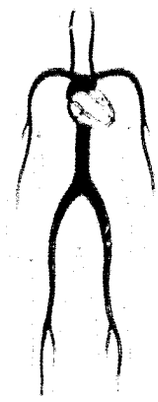
CR-160607

SQT



TECHNOLOGY INCORPORATED
LIFE SCIENCES DIVISION

FINAL REPORT

A MICROPROCESSOR-BASED CARDIOTACHOMETER

Prepared for the NASA Johnson Space Center
Cardiovascular Research Laboratory

October 31, 1979

Contract NAS9-14880
Project 0160-20

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Prepared by:

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A MICROPROCESSOR-BASED CARDIOTACHOMETER

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TABLE OF CONTENTS

INTRODUCTION

In the early development of the Cardiopulmonary Data Acquisition System (CDAS) for the NASA/JSC Cardiovascular Laboratory, one of the main requirements was a device which would provide reliable measurements of instantaneous heart rate during treadmill and ergometer stress testing. Cardiotachometers which were commercially available generally were not designed to handle the rather large amount of noise, baseline wandering, and amplitude changes that are frequently seen in the electrocardiogram (ECG) during exercise testing. In addition, most commercial units were not reliable enough for research use and generally would be difficult to interface with the existing laboratory instrumentation and computers. As a result, the development of a completely new cardiotachometer was undertaken so that highly accurate and reliable measurements could be made of the heart rate of test subjects.

In summary, the principle requirements for the new cardiotachometer were as follows:

(1) Reliable heart rate mesurements during either rest or exercise stress testing.

(2) Accurate heart rate measurements over the range of 30 to 250 beats/minute.

(3) Analog output for interfacing with an FM tape recorder and a microcomputer analog to digital (A/D) converter.

(4) Instantaneous (beat to beat) updates on the system output were also desirable so that occasional noise artifacts or ectopic beats could be more easily identified except that occasional missed beats caused by switching ECG leads should not cause a change in the output.

The first unit developed for this task utilized discrete transistors and small and medium-scale integration integrated circuits (IC's) for all of the logic and digital-to-analog (D/A) conversion required. This original system has been in use for about 3 years and has been fairly reliable, but its accuracy and noise immunity sometimes were not satisfactory. In addition, modifications to this system were difficult to make since any logic modifications would require wiring changes and hardware additions. As a result, a completely new cardiotachometer was developed, using an improved analog filter and R-wave detector and an Intel 8080A microprocessor to handle all of logic and arithmetic necessary. By using the microprocessor, all of the above requirements could more easily be met and future hardware modifications could be minimized if functional changes were needed.

GENERAL DESCRIPTION

In the implementation of the new cardiotachometer, a new approach was used to calculate heart rate. Instead of using the discrete transistor D/A converter to invert and display the count as was used before, a 16 bit precision software math routine is used, together with a monolithic 8-bit D/A converter. Also the previous model used 8 bit wide counters while the new one uses 16 bit wide registers. Thus accuracy and resolution is greatly increased. The interface hardware was built around an 8255 programmable peripheral interface IC. To this IC was added a D/A IC, switches with debounce circuits, light emitting diodes (LED's) with drivers, and a single bit A/D consisting of a special filter, automatic gain controller (AGC), and pulse detector. Also a calibration circuit was used consisting of an 8253 programmable interval timer, opto-isolators, and a digital multiplexer.

By using a microprocessor based system, future modifications can be added easily. Such modifications could be software digital filtering, a continuously updated averaging heart rate output, or other similar features.

A summary of the characteristics of the new cardiotachometer is given in Table 1.

TABLE 1

DEVICE OPERATIONAL SPECIFICATIONS

Input	-Single lead ECG
Output	-Analog voltage 0-3VDC representing 0-300 beats/min. (BPM)
Accuracy	-Better than 2% of reading over entire range Typically better than 1% over the range 30-230 BPM
Output Resolution	-1.13 BPM
Internal Resolution	-0.45 msec. in R-R interval measurement
Under & Over Range Indications	-LED illuminates and output drops to 0 when heart rate drops below 30 BPM or increases above 300 BPM
Calibration	-60 BPM or 180 BPM pulses obtained by dividing CPU crystal-controlled clock pulses can be switched to the system analog input for calibration and troubleshooting. Accuracy: $\pm$ 1 msec.

HARDWARE DESCRIPTION

The Central Processing Unit (CPU) board consists of the following:

8080A - CPU

8228 - System controller

8224 - System clock generator

74LS138 - Memory decoder

2708 - 1K x 8 bit Erasable Programmable Read-Only Memory (EPROM)

2111-1 - 256 x 4 bit static RAM (2 ea)

C6136P - -5VDC 50 MA regulator

7404 - Hex inverter

18.432 MHz - crystal

The 8080A chip set is configured as a 2 MHz system using isolated I/O-linear select. This allows up to 14 devices to be selected without a decoder chip.

The memory is configured by using a 2708 EPROM and two 2111-1 RAM's. This gives 1K of ROM and 256 bytes of RAM's. Due to using wire-wrap techniques and the availability of 2716 2Kx8 and 2732 4Kx8 EPROMS and 2114-1 1Kx4 static RAM's, the memory could be expanded up to 8K of ROM and 2K of RAM. Only minor changes in the wire-wrapping would be needed.

The 8224 system clock chip uses an 18.432 MHz crystal which gives a system clock frequency of 2.048 MHz.

The Input/Output (I/O) board consists of the following:

8255 - Programmable peripheral interface

8253 - Programmable interval timer

DAC-IC8BC - 8 bit D/A converter

LM1458 - Dual 741 op-amps

SN7404 - Hex inverter

SN7406 - LED Drivers

74153 - 4 to 1 digital multiplexer

6N138 - Opto-isolators

74123 - Dual one-shot multivibrators

The 8255 is the main IC for interfacing inputs and outputs to the CPU-Memory board. Port A (PA0-PA7) are used to feed the 8-bit output to the D/A converter and half of a LM1458 op amp to produce a 0-3VDC analog signal. This signal represents heart rate (0-300 BPM).

Port B (PB0-PB7) is not used at the present time.

Port C (PC0-PC7) is split via software control to use (PC0-PC3) as input and (PC4-PC7) as output. All outputs used are latched outputs so no refreshing is required.

Port C inputs (PC0-PC3) are not latched.

The 8253 is configured via software as a rate generator (mode 2) for constant output, and has three separate 16-bit timers.

Timer 0 is used to divide the main CPU clock via 2048 to produce a 1KHZ signal.

Timer 1 is used to divide the 1KHZ output from timer 0 to produce the Low Cal

signal. This signal is fed to half of the 74123 to produce a 10 msec. wide 60 BPM Low Cal signal. Timer 2 is used to divide the 1KHZ output from timer 0 to produce the High Cal signal. This signal is fed to the other half of the 74123 to produce a 10 msec. wide 180 BPM High Cal signal.

These two signals plus the TTL pulses from the conditioned ECG input signal are fed to a 74153 4-input, 1 output digital multiplexer. This multiplexer is controlled from the main CDAS computer via two 6N138 opto-isolaters. Control codes are:

00 input to the 6N138's connects the ECG input to the cardiotachometer peripheral interface input.

01 input to the 6N138's connects the 60 BPM Low Cal pulses to the input.

10 input to the 6N138's connects the 180 BPM High Cal pulses to the input.

11 input to the 6N138's disconnects the cardiotachometer input for the Standby mode.

The raw ECG signal is specially conditioned by 3 circuits which were developed from a modified Skylab type cardiotachometer to produce a 10 msec. pulse which represents the R-wave of the ECG. The ECG is first sent to a 10 HZ-30HZ bandpass filter. The output of the filter is then sent to the automatic gain control (AGC) circuit. The AGC circuit outputs a pulse with constant amplitude even with varying ECG input amplitudes. This output is then sent to the pulse detector.

The pulse detector outputs a 10 msec. wide pulse. The pulse detector also incorporates a pulse width controller. This circuit produces a constant pulse

width output even with changes in the ECG input. This allows the 8080 CPU to do all of its calculations and displaying during the pulse. The output, along with the 60 BPM Low Cal, 180 BPM High Cal, and 0 BPM Standby signals, is then fed to the 74153 digital multiplexer. The multiplexer output is then fed to the PC0 input of the 8255 peripheral interface.

PC1 and PC2 are also inputs which are connected to two SPDT push button switches via 7404 debounce circuits. Switch 1, connected to PC1, causes the CPU to select a D/A setup routine. This routine outputs via the D/A either a 0 or full scale signal each time switch 1 is pushed. This allows for adjustments of the D/A for zero and full scale values. Switch 2, connected to PC2, causes the CPU to select a ramp routine. This allows for checking D/A linearity and missing code conditions, and checks other functions of the microprocessor as well.

The front panel LED's are connected to other 8255 port C outputs via 7406 LED drivers as follows: ECG LED to PC0, Underrange LED to PC4, and Overrange LED to PC5. PC3, PC6, and PC7 are not used at present.

SOFTWARE DESCRIPTION

Heart Rate Monitor

Refer to the flowcharts and program listing for this discussion. The program starts at address 0000. None of the interrupts are used. The stack pointer is set and then the initialize routine initializes the 8255, 8253 timers, ectopic flag, pause flag, misbeat reference storage area, and the ectopic reference storage area.

It next calls the input routine from the start routine and waits for either a ECG/Cal input or for switch 1 to be pushed. If switch 1 is pushed, the program jumps to the D/A setup routine. If an ECG/Cal pulse is present, it returns and waits for the ECG/Cal pulse to end.

When the pulse has ended the program enters the Count routine, where the HR counter is initialized and then a timing loop is entered. The program loops until either the count reaches the under range count or there is another ECG/Cal/Switch input.

If the count reaches the underrange count, it then jumps to the underrange routine ERR1. The D/A is set to 0 VDC and the underrange LED is turned on. The program then jumps to start.

If an ECG/Cal pulse is detected, the program then enters the Check routine. There it first determines if the ectopic flag, ECTFLG, was set on the previous beat. If so, the Pause flag is then set, since there may be a compensatory

pause (longer than normal R-R interval) following a premature beat. If ECTFLG was not set, then the current R-R interval count is compared with the missed beat reference value (MISBEAT), which is a number equal to slightly less than twice the previous normal R-R interval count. If the current count is greater, then the program simply assumes that one or more beats have been missed due to an ECG dropout, lead change, or similar temporary problem. MISBEAT is then reset and the program jumps back to Start.
Nothing is changed on the output, and this procedure therefore keeps a short signal dropout from causing an erroneous heart rate from being output.

If there was no missed beat condition or if the Pause flag was set, then the current count is compared with the ectopics reference count, ECT. This number is approximately 3/4 of the previous normal R-R interval count. If the current count is less, then the current beat is probably an ectopic and therefore the ectopic flag ECT is set before continuing.

Next, the count is checked for an overrange condition. If the count is less than that corresponding to a heart rate of 300, the program jumps to ERR2. There, the D/A converter is set to 0 VDC, the overrange LED is turned on, and the program jumps back to start.

If it is not overranged then ECTFLG is checked. If ECTFLG is set, the program goes to the output routine. If not set, the pause flag is checked. If the pause flag is set the program goes to the output routine. If the pause flag is not set then a new MISBEAT reference count and ECT reference count are calculated and stored and then the program goes to the output routine.

The MISBEAT reference and ECT reference are variable indicators, based on the previous normal R-R interval count, which are used to determine if a missed beat or ectopic has happened.

The program then goes to the Output routine. The count is divided by a constant. The result is an eight bit number which is sent to the D/A and outputed. Both under and overrange LEDS are turned off and the pause flag is reset. The program then goes back to Start for the next heart beat.

D/A Setup Routine

In the Heart Rate Monitor Program if the Input routine detects switch 1 it then jumps to the setup routine.

The setup routine first outputs a 00 to the D/A converter. This sets the D/A to zero volts output. This allows for adjustment of the D/A zero.

When switch 1 is pushed again a FF is sent to the D/A. This is the full scale condition and allows for adjustment of the full scale value (normally 3 volts) on the D/A.

Each time switch 1 is pushed either a zero or full scale output appears on the output of the D/A.

D/A Ramp Routine

If switch 2 is pushed during the setup routine, the program jumps to the D/A Ramp routine. This routine first outputs a zero to the D/A. It then enters

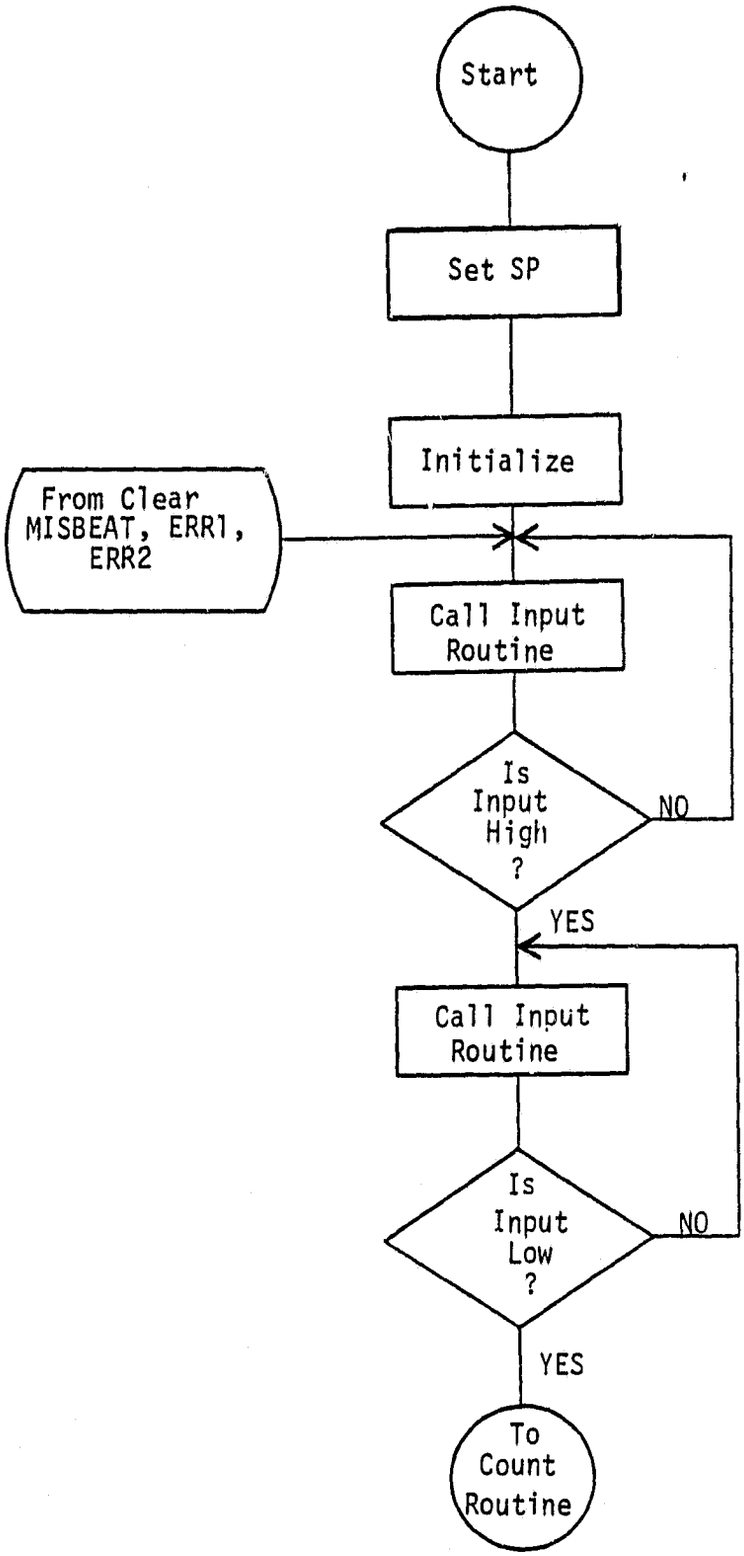
a wait loop. Upon completion of the wait period the D/A is updated by one count and the routine jumps back to the wait loop,

This routine allows for checking that the D/A responds correctly and if the 8255 outputs a wrong code.

Pressing the reset switch at any time returns the program to the beginning of the Heart Rate Monitor routine.

