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THESIS

Microprocessor Generated
Vertical Gyrohorizon Instrument
for the Blue Bird Simulator,

by

Marc A. Lucchesi

December 1980

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Thesis Advisor:

D. M. Layton

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Microprocessor Generated
Vertical Gyrohorizon Instrument
for the Blue Bird Simulator

by

Marc A. Lucchesi
Lieutenant, United States Navy
B.S., Miami University, 1974

Submitted in partial fulfillment of the
requirements for the degree of

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Author

Marc A. Lucchesi

Approved by:

Donald M. Layton

Thesis Advisor

Wes F. Platte

Chairman, Department of Aeronautics

William M. Holler

Dean of Science and Engineering

ABSTRACT

An X-Y cathode ray tube display for use in a high-performance aircraft simulator facility as a Vertical Gyrohorizon Instrument was investigated. A microprocessor was used to generate the correct angle for the display corresponding to the analog equations of motion of the simulator. An unfavorable displayed result was obtained. Detailed conclusions and recommendations for further study are presented.

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I. INTRODUCTION

In any academic environment there exists a vast separation between the course work (theory) and practical experience (laboratory). At the Naval Postgraduate School, in order to bridge this gap, some laboratory sessions of the Aeronautics Department use a large computer to simulate real world conditions. By inserting certain parameters into the computer one can observe the effects these parameters have on the modeled world. However, this type of simulation has several drawbacks, two of which are very detrimental to the learning process: one is the lack of instant response which causes a loss of interest in any problem and the other is the lack of realism which causes a loss of stimulation for the learning process itself.

A. BACKGROUND

For laboratory simulation of aircraft dynamics, it is desired to utilize a device that; (a) presents to the operator (pilot) a realistic cockpit environment and (b) provides external monitoring of inputs and outputs. Such a device may range from a relatively simple, fixed-based, two-degree-of-freedom simulator to a more complex, moving base, six-degree-of-freedom device. And, although a wide range of commercial simulators are available, not only are these devices costly, but they require extensive modifications to meet the demanding requirements of academic laboratory exercises.

Therefore, to circumvent this situation, it was decided to install a Cockpit Procedures Trainer (CPT) and to convert it to a six-degree-of-freedom, fixed-based simulator, the "Blue-Bird". In order to get this simulator to "fly", James H. Aldrich devised complex and extensive analog programs simulating the F-4 Phantom II aircraft equations of motion. After completion of this task (Ref. 1), the simulator could be used for supplemental instruction in courses in the Aeronautics Department (Static Stability and Control, AE 2036; Dynamic Stability, AE 4301; Flight Evaluation Techniques, AE 4323). Unfortunately these analog programs were so complex that there was little difference between using this system and putting numbers into a large digital computer. To simplify the programming, simple spring-mass-damper equations

$$m\ddot{x} + c\dot{x} + kx = f(t)$$

were used for the analog programs (Ref. 2) which allows for a quicker understanding of aircraft motion.

At this point one could sit in the cockpit, move the flight controls, and watch the results on strip chart recorders, but there was no visual display of longitudinal or lateral motion in the cockpit. This, of course, still did not provide all the realism desired, but it was a vast improvement over the large digital computer.

B. THE PROBLEM

The problem therefore, was to design and construct a two-dimensional visual display apparatus that would simulate

a Vertical Gyrohorizon Instrument (VGI) of an actual aircraft. This display would accept inputs from the new analog computer program output (pitch angle and bank angle), and display this information in a dynamic manner. The visual display was meant to simulate an actual VGI, but was not intended to have the exact visual characteristics of any actual instrument. It should have the generic characteristics acceptable by those pilots who might use the facility. This would provide one more step to the complete simulator.

II. APPROACH

There are three basic ways to address the problem of constructing a VGI: purely mechanical, purely video, or computer generated. Combination of these three are, of course, feasible, but will not be discussed in detail.

1. The purely mechanical approach would probably require a purchase of a VGI display specifically designed for the F-4 aircraft or a VGI instrument designed for flight simulator use. In either case, the installation would require a high frequency alternating current source and some sort of servo drive system that would respond to a varying voltage, direct-current output. In addition to being expensive, nothing would really be learned from this approach.

2. The purely video approach, again, would be very expensive, requiring the purchase of a video camera, and the building of a gimbed platform that would be linked to the equations of motion for roll and pitch. Although challenging from a design viewpoint, this is not very practical.

3. The computer generated approach, therefore, seemed the most fruitful. The low cost of computer chips, the available documentation to develop a circuit, the relatively small size of the computer board, and the fact that the simulator contains all the necessary power, made this approach the most practical one.

In any design procedure chosen, however, the input voltage to the VGI device (adjustable up to a positive/negative ten volts of direct current) needed to be massaged to produce a display with the following characteristics: (a) at least a sixty degree bank angle in either direction, (b) at least a twenty degree nose up/nose down pitch angle, and (c) at least a twenty-five degree per second roll rate. These parameters were considered the absolute minimum to insure realism of any type of VGI design.

III. HARDWARE DEVELOPMENT

Once a computer generated design was decided upon, the type of computer needed to be addressed. The design application called for a computer that would receive input from the analog equations of motion, massage the data, and put it out to some sort of display device. Inasmuch as this was to be a "real time" simulation, a computer was needed that was fast enough for real time. It was decided that, since the job required little actual memory, a microprocessor based system would be utilized. Of all the microprocessors available on the open market that would be useful, the Intel 8035 was chosen. Although the 8035 is not the fastest computer (cycle time of twenty-five micro-seconds) available, its all-in-one chip design, its quickness and variety of its instructions set (no instruction took longer than two cycles), and its availability made this chip the perfect choice. (Details on the 8035 are presented in Appendix A.)

Next, the matter of a cockpit display device needed to be addressed. The nature of a VGI lends itself to the concept of an X-Y plotter. In other words, if two sets of coordinates are put on a plotter, a straight line can be drawn between the two points. In order to accomplish this task, an oscilloscope with a horizontal input with calibration was needed. Since the two inputs (horizontal and vertical) were supplied to the oscilloscope, a X-Y cathode ray tube (CRT) was produced.

