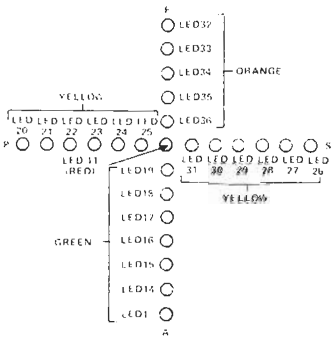


Fig. 6d. Panel LED display.

HOW IT WORKS

LED DISPLAY MARTIX DRIVERS, MULTIPLEXERS, AND LOGIC, PLUS AUDIO AMPLIFIER AND POWER SUPPLY CONNECTIONS

THE MAIN PART of the LED display matrix is made up of four lines of LED's, arranged in the form of a cross. The upper (Forward) line is five LED's long, the lower (Aft) line is seven LED's long, and the other two lines are each six LED's long. The individual LED's in each line are selected by IC12, a 4017 decade counter with ten decoded outputs, and the lines are selected by multiplexer IC13/1. Note that diodes D15 to D25 are used to eliminate sneak paths in the matrix, and ensure that only a single selected LED turns on at any one time. Figure 6b shows the positions of the LED's in the actual display. Note that LED 11, at the centre of the display, is normally on and represents the players own vessel.

Prior to the start of each attack IC12 is in the RESET state, so all LED's in the matrix (except LED 11) are off. As soon as an attack starts, IC13/1 selects a line of length 'n' in the display matrix, and IC13/2 connects the 'n+1' output of IC12 to its own pin-13 'clock disable' terminal. Thus, when an attack starts the LED's in the selected line turn on sequentially and run towards the centre of the cross: if a RESET signal is fed to pin-15 of IC12 from the 'FIRE' logic circuitry before the 'n+1' state is reached, the attack is defeated: if the attack is not defeated, pin-13 of IC12 is driven high as the counter reaches the 'n+1' state, and all further clock signals are inhibited and all GAME LOST indicators are activated.

All sound effects signals that are generated in the game are digital in form, and are fed via gate diodes and amplitude-determining resistors to the simple Q1-Q2 audio amplifier stage, which is unbiased. The amplifier directly drives a 40R speaker, which has transient limiting provided by D14.

The game is powered by a 12 V battery supply, and typically consumes 50 mA to 150 mA of current, depending on the state of play. Readers can, if they wish, power the game via a simple mains adaptor.

PARTS LIST

R1	6M8
R2	390k
R3, 8, 9, 10, 11, 31, 40, 48	22k
R4	10M
R5, 26, 28, 29, 30, 39	47k
R6, 16-25, 36, 37, 47	1k
R7, 12, 13, 14, 15	100k
R27	330k
R32	6k8
R33	680k
R34, 41, 42, 46	10k
R35	2M2
R38	270R
R43	33R
R44, 45	1M5
R49-62	470R
POTENTIOMETER	
RV1	1MO
CAPACITORS	
C1, 5, 6, 7, 8, 11, 14, 15	100n
C2, 3, 4, 10, 12, 13	10n
C9	150n

SEMICONDUCTOR	
IC1	4016
IC2, 13	4052
IC3, 9, 10	4001
IC4, 6, 12	4017
IC5, 17, 11	4011
IC7	4040
IC8, 16	4026
IC14, 15	4013
NOTE. All CMOS devices are B Series.	
Q1	BC109
Q2	BFY50
D14	1N4001
All other diodes are	1N4148
LED 1-37 are standard 0.2in dia.	
LED 7 segment displays are common cathode 0.3in	
MISCELLANEOUS	
LS1 2in 40R	
5 off SPST push buttons	
1 off SPST latching push button	
1 off DPDT min. toggle	
8 off HP11	
2 off 4 section battery holders	
case to suit	

BUYLINES

The case we used for the Ambush project is available from Boss Industries. Full details next month. Since panel layout is not critical, inventive ETI readers may be able to come up with their own hardware designs. All the ICs are common types, available from most component mail order firms.

If you think you are likely to spend every waking hour zapping the starfleet, it's worthwhile investing in a mains adaptor, available from your local Tranny shop.

HOW IT WORKS

THE ATTACK COUNTER AND GAME won detector and indicators

THE '1' OUTPUT of IC12 (the display matrix driver) briefly goes high at the start of each attack. This '1' signal provides the clock signal to the IC14-IC15 ATTACK COUNTER. These two IC's are 4026 decade counters with decoded outputs suitable for directly driving common cathode 7-segment LED displays at low power levels. The two counters are cascaded, to give 00 to 99 indications: leading zero suppression is not used in the counter.

The 'GAME WON' detector is designed around IC16, a 4013 dual D flip-flop, and IC10/4, a NOR gate. IC16/1 is connected as a bistable divider stage, and is clocked via one or other of the attack counter outputs. The action is such that its $\bar{Q}$ output is normally high, but switches low at the start of the 10th attack in a DEK game or the 100th attack in a CENT game. The $\bar{Q}$ output is fed to one of the inputs of the IC10/4 NOR gate, which has its other input provided from the normally-high output of the IC5 'FIRE' sound generator. The output of the NOR gate is fed to the SET (pin 8) terminal of IC16/2, which is wired as an R-S flip-flop. Both bistables are reset at the start of each game.