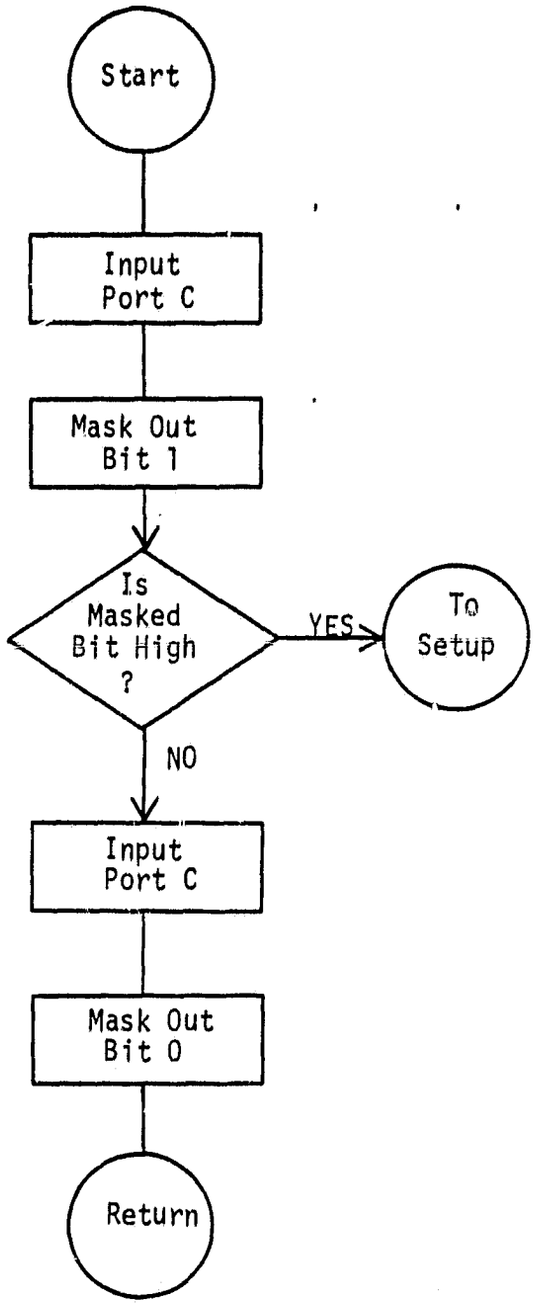
APPENDIX A

START ROUTINE

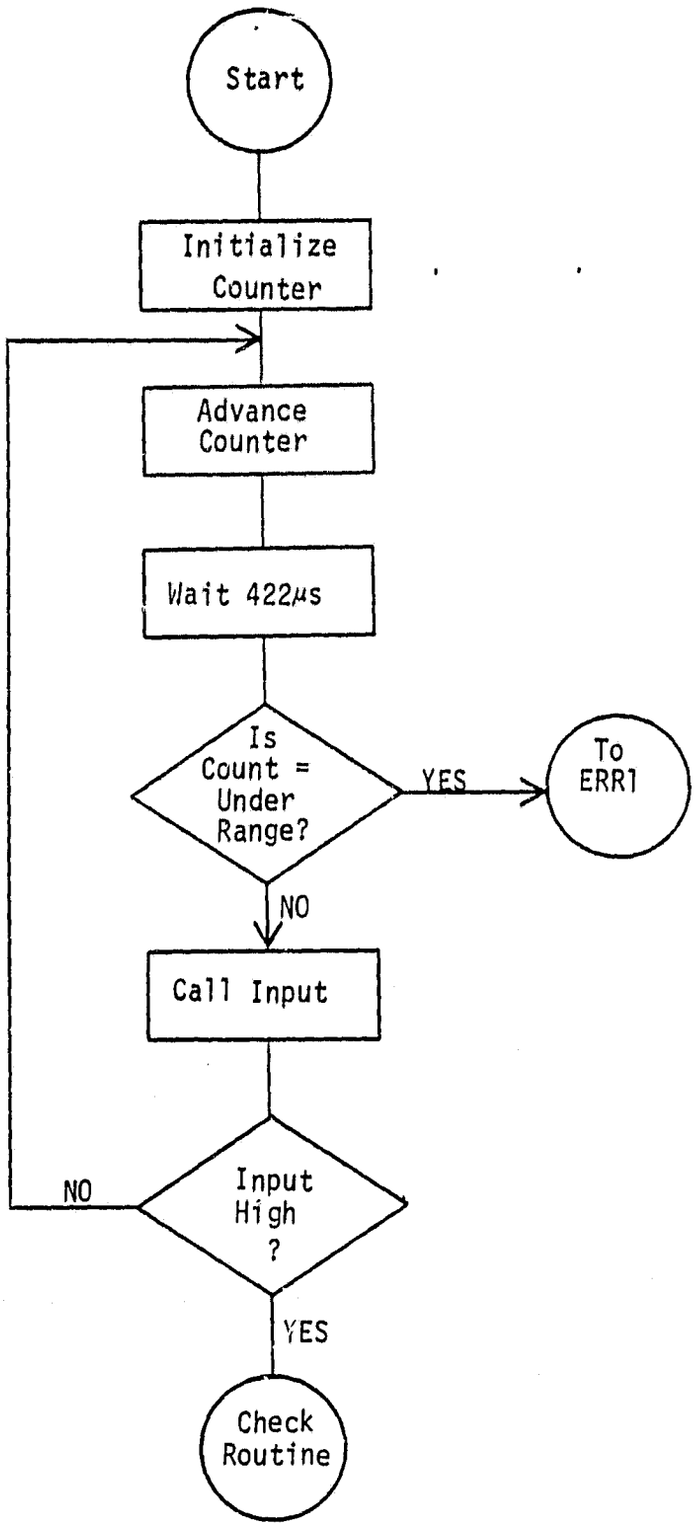


INPUT ROUTINE

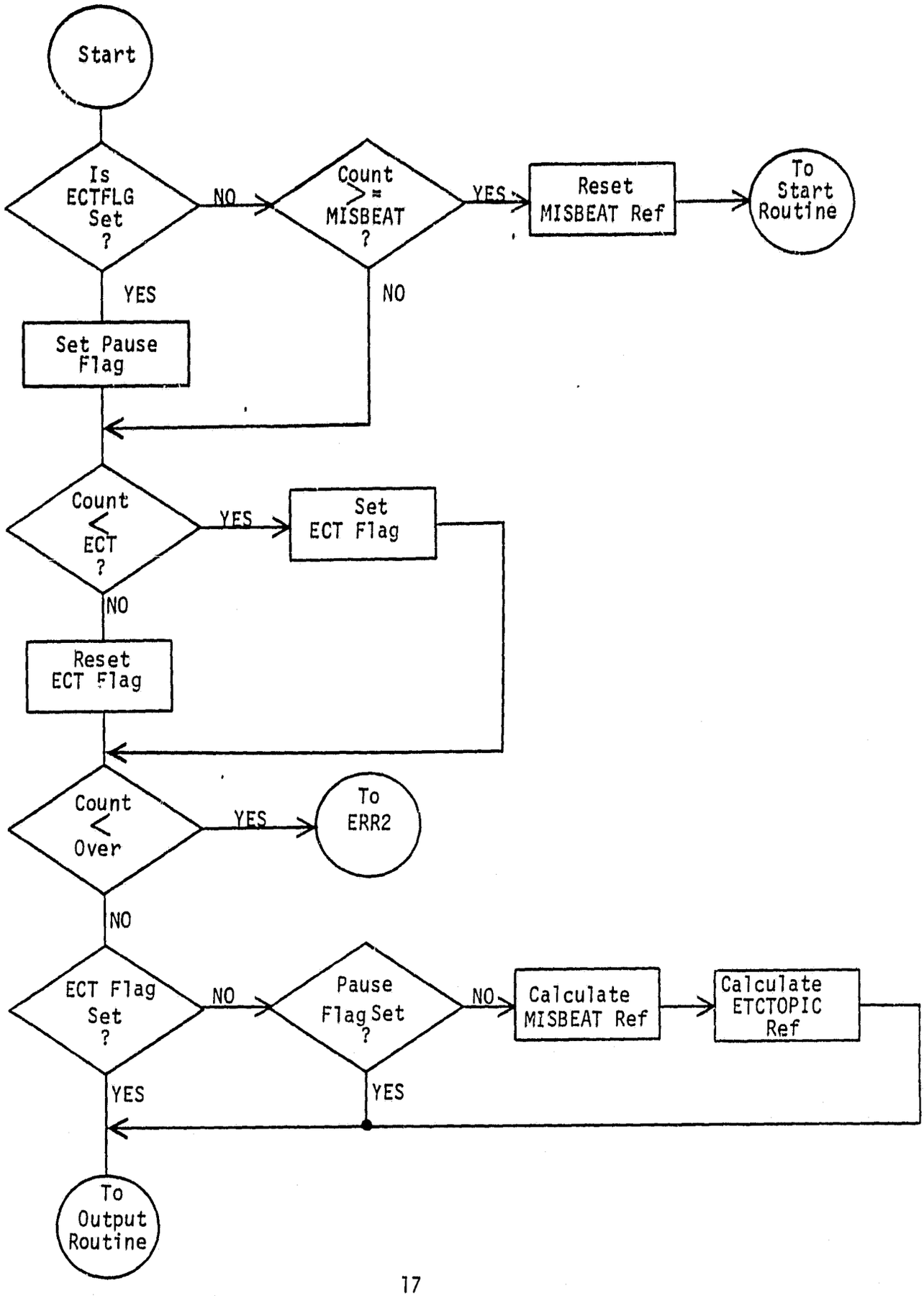
(For Switch 1 and ECG/Cal Pulses)



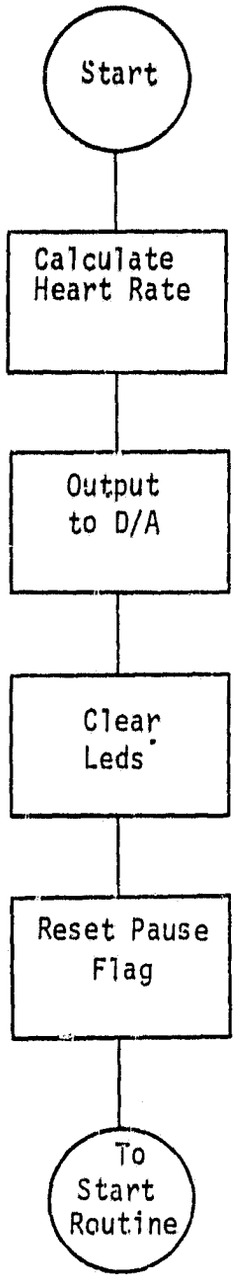
COUNT ROUTINE



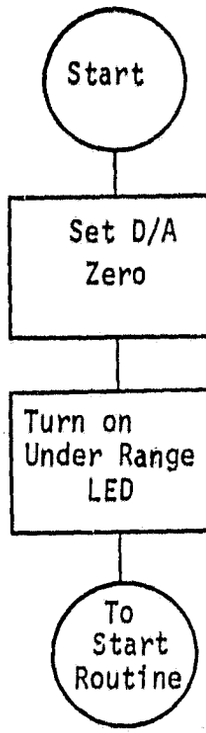
CHECK ROUTINE



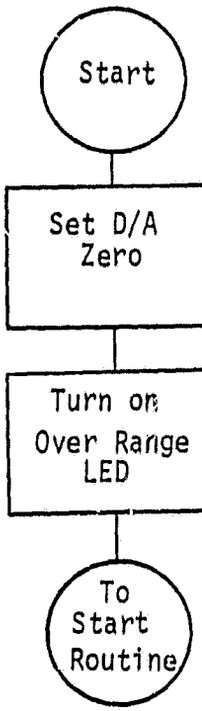
OUTPUT ROUTINE



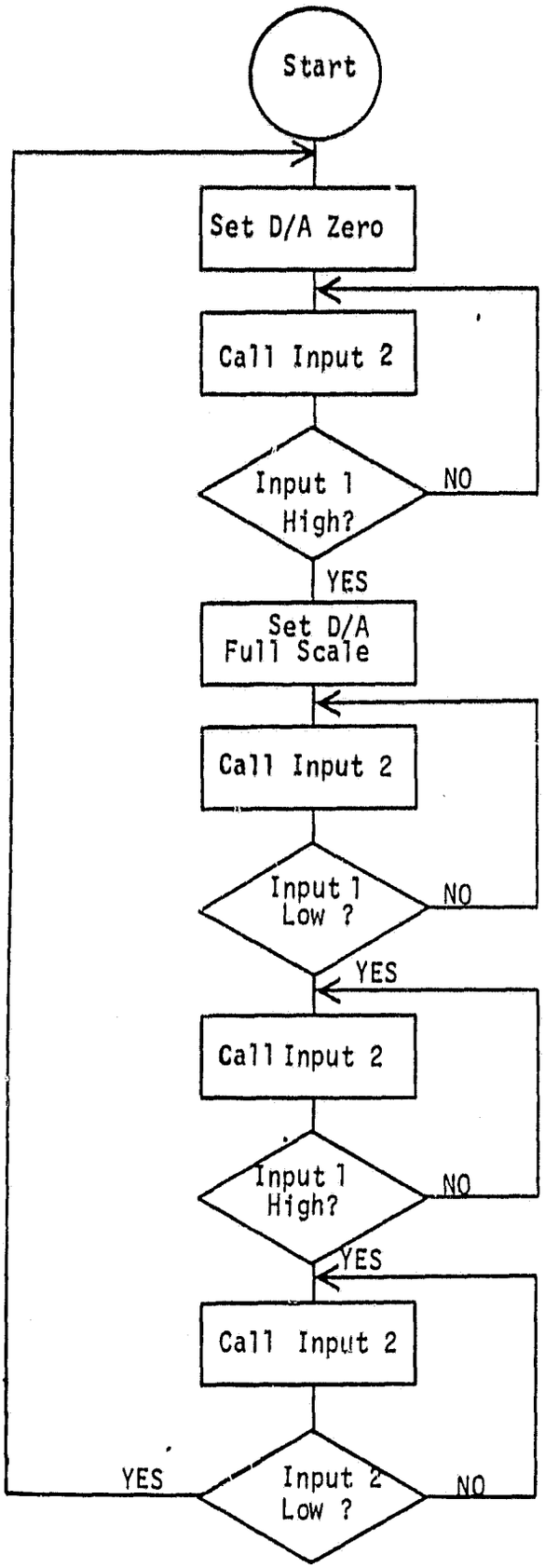
ERR 1 (Underrange)



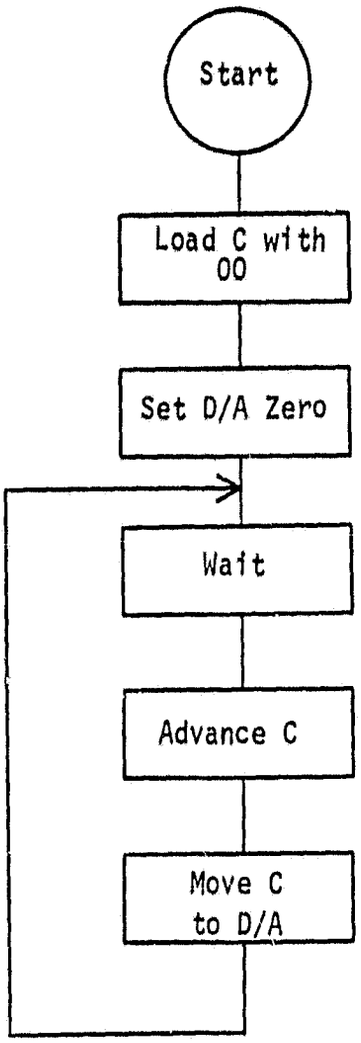
ERR 2 (Overrange)



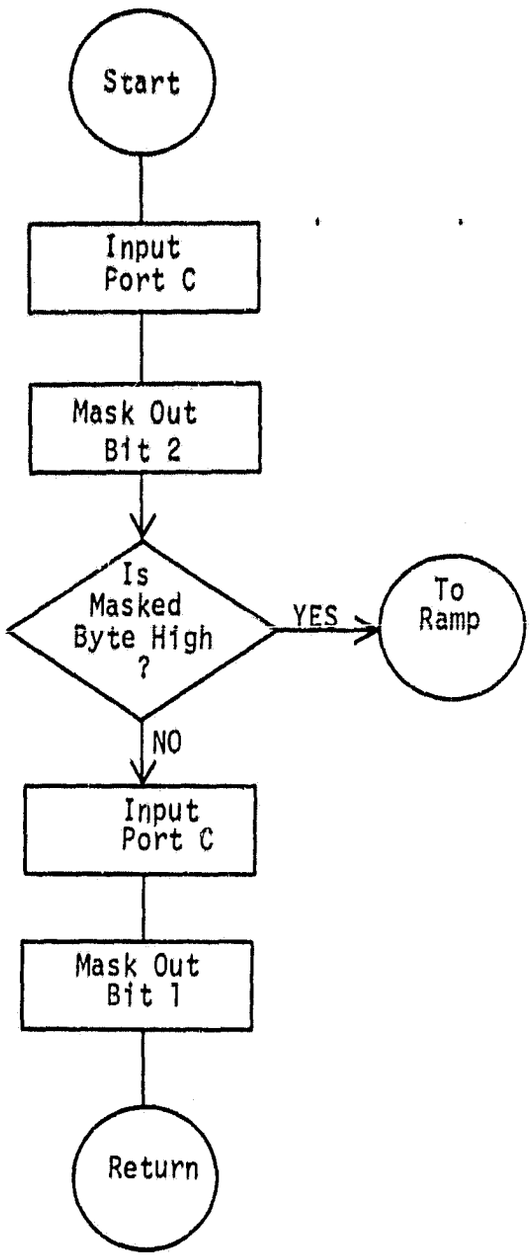
D/A SETUP ROUTINE



D/A RAMP ROUTINE



INPUT 2 ROUTINE
(For Switch 2)