Next the circuit for connecting the computer to the input and output devices needed to be constructed. To change the analog data from the equations of motion, two eight-bit analog to digital converters were used. One converter was used for the pitch equation of motion, and the other for the roll equation of motion. The AD570S analog to digital converter was chosen because of its extremely fast conversion time (twenty-five micro-seconds) and its availability. These were connected to an Intel 8255A programmable peripheral interface chip which provided the necessary communication between the converters and the computer chip. These three chips comprised the input section.

The output section, on the other hand, was comprised of essentially only one chip: the Burr-Brown MP-10 microprocessor interfaced, eight-bit, analog output system. This chip contained one 8255 and two digital-to-analog converters on board. Therefore, only one chip provided the two outputs needed for the X-Y concept. Although these converters are slow for digital-to-analog converters (twenty-five micro-seconds), the one chip design far outweighed any increase in speed. The only problem with this device was synchronizing its timing with that of the 8035 computer. This was overcome by the use of two 74121 one shot chips. These chips were needed to delay the write pulse from the computer 600 nano-seconds to allow for a longer address set-up time on the MP-10. (figure 1)

The other chips required were from one to three Intel 8038 electrically programmable read only memory (EPROM) and an Intel

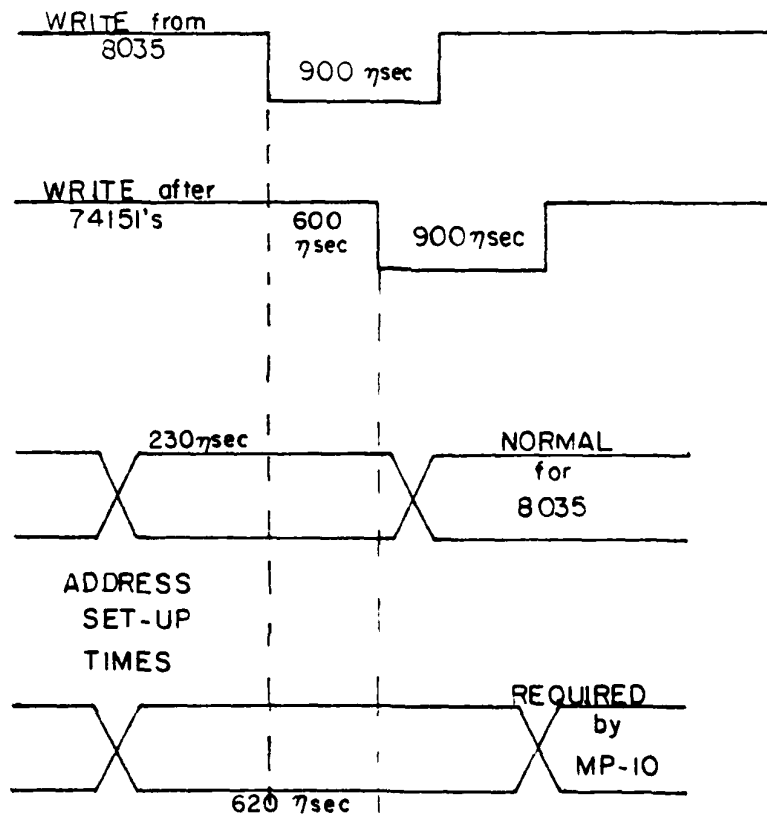


FIGURE 1 SET-UP TIMES

8212 eight-bit input/output port used as an address latch to hold data for addressing the 8255A, MP-10, and the 8700 chips.

The other two chips of the board were used as follows: the 7402 dual input NOR gate was used for external system reset and for external test for altitude and airspeed inputs, and the 74155 demultiplexer was used to select between the three 8708 memory chips.

Following the preliminary design it was necessary to construct the computer board. It was decided that since there were so many connections to be made (figure 2), "bread boarding" would not be the most practical approach. By using a photo-etching technique all the interconnections would automatically be made and, as a result, tracing probable errors would become relatively simple. Therefore, a two sided board was designed and etched (figures 3 & 4).

Finally, several power supplies were required. All the chips on the board required a positive five volts. Additionally, the MP-10 and the two AD570Ss required a positive and negative fifteen volts, and the 8708s required a positive twelve and a negative five volts.