The action of the complete 'GAME WON' detector is such that 'FIRE' signals are fed to one input of the NOR gate each time a 'FIRE' signal is generated, but are unable to reach IC16/2 until IC16/1 changes state after the start of the 10th (in a DEK game) or 100th (in a CENT game) attack, at which point the Q output of IC16/2 goes low and drives green 'WIN' LED 37 'ON' via IC9/4, and the $\bar{Q}$ output goes high and activates the 'WIN' sound generator.

The 'WIN' sound generator is designed around IC17, and consists of two virtually identical medium-frequency gated astable multivibrators, which are operated in parallel and have their outputs fed to the audio amplifier via the D26-D27-R46 diode OR gate. Because of inevitable slight differences in timing component values, these two astables oscillate at slightly different frequencies, and produce a coarse 'beating' or 'throbbing' sound when they are activated by the 'WIN' detector.

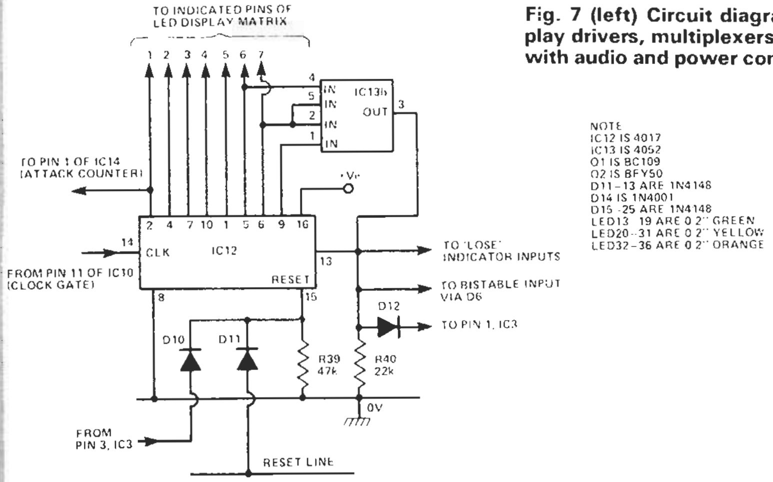


Fig. 7 (left) Circuit diagram of display drivers, multiplexers and logic with audio and power connections.

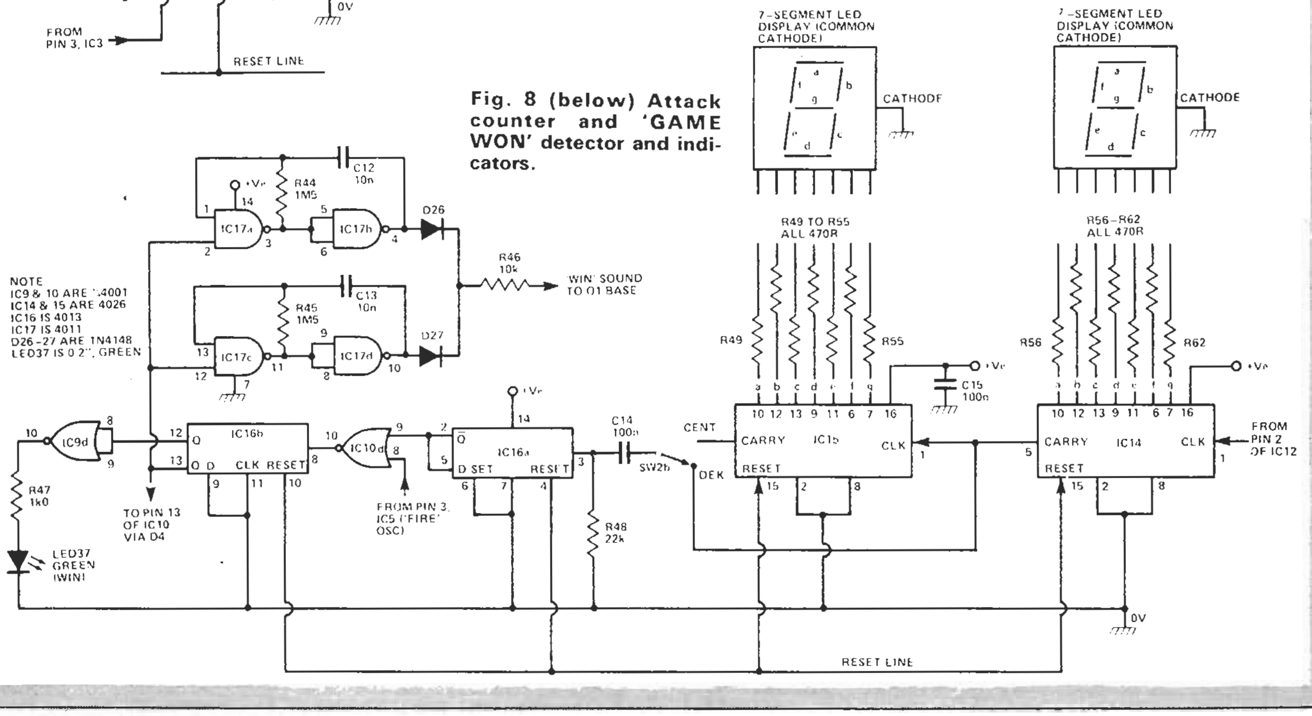


Fig. 8 (below) Attack counter and 'GAME WON' detector and indicators.

Next month we conclude the project with full constructional details and component overlays. In addition we'll show you the act of inspired heroism which led to the saving of the starship Eatyeigh and the designing of this project! For those who to get started the Parts List and circuit diagrams given here are complete.

ETI