APPENDIX B

```
0000    31FF1C      BEGIN:  LXI,SP          ;SET UP STACK POINTER
0003    CDCA00              CALL INIT       ;INITIALIZATION ROUTINE
0006    CD0A01      START:  CALL INPUT
0009    CA0600              JZ   START
000C    CD0A01         S1:  CALL INPUT      ;WAIT FOR R-WAVE
000F    C20C00              JNZ  S1         ;TO END THEN GO
0012    110000      COUNT:  LXI D,E         ;INITIALIZE HR COUNTER
0015    13             C1:  INX D,E
0016    011301      TIMER:  LX1 B,C
0019    0D             T1:  DCR C
001A    79                  MOV A,C
001B    FE00                CPI A,00        ;SEE IF C IS ZERO
001D    C21900              JNZ  T1         ;IF NOT GOTO T1
0020    05                  DCR B
0021    78                  MOV A,B
0022    FE00                CPI A,00        ;SEE IF B IS ZERO
0024    C21900              JNZ  T1         ;IF NOT GOTO T1
0027    EB          UNDER:  XCHG            ;SWAP D,E WITH H,L
0028    11F813              LXI D,E         ;LOAD UNDER RANGE CODE
002B    CD1801              CALL HILO       ;CHECK FOR UNDER RANGE
002E    CD3E01              JC   ERR1       ;IF SO GOTO ERR1
0031    EB                  XCHG            ;SWAP D,E WITH H,L
0032    CD0A01         C2:  CALL INPUT      ;LOOK FOR NEXT R-WAVE
0035    CA1500              JZ   C1         ;IF NOT GOTO C1
0038    3A041C      MISBT:  LDA ECTFLG      ;LOAD ECTOPIC FLAG
003B    FEFF                CPI A,FF        ;SEE IF SET
003D    C27401              JNZ MISCNT      ; IF FLAG NOT SET JMP
0040    3E01                MVI A,01        ; IF FLAG SET THEN
0042    32041C              STA PAUSE       ; SET PAUSE FLAG
0045    2A021C        ECT:  LHLD            ;LOAD ECTOPIC REF INTO H,L
0048    EB                  XCHG            ;SWAP D,E WITH H,L
0049    CD1801              CALL HILO       ;CHECK FOR ECTOPIC BEAT
004C    D25A00              JNC  FLAG1      ;IF SO GOTO FLAG1
004F    3A041C              LDA  ECTFLG     ;GET ECTOPIC FLAG
0052    3E00                MVI A,00        ;RESET ECTOPIC FLAG
0054    32041C              STA  ECTFLG     ;STORE ECTOPIC FLAG
0057    C36100              JMP  OVER
005A    3A041C      FLAG1:  LDA  ECTFLG     ;GET ECTOPIC FLAG
005D    2F                  CMA             ;COMPLIMENT FLAG
005E    32041C              STA  ECTFLG     ;STOR ECTOPIC FLAG
0061    00           OVER:  NOP             ;SWAP D,E WITH H,L
0062    11C001              LXI D,E         ;LOAD OVER RANGE CODE
0065    CD1801              CALL HILO       ;CHECK FOR OVER RANGE
0068    D24901              JNC  ERR2       ;IF SO GOTO ERR2
006B    EB                  XCHG            ;SWAP D,E WITH H,L
006C    00                  NOP
006D    3A041C      FLGCK:  LDA  ECTFLG     ;GET ECTOPIC FLAG
0070    FEFF                CPI A,FF
0072    CA8D00              JZ   DIVIDE     ;IF NOT SET GOTO DIVIDE
0075    3A051C              LDA  PAUFLG     ;GET PAUSE FLAG
0078    FE01                CPI A,01
007A    CA8D00              JZ   DIVIDE     ;IF NOT SET GOTO DIVIDE
007D    0E1C        HRREF:  MIV C,1.75      ;MISBT CONSTANT
```

```
007F    CD5401              CALL MULT       ;CALCULATE NEW MISBT
0082    22001C              SHLD            ;STORE NEW MISBT REF
0085    0E0C                MIV C,.75       ;ECTREF CONSTANT
0087    CD5401              CALL MULT       ;CALCULATE NEW ECTREF
008A    22021C              SHLD            ;STORE NEW ECTREF
008D    010507      DIVID:  LXI B,C         ;THIS ROUTINE IS
0090    7A                  MOV A,D         ;AN UNSIGNED 16-BIT
0091    2F                  CMA             ;DIVIDE ROUTINE
0092    57                  MOV D,A
0093    7B                  MOV A,E
0094    2F                  CMA
0095    5F                  MOV E,A
0096    13                  INX D,E
0097    210000              LXI H,L
009A    3E17                MVI A,17
009C    E5            DV0:  PUSH H,L        ;REGISTERS H,L USED
009D    19                  DAD D,E         ;TO STORE DATA
009E    D2A200              JNC  DV1        ;TEMPORARILY
00A1    E3                  XTHL
00A2    E1            DV1:  POP H,L
00A3    F5                  PUSH PSW
00A4    79                  MOV A,C
00A5    17                  RAL
00A6    4F                  MOV C,A
00A7    78                  MOV A,B
00A8    17                  RAL
00A9    47                  MOV B,A
00AA    7D                  MOV A,L
00AB    17                  RAL
00AC    6F                  MOV L,A
00AD    7C                  MOV A,H
00AE    17                  RAL
00AF    67                  MOV H,A
00B0    F1                  POP PSW
00B1    3D                  DCR A
00B2    C29C00              JNZ DV0
00B5    B7          CLEAN:  ORA A
00B6    7C                  MOV A,H
00B7    1F                  RAR
00B8    57                  MOV D,A
00B9    7D                  MOV A,L
00BA    1F                  RAR
00BB    5F                  MOV E,A
00BC    79          OUTD/A: MOV A,C         ;PUT RESULT IN A
00BD    3C                  INR A           ;ADD ONE TO A
00BE    D304                OUT D/A         ;LOAD PORT A-D/A
00C0    3E00        CLEAR:  MVI A,00
00C2    D306                OUT LEDS        ;LOAD PORT B-LEDS
00C4    32051C              STA PAUFLG      ;SET PAUSE FLAG TO 00
00C7    C30600              JMP START
```

```
00CA    3E81        INIT:   MVI A,81        ;LOAD MODE 0 &
00CC    D307                OUT PPI         ;OUTPUT TO PPI-8255
00CE    3E34                MVI A,34        ;LOAD MODE 2 &
00D0    D30B                OUT IT0         ;OUTPUT TO COUNTER 0-8253
00D2    3E74                MVI A,74        ;LOAD MODE 2 &
00D4    D30B                OUT IT1         ;OUTPUT TO COUNTER 1-8253
00D6    3EB4                MVI A,B4        ;LOAD MODE 2 &
00D8    D30B                OUT IT2         ;OUTPUT TO COUNTER 2-8253
00DA    3E00                MVI A,FF        ;LOAD COUNTER 0
00DC    D308                OUT IT0         ;DIVIDE BY 2047
00DE    3E08                MVI A,07
00E0    D308                OUT IT0
00E2    3EE8                MVI A,E8        ;LOAD COUNTER 1
00E4    D309                OUT IT1         ;DIVIDE BY 1000
00E6    3E03                MVI A,03
00E8    D309                OUT IT1         ;60 BPM CAL SIGNAL
00EA    3E4D                MVI A,4D        ;LOAD COUNTER 2
00EC    D30A                OUT IT2         ;DIVIDE BY 333
00EE    3E01                MVI A,01
00F0    D30A                OUT IT2         ;180 BPM CAL SIGNAL
00F2    3EFF                MVI A,FF        ;INITIALIZE MISBT REFERENCE
00F4    32001C              STA             ;TO FFFF
00F7    32011C              STA
00FA    00                  NOP
00FB    3E00                MVI A,00
00FD    32021C              STA             ;INITIALIZE ECTOPIC
0100    32031C              STA             ;REFERENCE TO 0000
0103    32041C              STA             ;SET ECTOPIC FLAG TO ZERO
0106    32051C              STA             ;SET PAUSE FLAG TO ZERO
0109    C9                  RET

010A    DB06        INPUT:  IN PORTC        ;CHECK IF SWITCH 1
010C    0602                MVI B,02        ;WAS PUSHED
010E    A0                  ANA B
010F    C29401              JNZ SETUP       ;IF SO GOTO STEP
0112    DB06                IN PORT C
0114    0601                MVI B,01        ;CHECK FOR ECG OR
0116    A0                  ANA B           ;CAL SIGNAL
0117    C9                  RET

0118    C5          HILO:   PUSH B,C        ;THIS ROUTINE COMPARES
0119    47                  MOV B,A         ;H,L WITH D,E
011A    E5                  PUSH H,L
011B    7A                  MOV A,D
011C    B3                  ORA A           ;IF H,L IS LESS
011D    CA3901              JZ HILO1        ;THAN D,E THEN
0120    23                  INX H,L         ;CARRY IS SET 0
0121    7C                  MOV A,H
0122    B5                  ORA L           ;IF H,L IS GREATER
0123    CA3901              JZ HILO1        ;THAN OR EQUEL
```

```
0126    E1                      POP H,L         ;TO D,E THEN CARRY
0127    D5                      PUSH D,E        ;IS SET 1
0128    3EFF                    MVI A,FF
012A    AA                      XRA D
012B    57                      MOV D,A
012C    3EFF                    MVI A,FF
012E    AB                      XRA E
012F    5F                      MOV E,A
0130    13                      INX D,E
0131    7D                      MOV A,L
0132    83                      ADD E
0133    7C                      MOV A,H
0134    8A                      ADC D
0135    D1                      POP D,E
0136    78                      MOV A,B
0137    C1                      POP B,C
0138    C9                      RET
0139    E1              HILO1:  POP H,L
013A    78                      MOV A,B
013B    C1                      POP B,C
013C    37                      STC
013D    C9                      RET


013E    3E00            ERR1:   MVI A,00        ;SET D/A TO ZERO
0140    D304                    OUT D/A         ;AND TURN ON UNDER
0142    3E10                    MVI A,10        ;RANGE LED
0144    D306                    OUT LEDS
0146    C30600                  JMP START


0149    3E00            ERR2:   MVI A,00        ;SET D/A TO ZERO
014B    D304                    OUT D/A         ;AND TURN ON OVER
014D    3E20                    MVI A,20        ;RANGE LED
014F    D306                    OUT LEDS
0151    C30600                  JMP START


0154    D5              MULT:   PUSH D,E        ;THIS ROUTINE MULTIPLIES
0155    EB                      XCHG            ;2 UNSIGNED 8 BIT
0156    29                      DADH            ;NUMBERS AND
0157    29                      DADH            ;PRODUCES AN
0158    29                      DADH            ;UNSIGNED 16 BIT
0159    29                      DADH            ;RESULT
015A    EB                      XCHG
015B    0600                    MVIB,00         ;REGISTER D IS
015D    1E09                    MVI E,09        ;MULTIPLICAND
015F    79              MULTO:  MOV A,C
0160    1F                      RAR             ;REGISTER C IS
0161    4F                      MOV C,A         ;MULTIPLIER
0162    1D                      DCR E
```

```
0163    CA7001              JZ DONE          ;REGISTER B IS
0166    78                  MOV A,B          ;MSB RESULT
0167    D26B01              JNC MULT1
016A    82                  ADD D            ;REGISTER C IS
016B    1F          MULT1:  RAR              ;LSB RESULT
016C    47                  MOV B,A
016D    C35F01              JMP MULTO
0170    60                  MOV H,B
0171    69                  MOV L,C
0172    D1                  POP D,E
0173    C9                  RET

0174    2A001C      MISCNT: LHLD HR REF      ;LOAD HR RE
0177    EB                  XCHG
0178    CD1801              CALL HILO
017B    D20045              JNC ECT
017E    3EFF                MVI A,FF
0180    32001C              STA
0183    32011C              STA
0186    31FFIC              LXI SP
0189    C30600              JMP START
018C    000000              NOP
018F    000000              NOP
0192    0000                NOP
```

8080 MICRO CARDIOOTACHOMETER SOFTWARE

ZERO & FULL SCALE PROGRAM

```
0194    3E00        STEP:   MVI A,00         ;THIS ROUTINE
0196    D304                OUT D/A          ;ALLOW ADJUSTMENT
0198    CDD501        L1:   CALL IN2         ;OF THE D/A FOR
019B    CA9801              JZ L1            ;ZERO AND FULL
019E    3EFF                MVI A,FF         ;SCALE OUTPUT
01A0    D304                OUT D/A
01A2    CDD501        L2:   CALL IN2
01A5    C2A201              JNZ L2
01A8    CDD501        L3:   CALL IN2
01AB    CAA801              JZ L3
01AE    CDD801        L4:   CALL IN2
01B1    C2AE01              JNZ L4
01B4    C39401              JMP STEP
```

RAMP PROGRAM

```
01B7    0300        RAMP:   MVI C,00
01B9    79                  MOV A,C
01BA    D304                OUT D/A
01BC    CDDD01        T1:   CALL IN3
01BF    1B                  DCX D,E
01C0    7A                  MOV A,D
01C1    FE00                CPI A,00
01C3    C2BC01              JNZ T1
01C6    CDDD01        T2:   CALL IN3
```

```
01C9    1B                      DCX D,E
01CA    78                      MOV A,E
01CB    BA                      CMP D
01CC    C2C601                  JNZ T2
01CF    79                      MOV A,C
01D0    D304                    OUT D/A
01D2    C3B701                  JMP RAMP

                SUBROUTINE FOR STEP & RAMP PROGRAMS

01D5    DB06            IN2:    IN PORTC
01D7    0604                    MVI B,04
01D9    A0                      ANA B
01DA    C2B701                  JNZ RAMP
01DD    DB06            IN3:    IN PORT C
01DF    0602                    MVI B,02
01E1    A0                      ANA B
01E2    C9                      RET
*
```

APPENDIX C

8080 MICRO CARDIOTACHOMETER SOFTWARE

REAL-TIME HEART RATE PROGRAM
EXECUTION TIMES

OPERATION	TIMES
START-UP NO SIGNAL IN	144.6 μs
DELAY TIMER ROUTINE	422.08 μs
EACH COUNT OF D,E REGISTER	584.26 μs
UNDER RANGE LED & ZERO OUTPUT	21.98 μs
OVER RANGE LED & ZERO OUTPUT	21.98 μs
UNDER RANGE <30 BPM	2.307 sec.
OVER RANGE >300 BPM	187.07 ms
16 BIT DIVISION ROUTINE	1.74 ms
OUTPUT & CLEAR ROUTINE	23.94 μs
CALCULATE & DISPLAY TIME	1.77 ms
OPERATING SPEED RANGE	>187.07 ms to <2.307 sec.

APPENDIX D

WIRE WRAP LIST
CPU-MEMORY

+5VDC

C20 to +5
A1 to A2 to A3 to
A4 to A6 to +5
A27 to A28 to +5
B10 to +5
B18 to +5
B36 to +5
D22 to +5
D32 to +5
J1 to +5
J16 to +5
J29 to +5
A23 to +5

-5VDC

A44 to J32 to
J19 to C11 to
25

+12VDC

1 to 7 to
A34 to B17 to
E12 to J21 to
J34

-12VDC

24 to 30 to A45

GND

A17 to GND
A25 to GND
A42 to GND
A46 to GND
B5 to GND
B44 to B45 to GND
C2 to GND
C13 to GND
C30 to GND
C40 to GND
D25 to GND
D35 to GND
G14 to GND
G27 to GND
G40 to GND
J7 to GND
J22 to GND
J35 to GND

WIRE WRAP LIST

CPU-MEMORY

SIGNALS

B1 to A36 to A16 to 27
B2 to A37 to C14
B3 to B4 to 2
A5 to A11 to 3
B6 to A12
A15 to 26
A7 to A8
B7 to B11
B8 to B12
B24 to C15
A13 to E18
A10 to C12 to 40
A14 to C19
B16 to E19
C10 to J14
C9 to J12
C8 to G12
C7 to G10
C3 to G6
C4 to J10
C5 to J8
C6 to G8
E20 to G2
C17 to G4
C18 to G3
B34 to J6
J2 to 41
J4 to 42

CONTROL-SIGNALS

B19 to B27 to J20 ($\overline{CS0}$)
B20 to B28 to J33 ($\overline{CS1}$)
A24 to D30 to D40 ($\overline{CS7}$)
D24 to D34 to J5 ($\overline{MEMR}$)
C30 to C40 to J3 ($\overline{MEMW}$)
J6 to B34
J4 to 42 ($\overline{RD}$)
J2 to 41 ($\overline{WR}$)

DATA

G13 to G24 to G37 to D29 to 23 (D0)
J13 to G25 to G38 to D28 to 22 (D1)
G11 to G26 to G39 to D27 to 21 (D2)
G9 to J27 to J40 to D26 to 20 (D3)
G5 to J26 to J39 to D39 to 43 (D4)
J11 to J25 to J38 to D38 to 44 (D5)
J9 to J24 to J37 to D37 to 45 (D6)
G7 to J23 to J36 to D36 to 46 (D7)