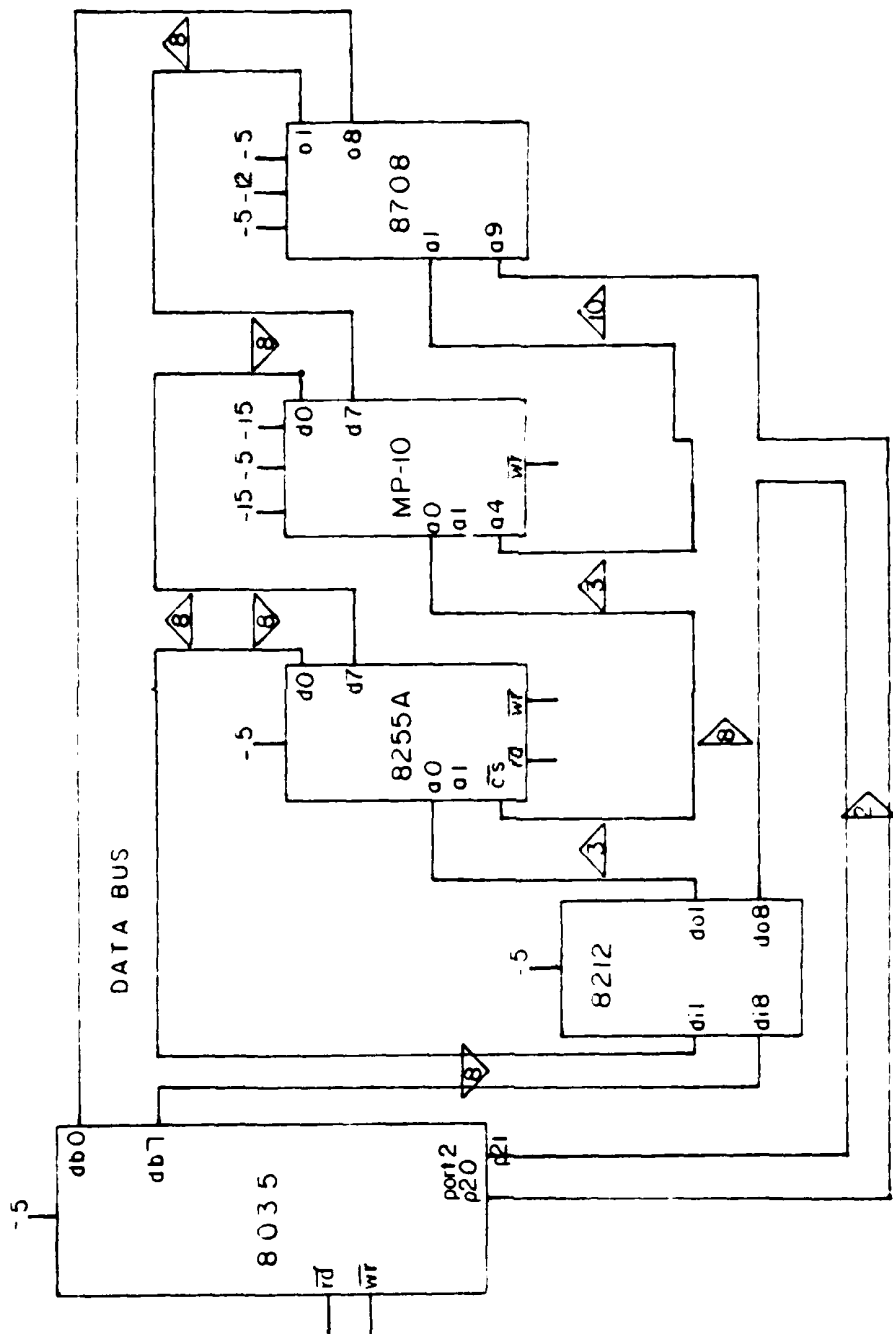


FIGURE 2 LOGIC FLOW

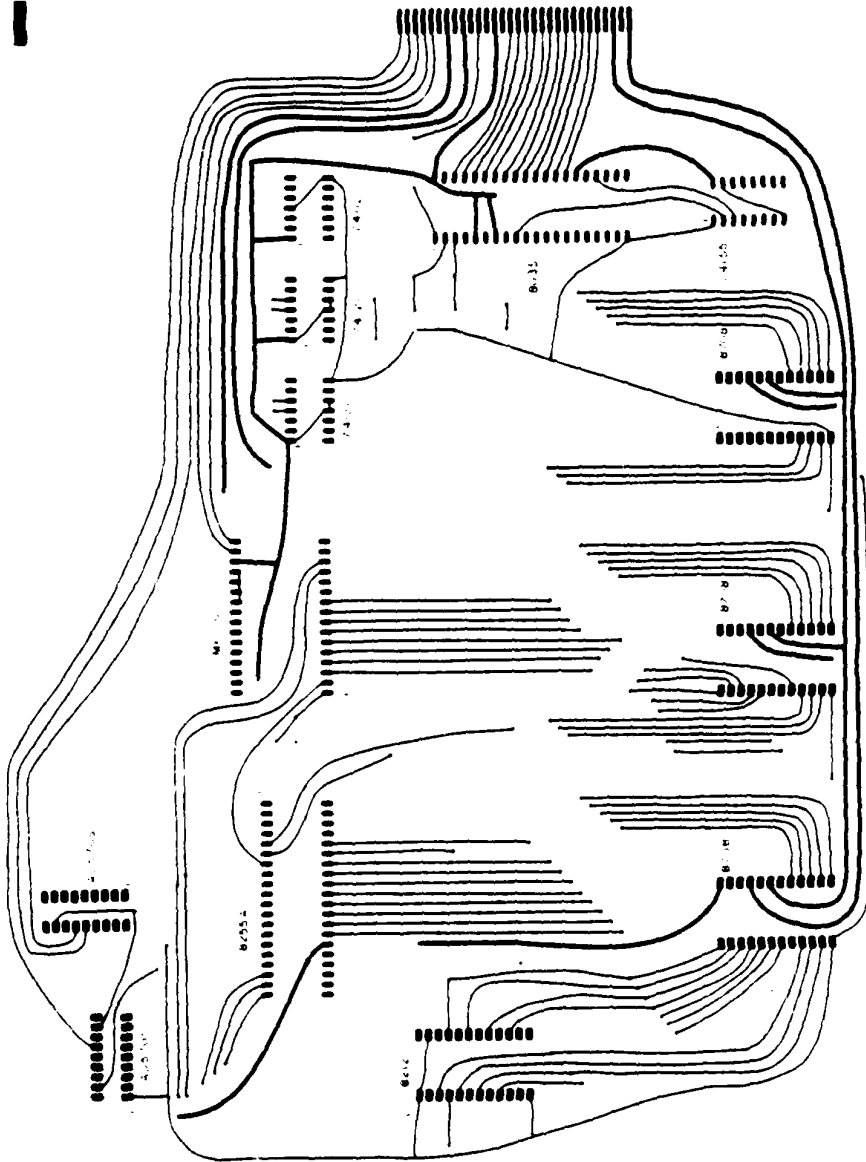


FIGURE 3 CIRCUIT DIAGRAM (TOP)