ADDR

E16 to G23 to G36 to C25 to C35 to 19 (A0)
E15 to G22 to G35 to C24 to C34 to 18 (A1)
E14 to G21 to G34 to C23 to C33 to 17 (A2)
E12 to G20 to G33 to C22 to C32 to 40 (A3)
E11 to G19 to G32 to D23 to D33 (A4)
E10 to G18 to G31 to C26 to C37 (A5)
E9 to G17 to G30 to C27 to C38 (A6)
E8 to G16 to G29 to C28 to C39 (A7)
E7 to J17 to J30 (A8)
E6 to J18 to J31 (A9)
C1 to A18 (A10)
E1 to A19 (A11)
E4 to A20 (A12)
E3 to A21 (A13)
E2 to A22 (A14)
(A15)

WIRE WRAP LIST

INTERFACE BOARD

GROUND-BLK

AC14 to GND
AA33 to GND
AD22 to GND
AH7 to GND
AH15 to GND

+5VDC-RED

AA6 to +5
AC22 to +5
AE15 to +5
AE9 to AF4 to +5
AJ1 to AJ9 to +5

+12VDC-WHITE

AE1 to GA7
AG5 to B43
AE1 to AE5

-12VDC-GREEN

AD4 to AD8 to
AB50 to AF10
to GA30

8255 & 8253 SIGNALS

GA40 to AH 3 to AC25
GA41 to AA16 to AC23
GA42 to AC16 to AC24
GA28 to AA15

8255 & 8253 SIGNALS

GA23 to AA14 to AA29
GA22 to AA13 to AA28
GA21 to AA12 to AA27
GA20 to AA11 to AA26
GA43 to AA10 to AA25
GA44 to AA9 to AA24
GA45 to AA8 to AA23
GA46 to AA7 to AA22
GA19 to AC12 to AC27
GA18 to AC13 to AC26
GA17 to AH1
AH2 to AC15

DEBOUNCE SWITCHES

GB23 to AH5 to AJ7
GB46 to AJ6 to AH6 to AC6
GB22 to AJ3 to AJ4
GB45 to AJ2 to AJJ to AC5

ECG LED

AH13 to BA16
AH14 to BC7
BD7 to 5B21 (LED1 out)

LEDS 2 & 3

LED2 under
LED3 over

UNDER LED

AC8 to AH9
AH10 to BC5
BD5 to 5B44 (LED2 out)

OVER LED

AC9 to AH11
AH12 to BC6
BD6 to GB20 (LED3 out)

WIRE WRAP LIST

INTERFACE GROUP

FILTER CIRCUIT

SIGNAL GND

AG30 to GND
AE27 to GND
AG34 to GND
AD30 to GND
AF33 to GND
AD37 to GND

SIGNALS

AD24 to AD25 to AG29
AD26 to AD27 to AF28
AF29 to AD28
AE28 to AE29 to AE31 to AG32
AD29 to AD33 to AG33
AE33 to AE34 to AE30 to AD31
AD34 to AD35
AE35 to AE36 to AE38 to AF31
AD36 to AD37 to AF32
AD38 to AE39 to AE37

INPUT

AD40

OUTPUT

AE25 to AF27

OUTPUT2

AE24 to AG28

PULSE DETECTOR

SIGNALS

AH32 to AH33 to AG26
AJ36 to AJ37 to AJ38 to AF24
AF23 to AJ31
AH30 to AH31
AJ30 to AJ27 to AJ44
AH44 to AH28
AH45 to AJ39
AH40 to AH41
AJ40 to AJ39

PULSE DETECTOR

GNDS

AJ17 to GND AJ24 to AJ26 to GND
AJ21 to GND
AJ32 to GND
AH37 to GND
AJ41 to GND
AH37 to GND

+12VDC

AG19 to AG23 to AG27 to AG31 to AG38

-12VDC

AF22 to AF26 to AF30 to AF34 to AH39

SIGNALS

AJ18 to AJ19 to AG21
AH19 to AH21 to AH22
AH20 to AG22
AJ20 to AD47
AD50 to AB43
AJ22 to AF19
AH24 to AH27 to AH28 to AF20
AH26 to AH35 to AH36 to AF21 to AF25
AJ28 to AH29 to AG25
AJ29 to AG24

LSI-11 INTERFACE

GNDS

BB4 to GND
BB8 to GND
BA17 to BB11 to GND
BA12 to GND

WIRE WRAP LIST
INTERFACE BOARD

D/A

AC17 to AE10
AC18 to AE11
AC19 to AE12
AC20 to AE13
AA20 to AD13
AA19 to AD12
AA18 to AD11
AA17 to AD10

AGC CIRCUIT
+12VDC
-

AD43 to AE43
AF38 to AF34
AG35 to AG31
AD50 to AE50

SIGNAL GND

AF44 to GND
AG46 to GND
BB47 to BB48 to GND
BB50 to GND

SIGNAL GND

AG4 to GND
AG7 to AG8 to AG4
AD6 to AD7 to
AD3 to GND
AG1 to AG4

SIGNAL

AF1 to AF2 to AF3 to
AD2 to AD9 to AC43
AD1 to AG3 to AC50 to
GB18
AE8 to AG6
AG10 to AE6
AG2 to AA47
AF6 to AF5 to AF8
AF7 to AE7

CIRCUIT

AG40 to AG41 to AG42 to AF36
AF41 to AF43 to AG46
AG44 to AF37
AG43 to BB44 to AF35
AF45 to AF47
BA44 to BA45
BB45 to BB46
BA46 to BA47 to BA48 to AG38
BA49 to BA50 to AG37
BB49 to AG36 to AG45

OUTPUT

BB44 to AJ35

INPUT

AF27 to AF40

INPUTS

AJ33 to AJ35

OUTPUTS

AH17 to AH18 to AG20 to BA15

LSI-11 INTERFACE

+5VDC

BB1 to +5
BB5 to +5
BB10 to +5
BD3 to BD4 to +5

SIGNALS

BD1 to BD2 to GB42
BA3 to GB43 (CSR0)
BA7 to GB19 (CSR1)
BC1 to BA2
BC2 to BA6
BB3 to BC3 to BB12
BB7 to BC4 to BA11

INPUTS

AG20 to BA15 (ECG)
AE18 to BA14 (LOW CAL)
AD19 to BA13 (HIGH CAL)

OUTPUTS

BA16 to AC7

WIRE WRAP LIST

INTERFACE BOARD

CALIBRATION CIRCUIT

+5VDC

AA32 to +5
AC32 to +5
AC30 to +5
AE15 to +5
AD16 to AD17 to +5
AE19 to AE20 to +5
AF11 to AF13 to +5

GNDS

AD22 to GND

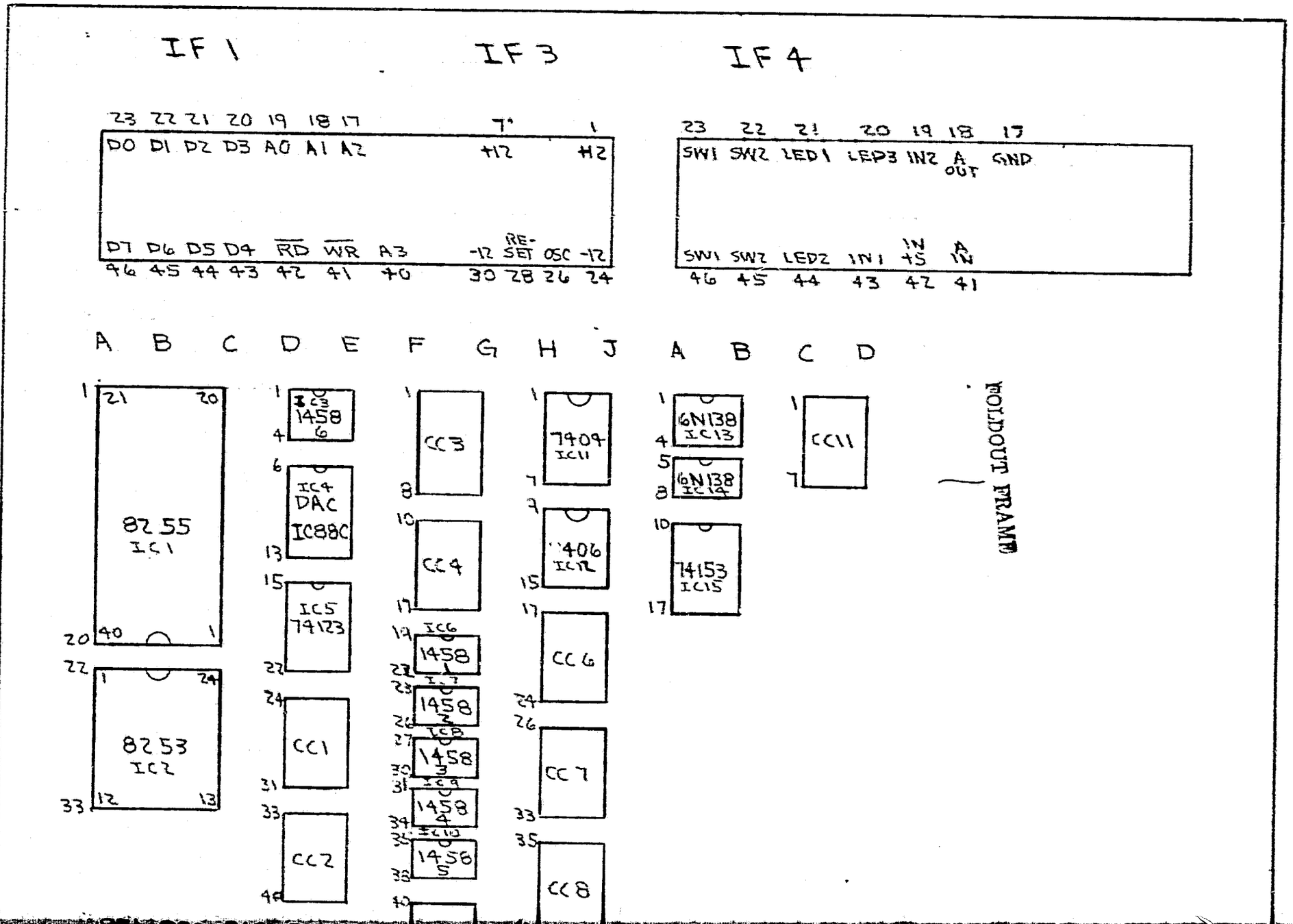
SIGNALS

GA26 to AA30
AA31 to AC28 to AC31
AC29 to AE22
AC33 to AD15
AG11 to AG12 to AE16
AG13 to AG14 to AD21
AF12 to AE17
AF14 to AD20

OUTPUTS

AE18 to BA14 (LOW CAL)
AD19 to BA13 (HIGH CAL)

APPENDIX E


IF 1
IF 3
IF 4
23 22 21 20 19 18 17
D0 D1 D2 D3 A0 A1 A2
D7 D6 D5 D4 RD WR A3
46 45 44 43 42 41 40
7 1
+12 +12
RE-SET -12 OSC -12
30 28 26 24
23 22 21 20 19 18 17
SW1 SW2 LED1 LED3 IN2 A OUT GND
SW1 SW2 LED2 IN1 IN +5 A IN
46 45 44 43 42 41
A B C D E F G H J
A B C D
8255 IC1
8253 IC2
IC3 1458
IC4 DAC IC88C
IC5 74123
CC1
CC2
CC3
CC4
IC6 1458
1458
IC8 1458
IC9 1458
IC10 1458
7404 IC11
7406 IC12
CC6
CC7
CC8
6N138 IC13
6N138 IC14
74153 IC15
CC11
TO/FROM FRAME

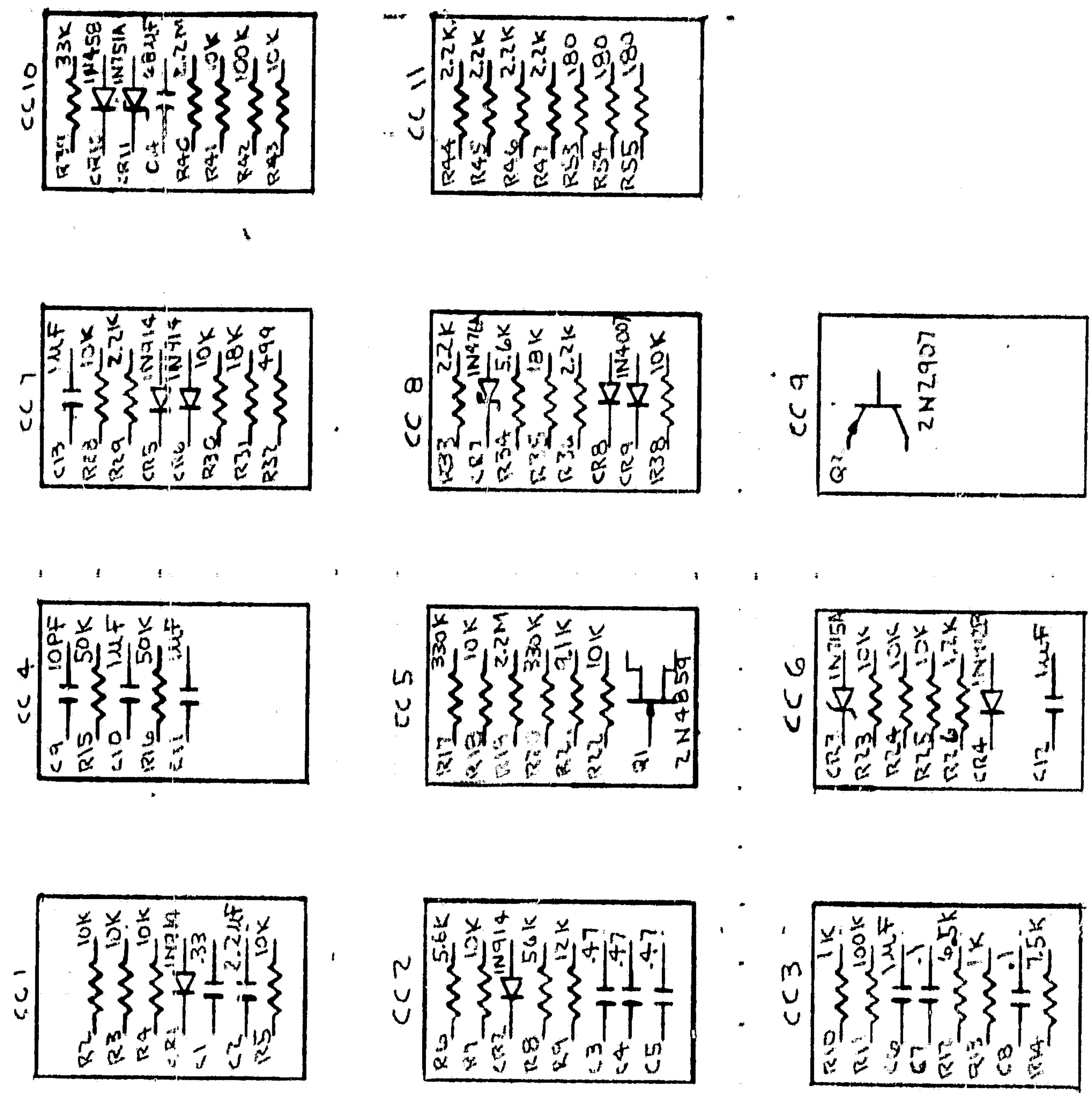
FOLDOUT FRAME

2

1458

(1) PULSE DETECT OUT
(2) PULSE DETECT IN
(3) FILTER OUT
(4) FILTER IN
(5) AGC
(6) D/A OUT

TECHNOLOGY INCORPORATED LIFE SCIENCES DIVISION HOUSTON, TEXAS 77058		
DRAWN BY M.H. UTLEY	DATE 9-30-79	TITLE 8080A-BASED CARDIOTACHOMETER COMPONENT LAYOUT INTERFACE BOARD
DESIGN ENG. J.A. DONALDSON	11-14-79	
PROJ. ENG. W. G. CROSIER	11-14-79	DWG. NO. MPCT-2009-L
		SHEET 1 OF 2

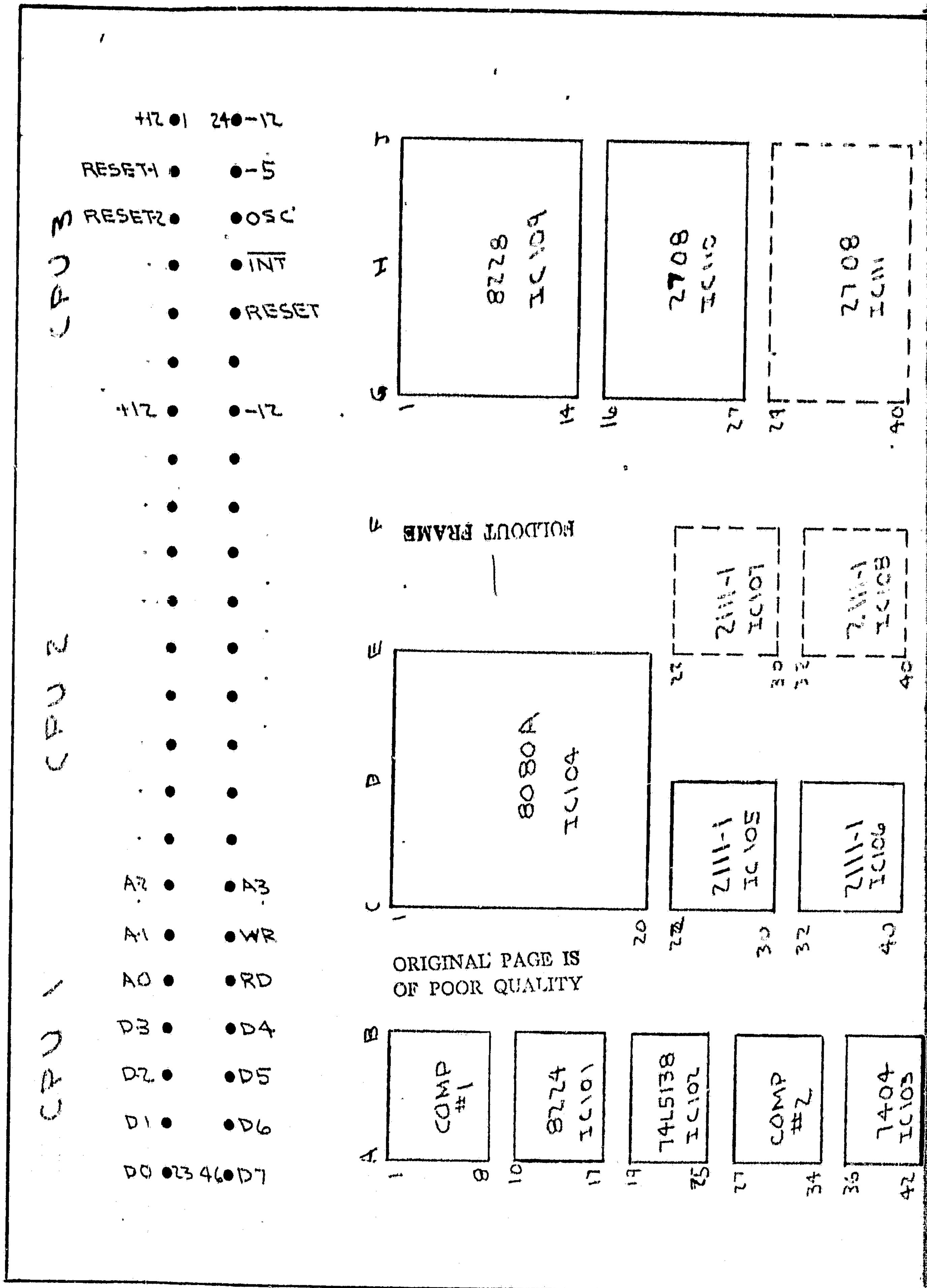


FOLDOUT FRAME

FOLDOUT FRAME

2

TECHNOLOGY INCORPORATED LIFE SCIENCES DIVISION HOUSTON, TEXAS 77058		
DRAWN BY M. H. UTLEY	DATE 9-28-79	TITLE 8080 A - BASED CARDIOTACHOMETER COMPONENT LAYOUT -INTERFACE BOARD
DESIGN ENG J.A. DONALDSON	11-14-79	
PROJ. ENG, W. G. CROSIER	11-14-79	DWG. NO, MPCT-2009-L
		SHEET 2 OF 2

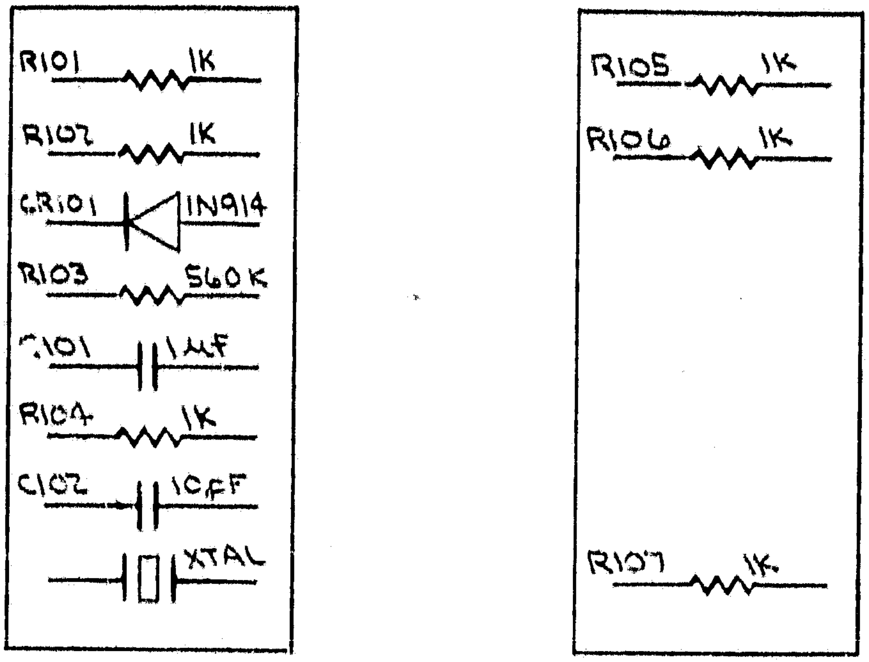


FOLDOUT FRAME 2

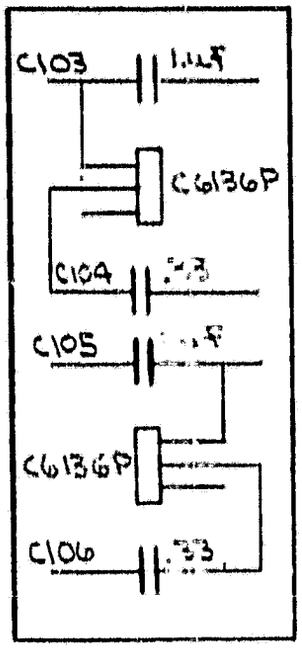
NOTES: (1) DASHED LINES INDICATE LOCATIONS FOR I.C.'S TO BE ADDED LATER FOR FUTURE EXPANSION, IF NECESSARY.

TECHNOLOGY INCORPORATED LIFE SCIENCES DIVISION HOUSTON, TEXAS 77058		
DRAWN BY M.H.UTLEY	DATE 10-17-79	TITLE 8080A-BASED CARDIOTACHOMETER COMPONENT LAYOUT CPU BOARD
DESIGN ENG J.A.DONALDSON	11-14-79	
PROJ. ENG W.G. CROSIER	11-14-79	DWG. NO. MPCT-2011-L
		SHEET 1 OF 2

COMP SYS
44 55



COMP 1 COMP 2

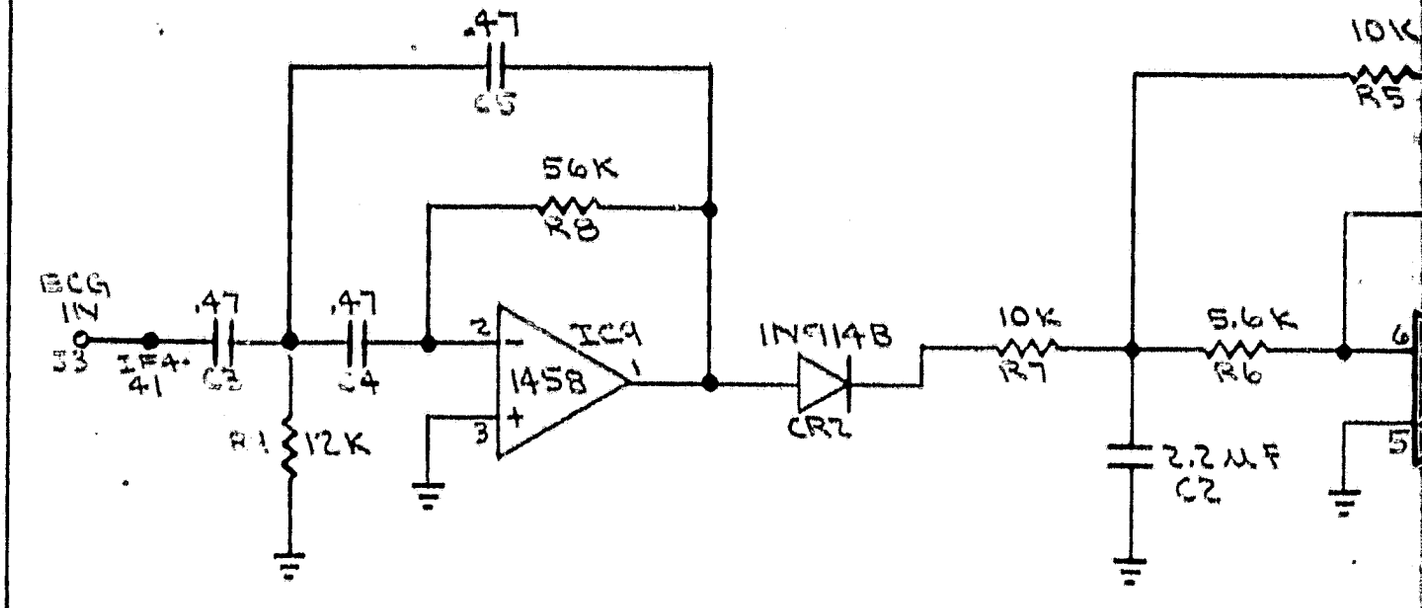


COMP 3

FOLDOUT FRAME
2

TECHOLOGY INCORPORATED LIFE SCIENCES DIVISION HOUSTON, TEXAS 77058		
DRAWN BY M.H.UTLEY	DATE 10-16-79	TITLE 8080A - BASED CARDIOTACHOMETER COMPONENT LAYOUT CPU BOARD
DESIGN ENG. J.A. DONALDSON	11-14-79	
PROJ. ENG. W. G. CROSIER	11-14-79	DWG. NO. MPCT-2011-L
		SHEET 2 OF 2

APPENDIX F



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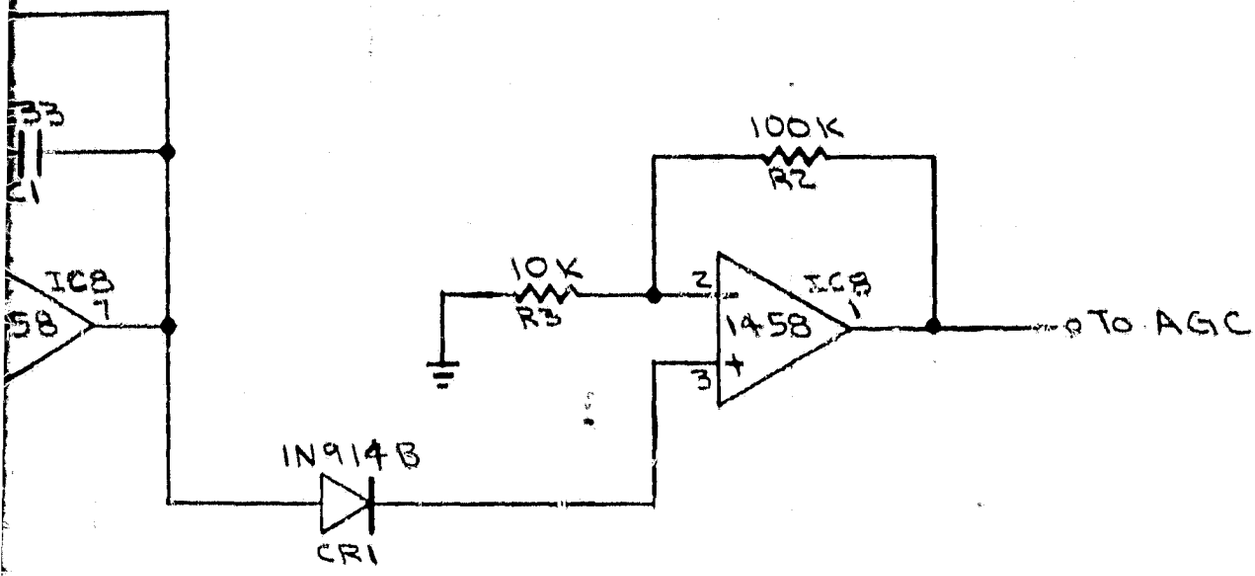
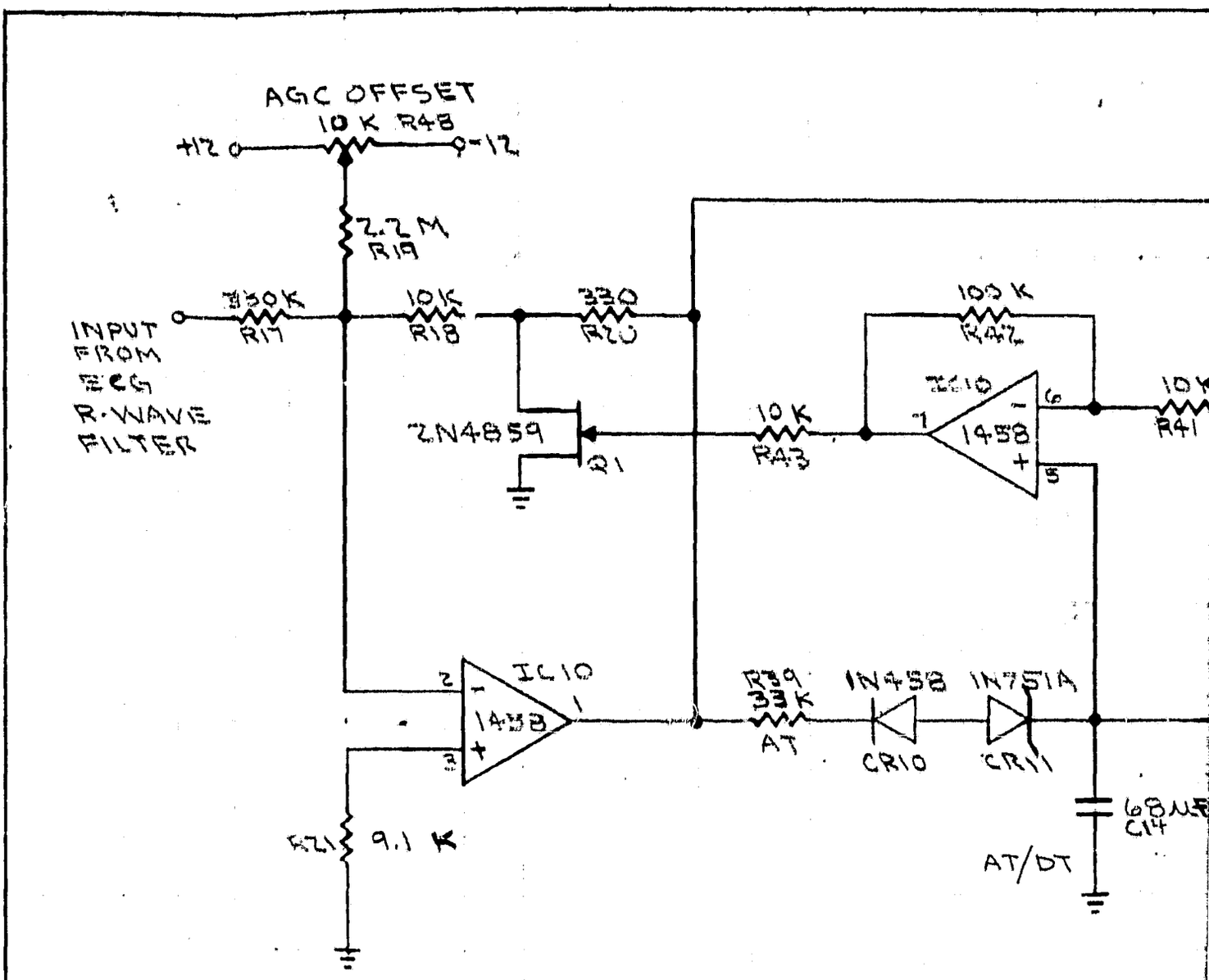


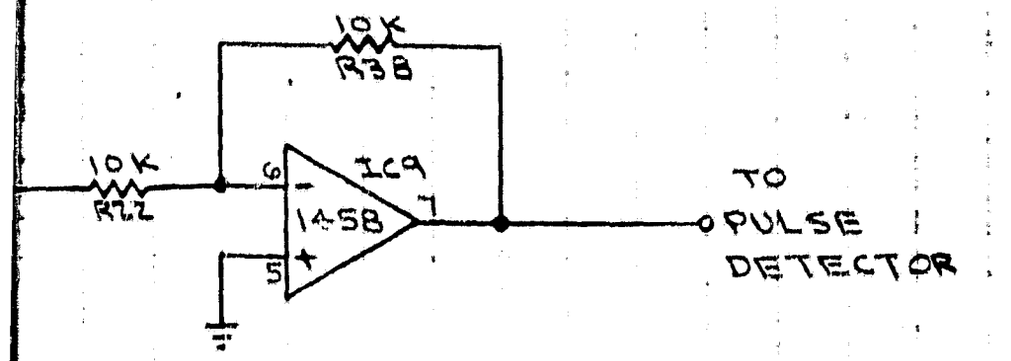
FOLDOUT FRAME

2

TECHNOLOGY INCORPORATED LIFE SCIENCES DIVISION HOUSTON, TEXAS 77058		
DRAWN BY M. H. UTLEY	DATE 9-29-79	TITLE 8080A - BASED CARDIOTACHOMETER ECG - R - WAVE FILTER
DESIGN ENG. J. A. DONALDSON	11-14-79	
PROJ. ENG W. G. CROSIER	11-14-79	DWG. NO MPCT - 7001 - S
		SHEET 1 OF 1