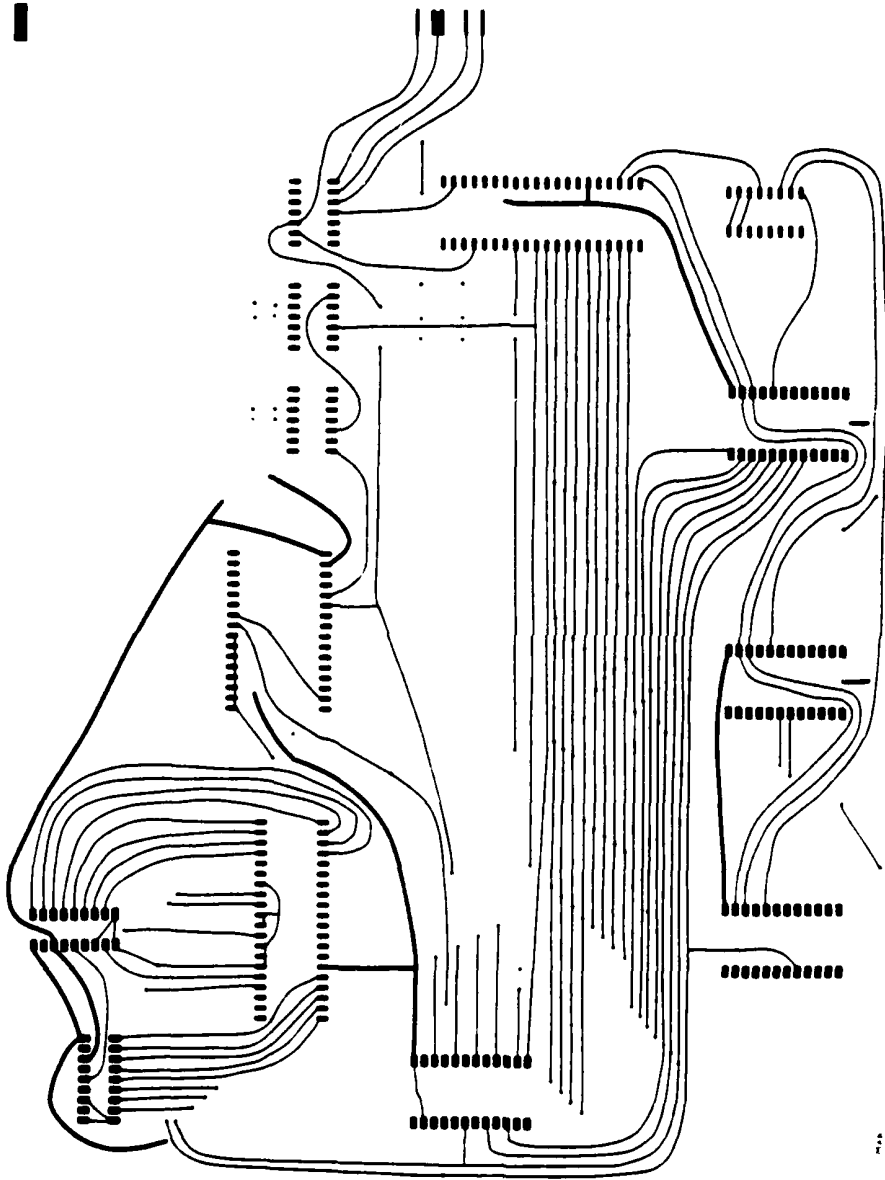


FIGURE 4 CIRCUIT DIAGRAM (BOTTOM)

IV. SOFTWARE DEVELOPMENT

The program logic flow was a relatively straight-forward process (figure 5). The basic format was to bring in the roll and pitch motions separately, couple them, and put them out to the X-Y CRT. The input needed to be brought in only once to produce the desired output. The design called for the first end point to be at the far left of the CRT and the second end-point to be at the far right. (Since the input and output devices are bipolar, i.e., accept both positive and negative voltages, the scaling of the output is as shown in figure 6.) The theory dictates that if a vertical voltage is applied to the CRT (roll motion) then the position on the Y axis should change in opposite directions at the two endpoints. And if the switching between these endpoints were done quickly enough a straight line at any angle should be formed.

With this theory as a reference point, the program began to take shape. To start the sequence of operation, the 8255A and the MP-10 chips needed to be initialized. The MP-10 is a straightforward, two step process (Ref. 3), while the 8255A is quite another story. There are many modes to the 8255A that can be programmed as either input or output. The design called for two input ports and one split input/output port for communication to the analog-to-digital converters. Therefore, ports A and B are pure input while port C was the split one (Ref. 4). Once the chips have been initialized, the computer

then requests the data from the analog-to-digital converters. The program then uses the data from the converters to select the proper output data that was fed to the MP-10. The output data is stored on a sine look-up table in order to arrive at the correct angle. (A Texas Instruments TI-59 programmable calculator was used to generate the sine look-up table appearing in the main program. The TI-59 program is in appendix B.) Once the data is received from the look-up table it was put out as follows: Y position on output 1 (sine of the angle), and X position on output 2 (cosine of the angle) of the MP-10. The pitch was added to the Y position to move the center of the line either up or down.

Once the program was written it was keyed into the Intel Prompt 80/85. This device does not belong to the MCS-48 computer systems (it is part of the MCS-80 system or better known as the 8080A based system), but its ability to program the 8708 EPROMS made this system indispensable. (Appendix C)

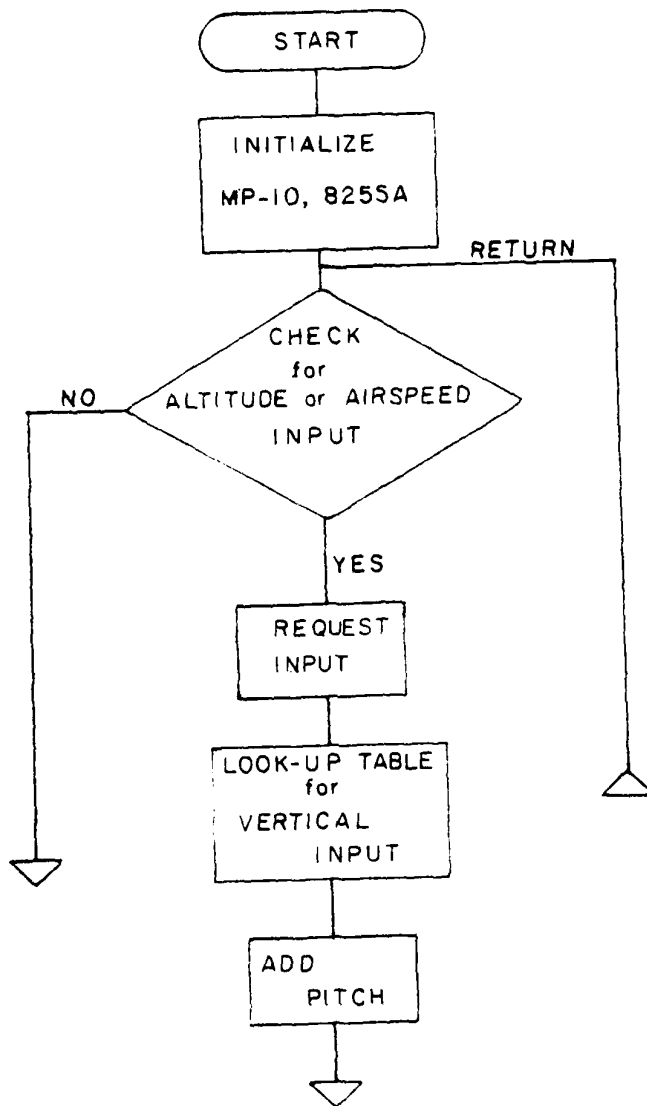


FIGURE 5 FLOW CHART

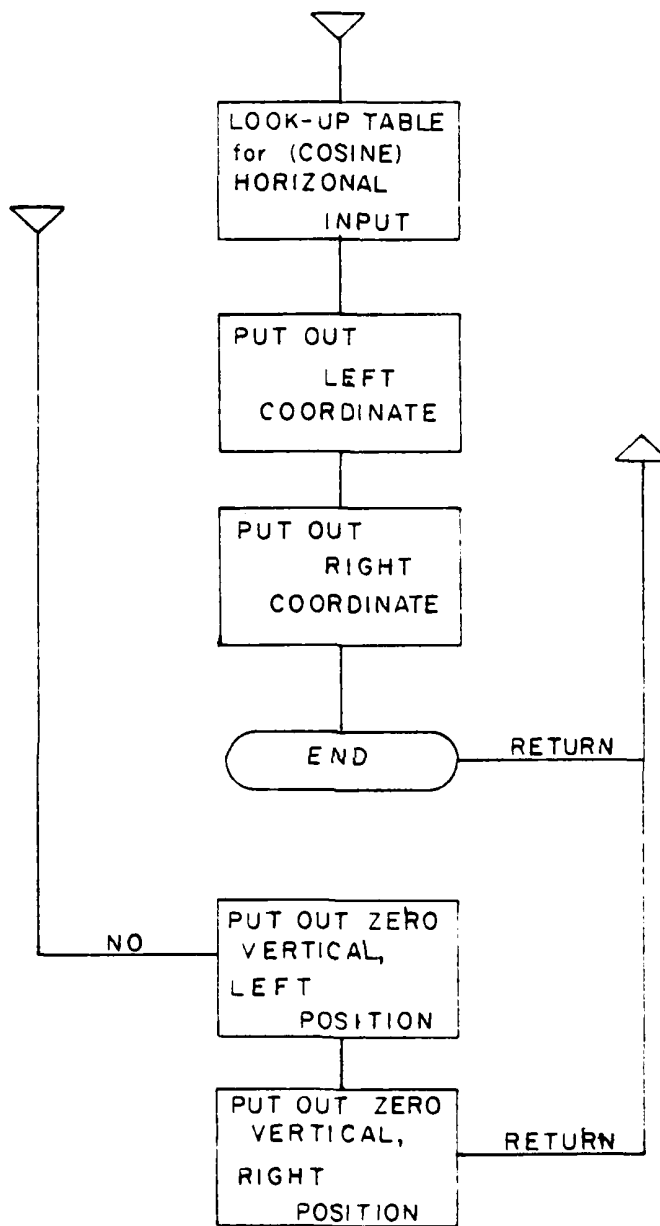


FIGURE 5 (CONTINUED)

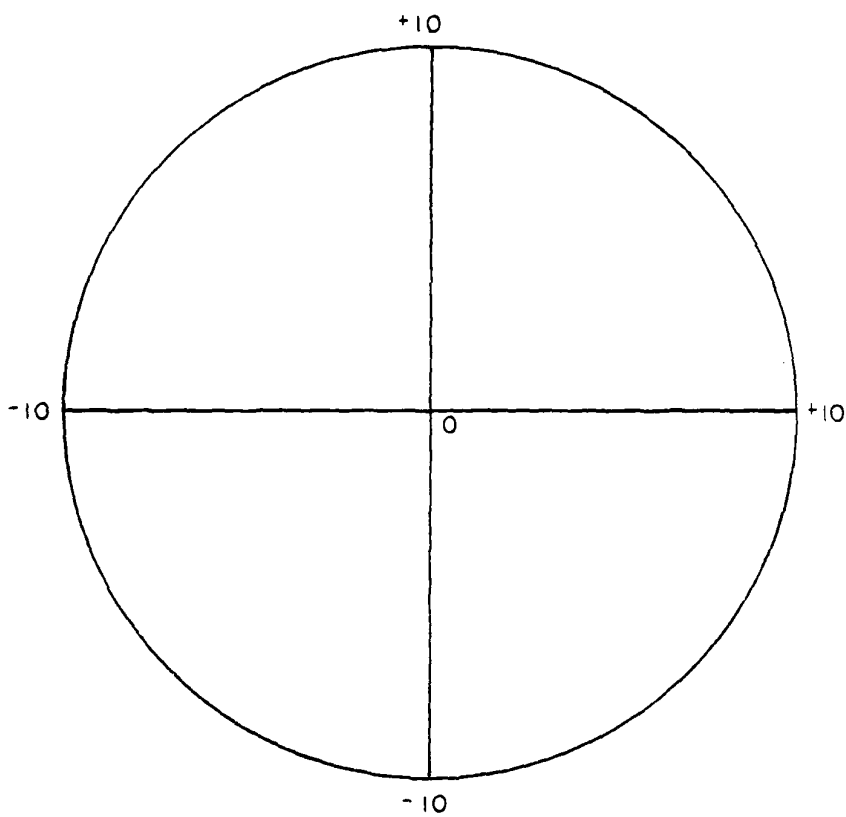


FIGURE 6 CRT SCALING

V. RESULTS AND CONCLUSIONS

Once the 8708 EPROM had been programmed it was put onto the board with the other chips, thereby making a complete computer.