FOLDOUT FRAME

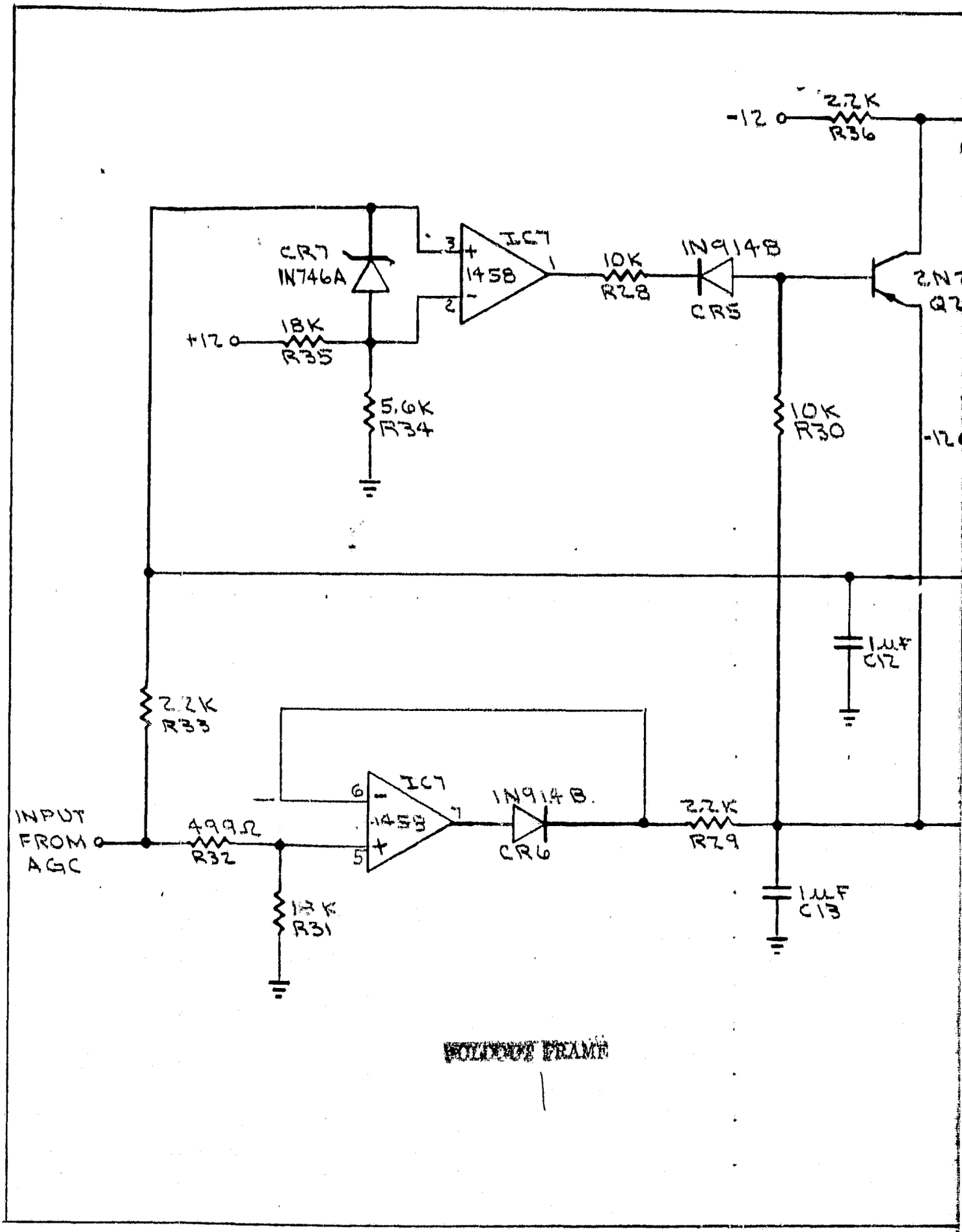


R40
2.2 M

DT

FOLDOUT FRAME
2

TECHNOLOGY INCORPORATED LIFE SCIENCES DIVISION HOUSTON, TEXAS 77058		
DRAWN BY M. H. UTLEY	DATE 9-26-79	TITLE 8080A-BASED CARDIOTACHOMETER AUTOMATIC GAIN CONTROL
DESIGN ENG. J. A. DONALDSON	11-14-79	
PROJ. ENG.		DWG. NO. MPCT-2002-5
		SHEET 1 OF 1



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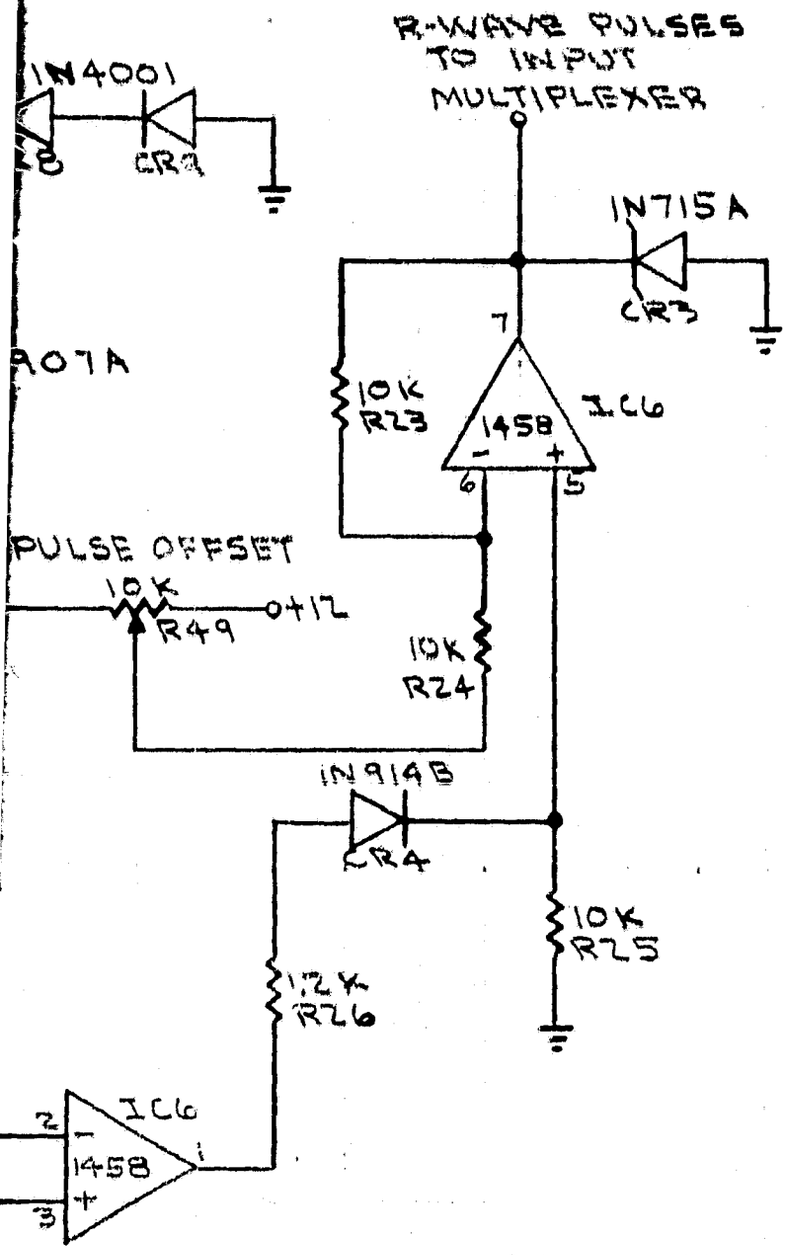
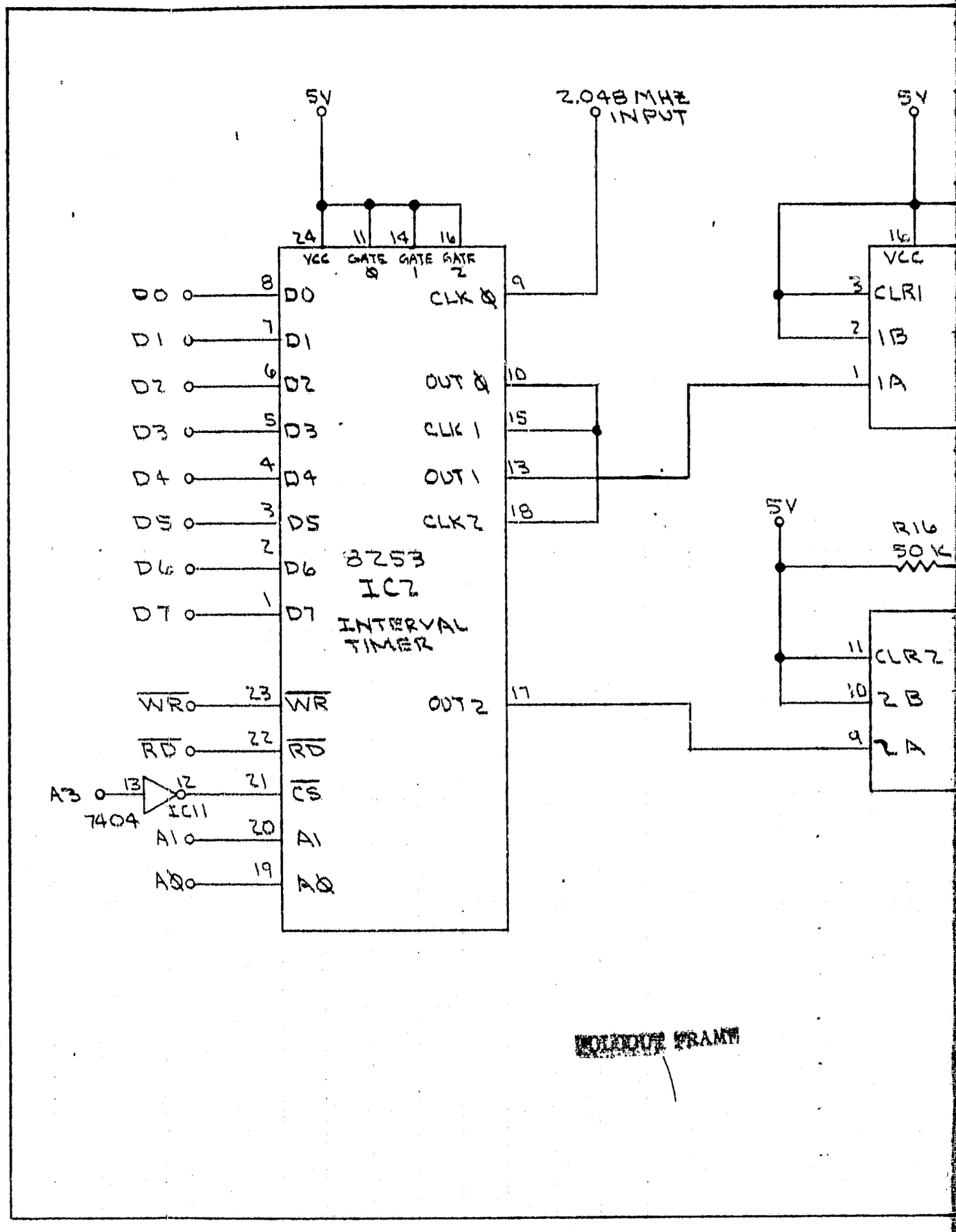
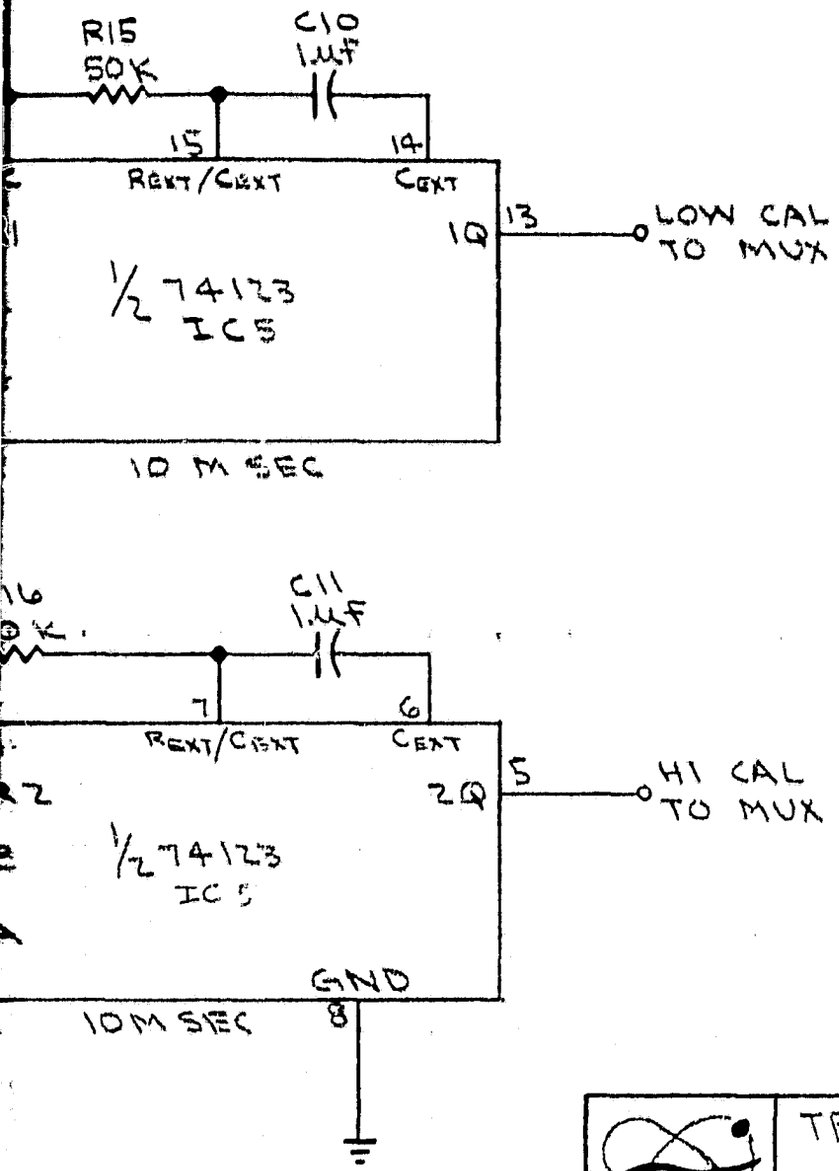


FOLDOUT FRAME

2

TECHNOLOGY INCORPORATED LIFE SCIENCES DIVISION HOUSTON, TEXAS 77058		
DRAWN BY M.H.UTLEY	DATE 9-21-79	TITLE 8080A-BASED CARDIOTACHOMETER PULSE DETECTOR
DESIGN ENG J.A.DONALDSON	11-14-79	
PROJ. ENG W.G.CROSIER	11-14-79	DWG. NO MPCT-2003-5
		SHEET 1 OF 1