Testing of the computer was accomplished with the use of a "bread board" box to supply the necessary power. A joy-stick was also connected through the "bread board" and used as the lateral and longitudinal inputs to simulate motion. The oscilloscope used for the X-Y CRT was the same as that for the cockpit display: the Tektronix Type 504 single trace, tube type oscilloscope.

When power was applied to the computer with the joy-stick in the neutral position, i.e., center, the face of the CRT lit up with a straight line from left to right across the center of the scope. This was exactly as predicted, but as the joy-stick was moved, the straight line expanded into a rectangle instead of a skewed straight line. This rectangle formed a square at the forty-five degree position of the joy-stick, then another rectangle, until at the ninety degree position of the joy-stick a vertical straight line was formed.

What was not recognized from the outset of this project was the fact that a CRT does not behave the same as a normal X-Y plotter. In other words, on a plotter the X and Y coordinates are put to a device before a point is printed, whereas on the CRT each coordinate is displayed independently.

Therefore, unless the X and Y coordinates are outputted to the display device simultaneously a box will be formed. Since it is impossible to have simultaneous data when using only one computer, the conclusion must be made that using only the endpoints of a line will not produce the desired skewed straight line.

VI. RECOMMENLATIONS

There exist a few areas of study that could produce the desired results of a skewed straight line. Unfortunately, time constraints have prevented the author from pursuing any of these.

1. Using the basic program to the point just after the data is retrieved from the look-up-table, one can divide this data into sixteen parts thereby producing a seventeen segmented output. This produces at any angle a straight line of sorts. In other words, the actual coordinates produce a small stair-step line the width of the scope. The seventeen segmented display should be small enough, however, so that the output is not distracting. The only problem with this approach is that the output may not be "real time"; i.e., there may be too much delay between the stick motion in the cockpit and what is perceived on the scope.

2. A hardware add-on which might be addressed is that of a resistor network in conjunction with a 555 timing chip to produce a raster scan on the oscilloscope. This essentially produces a stair-step, but the size of the step can be varied. Problems with this might lie in the fact that the line may not be able to be reversed; i.e., the scope would show only one direction of bank.

3. One other change is to use a different type of display. The Aeronautics Department has a television type monitor that accepts video like any other monitor, but is also gear driven to produce a skewed picture. By removing the video tube and supplying a motor to drive the screen, one can produce the desired effect. This makes for a much simpler software problem, but the current needed to drive the available motors are much beyond the output current of the computer.

4. If any of the above approaches accomplishes the desired effect, there should be further study to produce a "flying" simulator. The areas that need to be addressed are coupling for the airspeed and the altitude read outs. The present system allows only the operator to supply the necessary voltages to move the dials in the cockpit. Probably the best means of displaying the information would be to remove the present gauges and use digital displays. When this segment has been completed the simulator will be "flyable" in the true sense.

APPENDIX A

The Intel 8035 is part of the overall Intel MCS-48 family of computer systems. Designed as a special purpose system it can be adapted to most situations requiring small space and memory. (Reference 4)

The only difference between the 8035 and the other chips of the family was that the 8035 had no on board memory. This proved to be extremely useful because the number of 8708 memory chips available made program changes quicker than would have been trying to change only on 8748 computer chip.

APPENDIX B

TEXAS INSTRUMENTS TI-59 PROGRAM

```

000 76 1BL
001 11 A ; DECIMAL TO BINARY
; CONVERSION SUBROUTINE
002 29 CP ;CLEAR T REGISTER
003 42 STO
004 10 10 ;STORE NUMBER AT REGISTER 10
005 00 0
006 42 STO
007 11 11 ;STORE ZERO IN REGISTER 11
008 42 STO
009 02 02 ;AND REGISTER 2
010 76 LBL
011 87 IFF ;WORKING SUBROUTINE
012 53 (
013 43 RCL
014 10 10 ;PUT NUMBER INTO WORKING
015 55 / ;REGISTER
016 02 2
017 54 )
018 42 STO
019 01 01 ;STORE NUMBER/2 IN 1
020 59 INT ;INTEGER VALUE OF NUMBER/2
021 42 STO ;AND STORE IT IN 10
022 10 10
023 53 (
024 43 RCL ;PUT NUMBER/2 INTO
025 01 01 ;WORKING REGISTER
026 22 INV
027 59 INT ;KEEP ONLY NUMBER RIGHT
;OF DECIMAL POINT
028 69 OP
029 10 10
030 65 *
031 01 1
032 00 0
033 45 Y↑T ;RAISE THIS NUMBER TO THE
034 43 RCL ;POWER IN REGISTER 2
035 02 02
036 54 )
037 44 SUM
038 11 11 ;ADD THIS TO REGISTER 11
039 69 OP