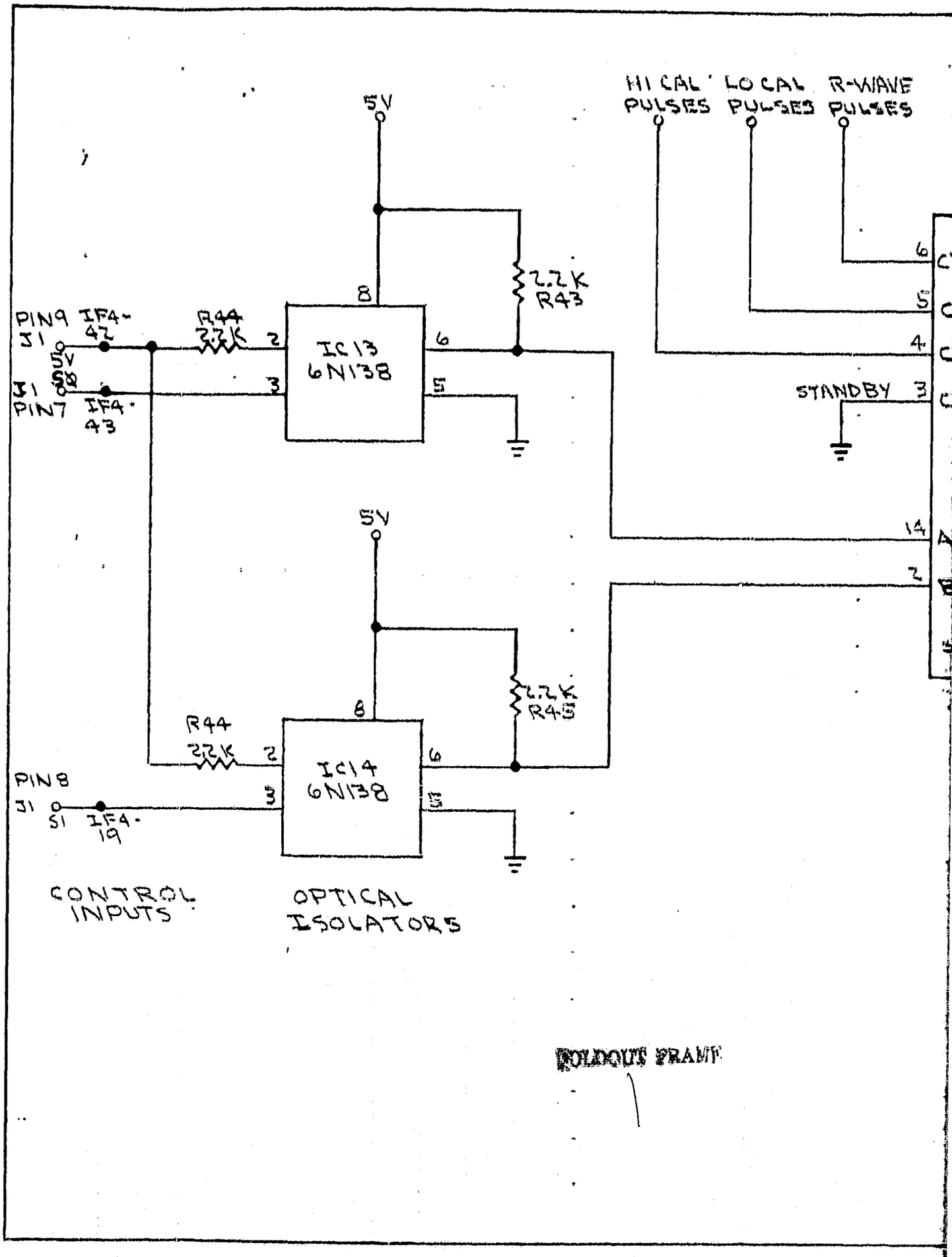


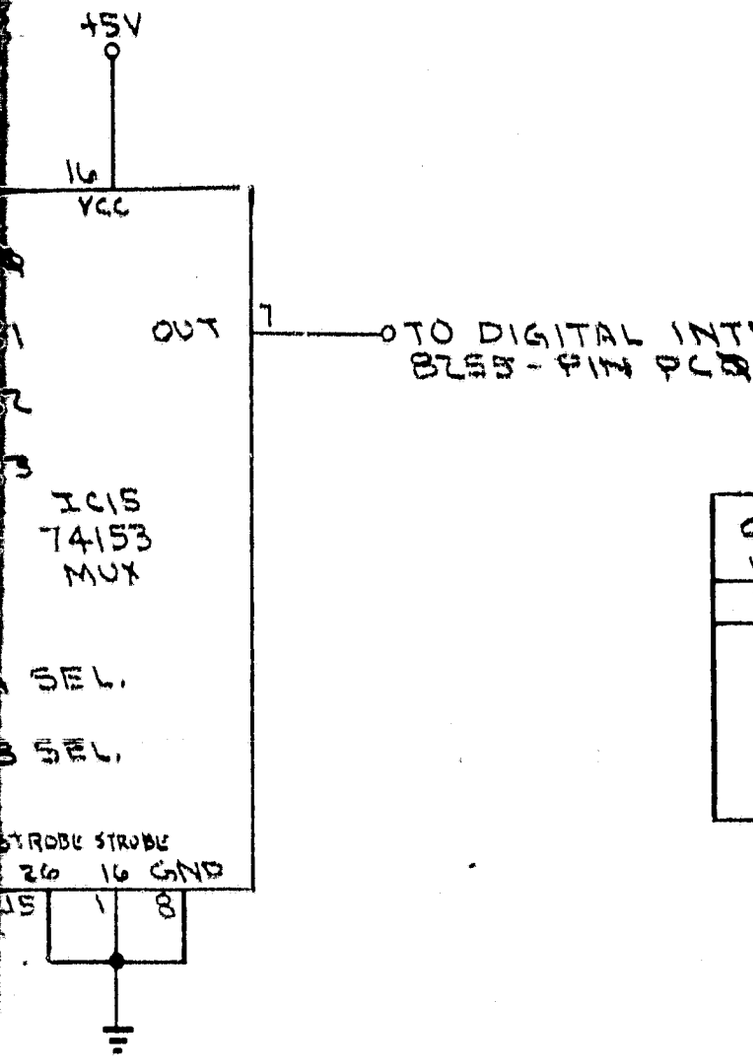


FOLDOUT FRAME

2

TECHNOLOGY INCORPORATED LIFE SCIENCES DIVISION HOUSTON, TEXAS 77058		
DRAWN BY M.H. UTLEY	DATE 10-13-79	TITLE 8080 A - BASED CARDIOTACHOMETER LO-HI CAL PULSE GENERATOR
DESIGN ENG. J.A. DONALDSON	11-14-79	
PROJ. ENG. W. G. CROSIER	11-14-79	DWG. NO. MPCT-2004-S
		SHEET 1 OF 1


HI CAL PULSES
LO CAL PULSES
R-WAVE PULSES
5V
2.2K R43
PIN9 J1
IF4-42
R44 22K
IC13 6N138
STANDBY
J1 PIN7
IF4-43
5V
2.2K R45
R44 22K
IC14 6N138
PIN8 J1 S1
IF4-19
CONTROL INPUTS
OPTICAL ISOLATORS
FOLDOUT FRAME



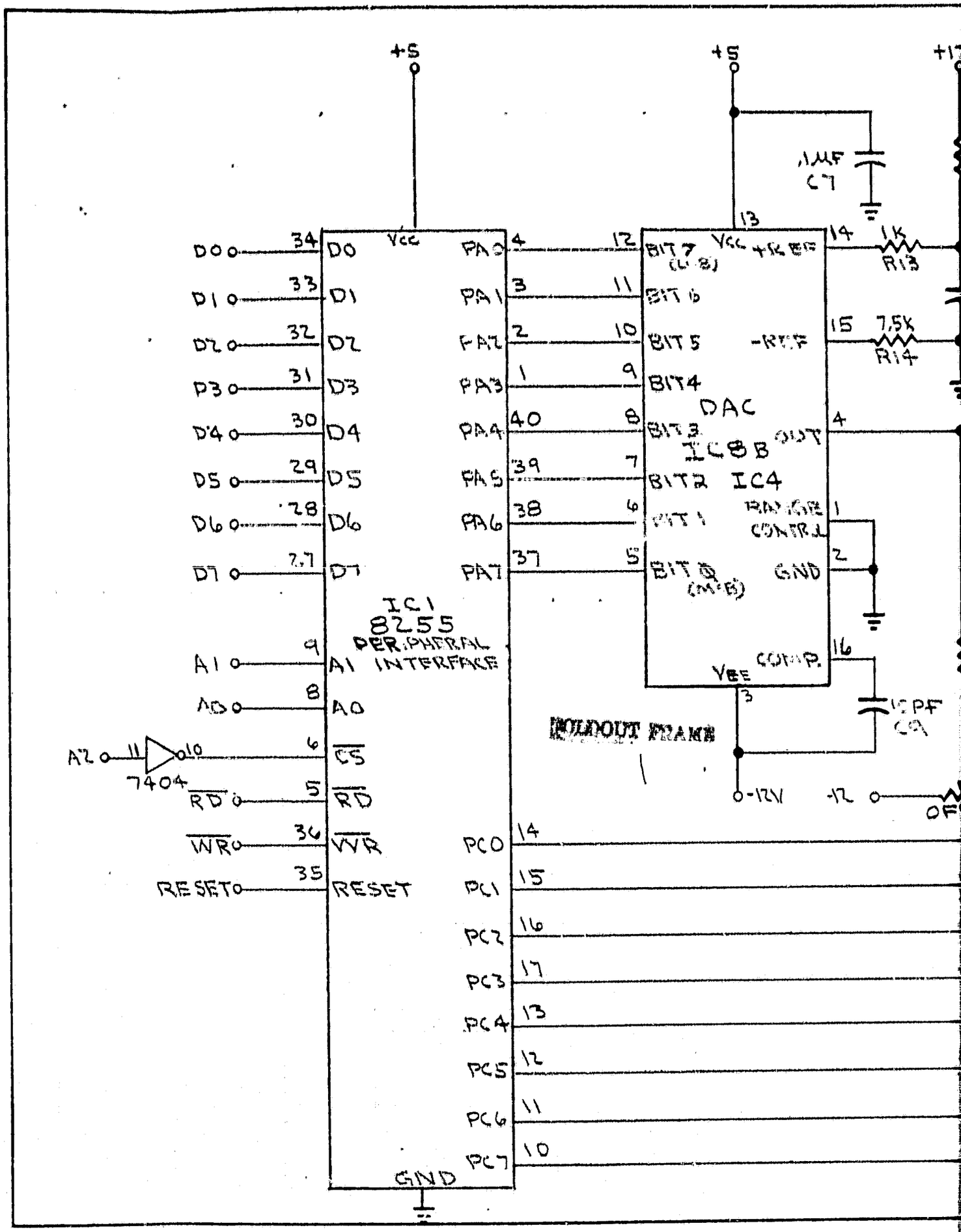
CONTROL INPUTS		74153
S2	S1	OUTPUT
0	0	ECG
1	0	LO CAL
0	1	HI CAL
1	1	STAND BY

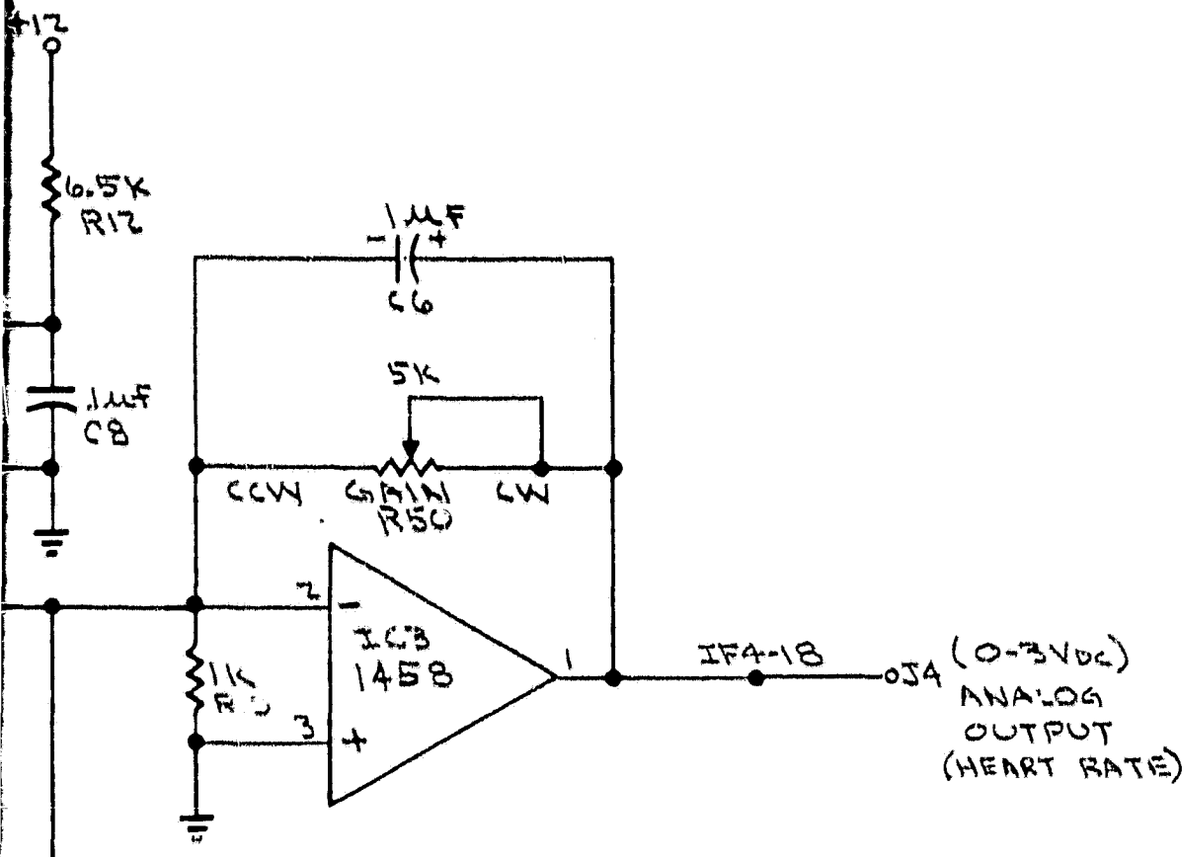
FOLDOUT FRAME

2

TECHNOLOGY INCORPORATED
LIFE SCIENCES DIVISION
HOUSTON, TEXAS 77058

DRAWN BY M.H.UTLEY	DATE 10-12-79	TITLE 8030 A - BASED CARDIOTACHOMETER COMPUTER CONTROL & INPUT MULTIPLEXER
DESIGN ENG. J.A. DONALDSON	11-14-79	
PROJ. ENG W.G. CROSIER	11-14-79	DWG. NO. MPCT-2005-S
		SHEET 1 OF 1


+5
+5
.1MF
C7
Vcc
D0
D1
D2
D3
D4
D5
D6
D7
34
33
32
31
30
29
28
27
IC1
8255
PERIPHERAL
INTERFACE
A1
A0
9
8
A2
11
10
7404
6
5
36
35
CS
RD
WR
RESET
RESET
PA0
PA1
PA2
PA3
PA4
PA5
PA6
PA7
4
3
2
1
40
39
38
37
PC0
PC1
PC2
PC3
PC4
PC5
PC6
PC7
14
15
16
17
13
12
11
10
GND
BIT 7
(LSB)
BIT 6
BIT 5
BIT4
BIT 3
BIT 2
BIT 1
BIT 0
(MSB)
12
11
10
9
8
7
6
5
DAC
IC8B
IC4
Vcc
+REF
-REF
OUT
RANGE
CONTROL
GND
COMP.
VEE
13
14
15
4
1
2
16
3
1K
R13
7.5K
R14
.1MF
C9
-12V
+12
OFF
BOLDOUT FRAME



FOLDOUT FRAME

2

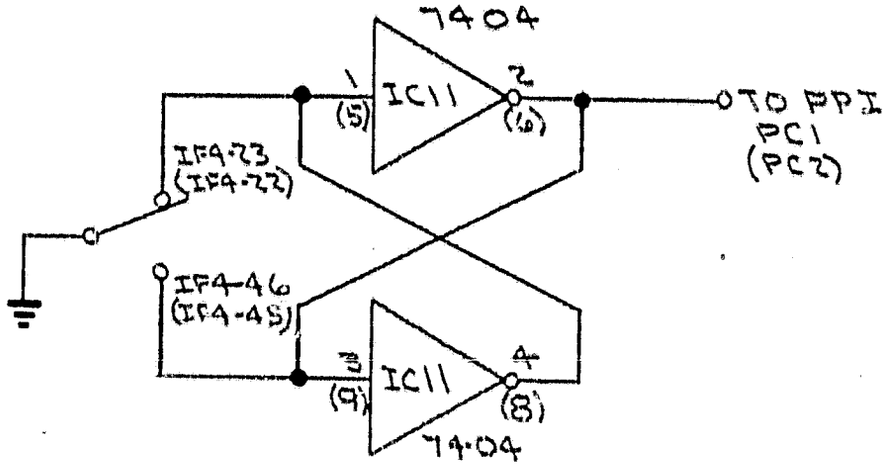
TECHNOLOGY INCORPORATED LIFE SCIENCES DIVISION HOUSTON, TEXAS 77058		
DRAWN BY M.H. UTLEY	DATE 10-6-79	TITLE 8080 A - BASED CARDIOTACHOMETER DIGITAL I/O AND ANALOG OUTPUT INTERFACE
DESIGN ENG J.A. DONALDSON	11-14-79	
PROJ. ENG.		DWG NO. MPCT-2006-S
		SHEET 1 OF 1