```

040	22	22	;INCREMENT REGISTER 2
041	43	RCL	
042	10	10	
043	22	INV	
004	67	EQ	;IF THIS NUMBER IS NOT
045	87	IFF	;EQUAL TO ZERO GO BACK TO
			;START OF THE SUBROUTINE
046	43	RCL	
047	11	11	;DISPLAY THIS NUMBER AND
048	92	RTN	;RETURN TO CALLED PLACE
049	76	L	;START OF THE PROGRAMBL
050	13	C	;SEQUENCE
051	42	STO	
052	20	20	;STORE BEGINNING NUMBER
053	01	1	
054	02	2	
055	08	8	
056	42	STO	;STORE 128 IN ZERO FOR A
057	00	00	;COUNTER
058	01	1	
059	42	STO	
060	05	05	;STORE 1
061	00	0	
062	42	STO	
063	06	06	;CLEAR REGISTER 6
064	43	RCL	
065	05	05	
066	69	OP	;PRINT REGISTER 5
067	06	06	
068	43	RCL	
069	06	06	
070	85	+	
071	43	RCL	
072	20	20	;ADD REGISTERS 6&20
073	95	=	
074	42	STO	
075	06	06	;STORE THIS SUM IN 6 AGAIN
076	38	SIN	
077	65	*	
078	05	5	
079	55	/	
080	93	.	
081	00	0	
082	03	3	
083	09	9	
084	03	3	
085	07	7	
086	95	=	;5*SIN(X)/.05937
087	69	OP	
088	06	06	;PRINT THIS

089	59	INT	;INTERGERIZE IT
090	11	A	;AND CALL SUBROUTINE A
091	69	OP	
092	06	06	;PRINT THE OUTPUT OF SUB-
			;ROUTINE A
093	98	ADV	;ADVANCE THE PAPER
094	69	OP	
095	25	25	;INCREMENT REGISTER 5
096	97	DSZ	;DECREMENT REGISTER ZERO
097	00	00	;AND SKIP TO THE END IF
			;IT IS ZERO
098	00	00	;OTHERWISE GO TO
099	64	64	;STEP 64
100	92	RTN	;STOP

APPENDIX C

DISPLAY PROGRAM

```

0000 00      NOP
0001 27      CLR A          ;CLEAR ACCUMULATOR
0002 17      INC A          ;
0003 AF      MOV R7,A       ;PUT "1" INTO REG 7
0004 17      INC A
0005 AE      MOV R6,A       ;PUT "2" INTO REG 6
0006 17      INC A
0007 A8      MOV R0,A       ;PUT "3" INTO REG 0-ADDRESS
                                ;FOR 8255A
0008 23      MOV A,#        ;SELECT 8255 AND PUT MODE
                                ;WORD OUT
0009 93      10010011B     ;(MODE 0; A, B, C LOWER ARE
000A 90      MOVX @R0,A     ;INPUT, C UPPER IS OUTPUT)
000B B9      MOV R1,#       ;PUT ADDRESS FOR MP-10 INI-
000C 83      10000011B     ;TIALIZATION INTO REG 1
000D 23      MOV A,#
000E 80      10000000B
000F AD      MOV R5,A       ;STORE INITIALIZATION DATA
0010 91      MOVX @R1,A     ;SELECT MP-10 AND INITIALIZE
0011 FE      MOV A,R6
0012 A9      MOV R1,A       ;PUT 2 INTO REG 1 (PORT C OF
                                ;8255A)
0013 47      SWAP A         ;NOW THE BLANK AND CONVERT
                                ;PIN IS SET
0014 AC      MOV R4,A       ;PUT 00100000 INTO REG 4
0015 91      MOVX @R1,A     ;INSURE BIT 6 IS HIGH TO
                                ;START DATA CONVERSION
0016 56      JT 1           ;JUMP IF THERE IS NO A/S OR
0017 53      01010011B     ;ALT INPUT
0018 27      CLR A
0019 91      MOVX @R1,A     ;INSURE BIT 6 IS LOW TO HOLD
                                ;DATA
001A 81      MOVX A,@R1     ;CHECK FOR DATA READY BITS
001B 53      ANL A,#
001C 0C      00001100B
001D 96      JNZ           ;TRY AGAIN IF BITS 2&3 ARE
001E 1A      00011010B     ;HIGH, BECAUSE THEY ARE NOT
                                ;READY
001F 85      CLR F0
0020 95      CPL F0        ;INSURE FLAG IS HIGH
0021 A8      MOV R0,A       ;INSURE R0 IS CLEARED
0022 80      MOVX A,@R0     ;BRING IN FORE AND AFT STICK

```



```

0023 AB      MOV R5,A          ;POSITION
0024 18      INC R0
0025 80      MOVX A,@R0     ;BRING IN LEFT AND RIGHT
0026 AA      MOV R2,A       ;STICK POSITION
0027 FC      MOV A,R4
0028 91      MOVX @R1,A     ;INSURE BIT IS HIGH FOR FREE
                                ;DATA CONVERSION
0029 FA      MOV A,R2       ;BRING BACK LEFT/RIGHT STICK
                                ;POSITION
002A F2      JB 7           ;JUMP IF BIT 7 IS HIGH
002B 2D      00101101B
002C 85      CLR R0        ;IF L/R INPUT IS NEG THEN
                                ;CLEAR FLAG
002D 53      ANL A,#        ;STRIP OFF BIT 7 AND DISCARD
002E 7F      01111111B
002F AA      MOV R2,A
0030 E3      MOVPS A,@A     ;BRING VALUE FROM LOOK UP
                                ;TABLE (5*SIN(Y))
0031 B6      JF 0           ;IF FLAG 0 IS SET DO NOT
0032 34      00110100B     ;COMPLEMENT (5*SIN(Y))
0033 37      CPL A
0034 6B      ADD A,R3       ;ADD 5*SIN(Y)+X FOR VERTICAL
                                ;SCOPE INPUT
0035 AB      MOV R3,A
0036 FA      MOV A,R2       ;BRING BACK LEFT/RIGHT STICK
                                ;POSITION
0037 37      CPL A         ;COMPLEMENT THE INPUT FOR
                                ;COSINE LOOK UP TABLE
0038 53      ANL A,#        ;STRIP OFF BIT 7 AND DISCARD
0039 7F      01111111B
003A E3      MOVPS A,@A     ;BRING IN VALUE FROM LOOK
                                ;UP TABLE
003B B6      JF 0           ;IF F0 IS SET DON'T
003C 3E      00111110B     ;COMPLEMENT
003D 37      CPL A
003E 37      CPL A
003F AA      MOV R2,A
0040 FD      MOV A,R5
0041 A8      MOV R0,A       ;REG 0 CONTAINS 10000000
0042 FB      MOV A,R3
0043 37      CPL A
0044 90      MOVX @R0,A     ;OUTPUT VERTICAL(LEFT)
0045 FA      MOV A,R2
0046 37      CPL A
0047 18      INC R0
0048 90      MOVX @R0,A     ;OUTPUT HORIZ. (LEFT)
0049 C8      DEC R0
004A FB      MOV A,R3
004B 90      MOVX @R0,A     ;OUTPUT VERTICAL (RIGHT)
004C 18      INC R0

```

```

004D FA      MOV A,R2
004E 90      MOVX @R0,A      ;OUTPUT HORIZ. (RIGHT)
004F FE      MOV A,R6      ;PUT 2 INTO ACC
0050 A9      MOV R1,A
0051 04      JMP
0052 16      00010110B
0053 FD      MOV A,R5
0054 A3      MOV R0,A      ;PUT 10000000 INTO REG 0
0055 90      MOVX @R0,A      ;OUTPUT ZERO VERTICAL (LEFT)
0056 18      INC R0
0057 23      MOV A,#
0058 FF      11111111B
0059 90      MOVX @R0,A      ;OUTPUT NEG HORIZ (LEFT)
005A C8      DEC R0
005B FD      MOV A,R5
005C 90      MOVX @R0,A      ;OUTPUT ZERO VERTICAL (RIGHT)
005D 27      CLR A
005E 18      INC R0
005F 90      MOVX @R0,A      ;OUTPUT POS HORIZ (RIGHT)
0060 04      JMP
0061 16      00010110B

```

0300	80	10000000B	;LOOK UP TABLE
0301	81	10000001B	
0302	83	10000011B	
0303	84	10000100B	
0304	86	10000110B	
0305	87	10000111B	
0306	89	10001001B	
0307	8A	10001010B	
0308	8C	10001100B	
0309	8D	10001101B	
030A	8F	10001111B	
030B	91	10010001B	
030C	92	10010010B	
030D	94	10010100B	
030E	95	10010101B	
030F	97	10010111B	
0310	98	10011000B	
0311	9A	10011010B	
0312	9B	10011011B	
0313	9D	10011101B	
0314	9E	10011110B	
0315	A0	10100000B	
0316	A1	10100001B	
0317	A3	10100011B	
0318	A4	10100100B	
0319	A6	10100110B	
031A	A7	10100111B	
031B	A9	10101001B	
031C	AA	10101010B	
031D	AC	10101100B	
031E	AD	10101101B	
031F	AF	10101111B	
0320	B0	10110000B	
0321	B2	10110010B	
0322	B3	10110011B	
0323	B4	10110100B	
0324	B6	10110110B	
0325	B7	10110111B	
0326	B9	10111001B	
0327	BA	10111010B	
0328	BB	10111011B	
0329	BD	10111101B	
032A	BE	10111110B	
032B	BF	10111111B	
032C	C1	11000001B	
032D	C2	11000010B	
032E	C3	11000011B	
032F	C5	11000101B	
0330	C6	11000110B	
0331	C7	11000111B	

0332	C9	11001001B
0333	CA	11001010B
0334	CB	11001011B
0335	CC	11001100B
0036	CE	11001110B
0337	CF	11001111B
0338	DO	11010000B
0339	D1	11010001B
033A	D2	11010010B
033B	D4	11000100B
033C	D5	11000101B
033D	D6	11000110B
033E	D7	11000111B
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0340	D9	11011001B
0341	DA	11011010B
0342	DB	11011011B
0343	DD	11011101B
0344	DE	11011110B
0345	DF	11011111B
0346	E0	11100000B
0347	E1	11100001B
0348	E2	11100010B
0349	E3	11100011B
034A	E4	11100100B
034B	E5	11100101B
034C	E6	11100110B
034D	E6	11100110B
034E	E7	11100111B
034F	E8	11101000B
0350	D9	11101001B
0351	EA	11101010B
0352	EB	11101011B
0353	EC	11101100B
0354	EC	11101100B
0355	ED	11101101B
0356	EE	11101110B
0357	EF	11101111B
0358	F0	11110000B
0359	F0	11110000B
035A	F1	11110001B
035B	F2	11110010B
035C	F2	11110010B
035D	F3	11110011B
035E	F4	11110100B
035F	F4	11110100B
0360	F5	11110101B
0361	F5	11110101B
0362	F6	11110110B
0363	F7	11110111B

0364	F7	11110111B
0365	F8	11111000B
0366	F8	11111000B
0367	F9	11111001B
0368	F9	11111001B
0369	F9	11111001B
036A	FA	11111010B
036B	FA	11111010B
036C	FB	11111011B
036D	FB	11111011B
036E	FB	11111011B
036F	FC	11111100B
0370	FC	11111100B
0371	FC	11111100B
0372	FD	11111101B
0373	FD	11111101B
0374	FD	11111101B
0375	FD	11111101B
0376	FE	11111110B
0377	FE	11111110B
0378	FE	11111110B
0379	FE	11111110B
037A	FE	11111110B
037B	FF	11111111B
037C	FF	11111111B
037D	FF	11111111B
037E	FF	11111111B
037F	FF	11111111B

LIST OF REFERENCES

1. Aldrich, J.H., A Simulator Evaluation of Pilot Response to an Aircraft Cockpit Spin Indicator System, MS Thesis, Naval Postgraduate School, California, 1979.
2. Lucchesi, M.A., Longitudinal Equations of Motion verses Spring Mass Damper System, paper presented for course AE5815, spring, 1980.
3. Burr-Brown General Catalog, p. 5-95-5-102, 1979.
4. Intel, MCS-48 Microcomputer User's Manual, 1976.
5. Intel, Application Techniques for the MCS-48 Family, p. 3-8, 1977.
6. National, Digital Integrated Circuits, p. 1-5, 1-75, 1-87, 1974.
7. Intel, Prompt 80 Microcomputer User's Manual, 1976.

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