UNDER RANGE PC4

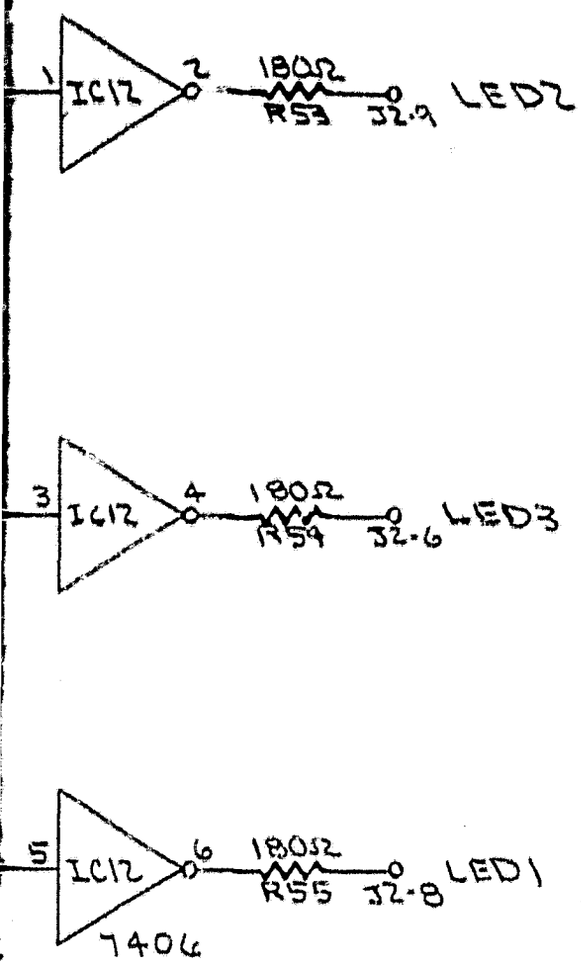
OVER RANGE PC5 3

ECG/CAL PC0 5

LED



SYSTEM CALIBRATE 1 & 2.
INPUT & DEBOUNCE



D OUTPUT DRIVERS

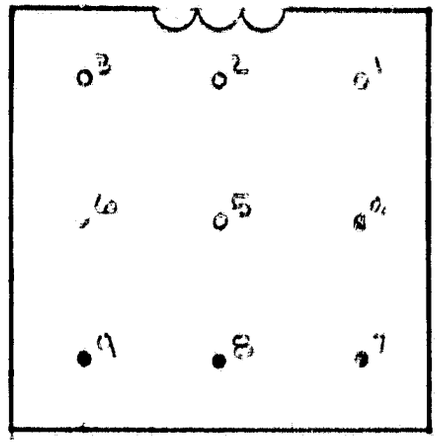
FOLDOUT FRAME

2

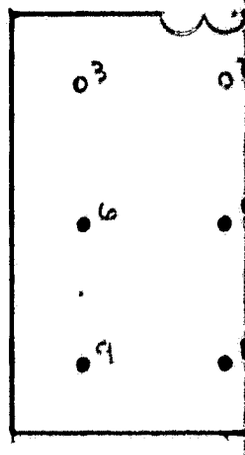
TECHNOLOGY INCORPORATED LIFE SCIENCES DIVISION HOUSTON, TEXAS 77058		
DRAWN BY M.H. UTLEY	DATE 10-13-79	TITLE 8080A - BASED CARTIOTACHOMETER CAL. 1&2, INPUT & DEBOUNCE AND LED OUTPUT DRIVERS
DESIGN ENG. J.A. DONALDSON	11-14-79	
PROJ. ENG W. G. CROSIER	11-14-79	DWG. NO. MPCT-2007-S
		SHEET 1 OF 1

EXTERNAL VIEW
PIN SIDE - PANEL C

J1
CONTROL
(MALE)



J2
I/O
(FEMA



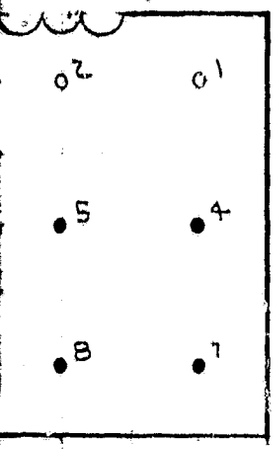
(1) SPARE
(2) SPARE
(3) SPARE
(4) GND
(5) SPARE
(6) SPARE
(7) IN1 (USR 2)
(8) IN2 (USR 1)
(9) +5V IN

(1) SPAR
(2) SPAR
(3) SPAR
(4) RESE
(5) [illegible]
(6) LED
(7) GND
(8) LED
(9) LED

BULKOUT FRAME

CONNECTOR

2
/0
EMALE)



PARE

PARE

PARE

ESET

PARE

ED 3 (OVER RANGE)

ND

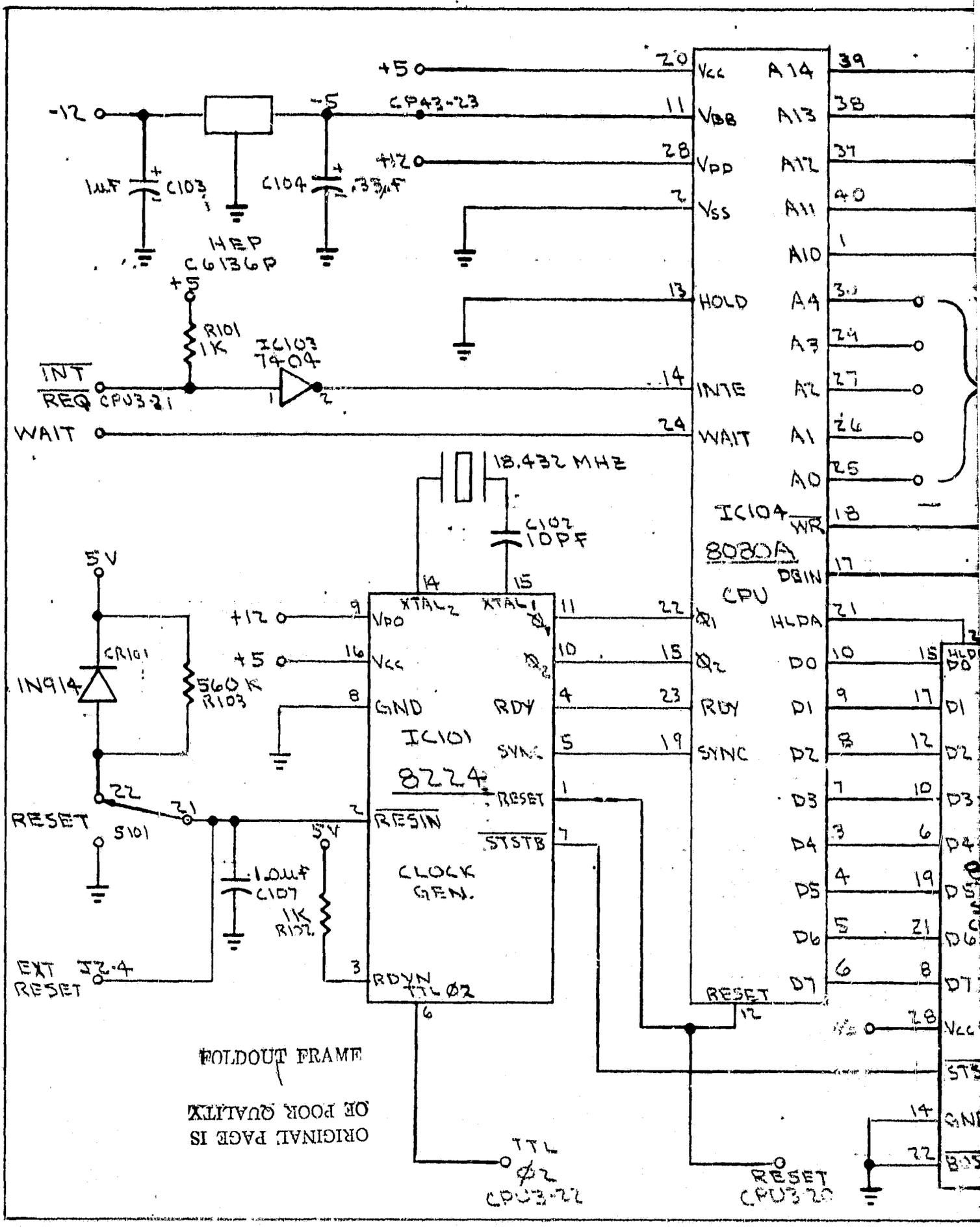
ED 1 (E.C.G/CAL)

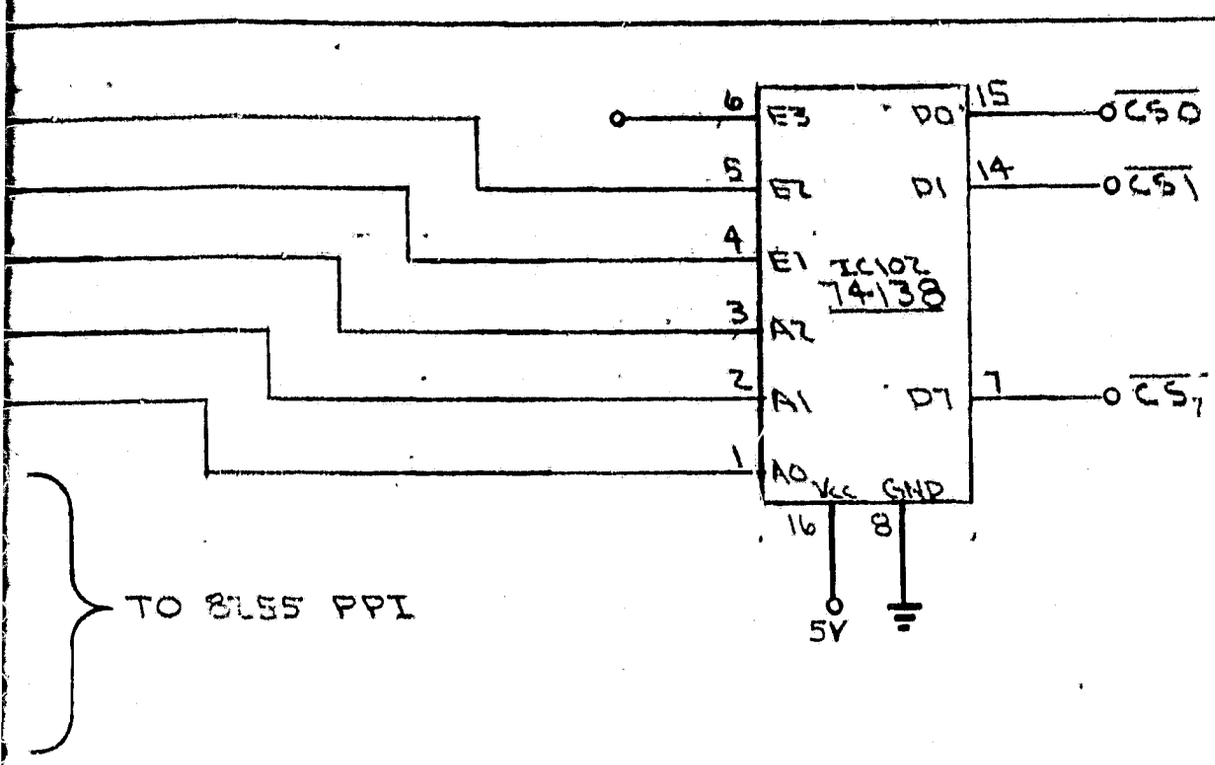
ED 2. (UNDER RANGE)

BOLDOUT FRAME

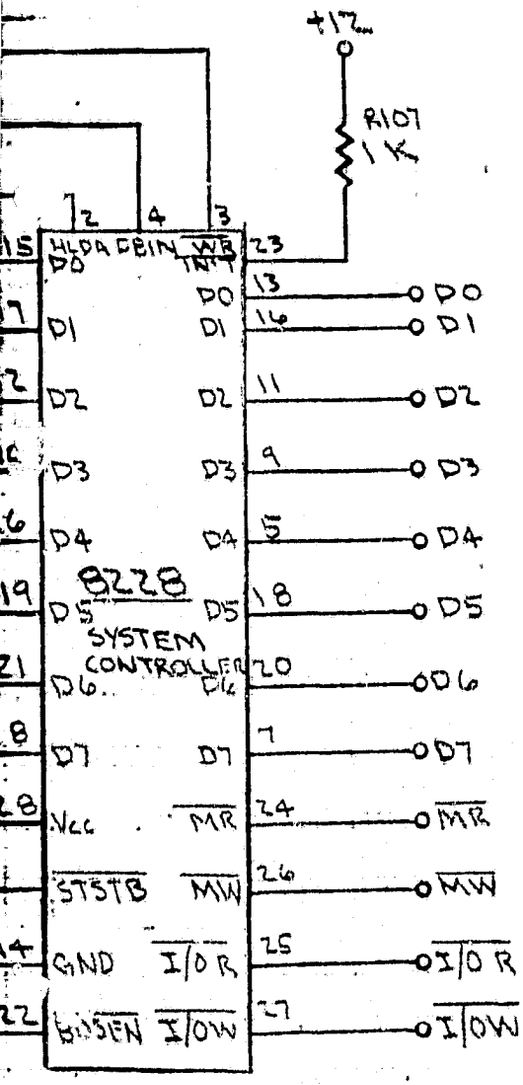
2

TECHNOLOGY INCORPORATED LIFE SCIENCES DIVISION HOUSTON, TEXAS 77058		
DRAWN BY M. H. UTLEY	DATE 9-24-79	TITLE 8080A-BASED CARDIOTACHOMETER CONTROL-I/O CONNECTOR
DESIGN ENG. J. A. DONALDSON	11-14-79	
PROJ. ENG.		DWG. NO. MPCT-2008-L
		SHEET 1 OF 1


+5
-12
-5
CP43-23
+12
1μF C103
C104 .33μF
HEP C6136P
R101 1K
IC103 7404
INT REQ CPU3-21
WAIT
18.432 MHZ
C102 10PF
5V
CR101 IN914
560 K R103
S101
RESET
EXT RESET J2-4
1.0μF C107
1K R102
IC101 8224
CLOCK GEN.
XTAL2
XTAL1
VDD
VCC
GND
RDY
SYNC
RESET
RESIN
STSTB
RDYN
TTL Ø2
IC104 8080A CPU
Vcc
VBB
VDD
VSS
HOLD
INTE
WAIT
DBIN
HLDA
WR
A14
A13
A12
A11
A10
A9
A8
A7
A6
A5
A4
A3
A2
A1
A0
D0
D1
D2
D3
D4
D5
D6
D7
Ø1
Ø2
TTL Ø2 CPU3-22
RESET CPU3-20
FOLDOUT FRAME
ORIGINAL PAGE IS OF POOR QUALITY



TO 8155 PPI



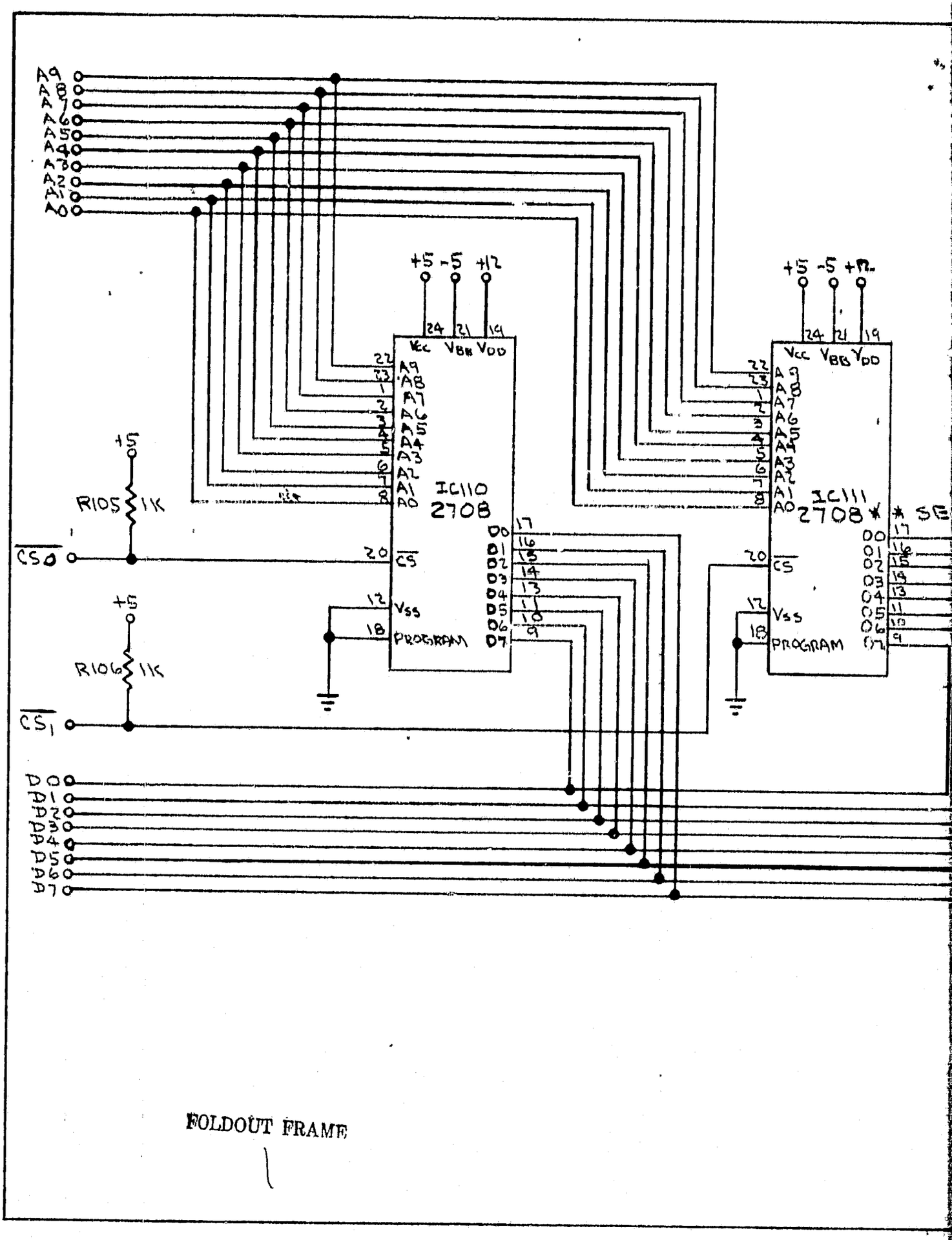
C50 - 0000 - 03FF EPROM 1
C51 - 0400 - 07FF EPROM 2 *
C57 - 1C00 - 1FFF RAM

FOLDOUT FRAME
2

* FOR FUTURE EXPANSION

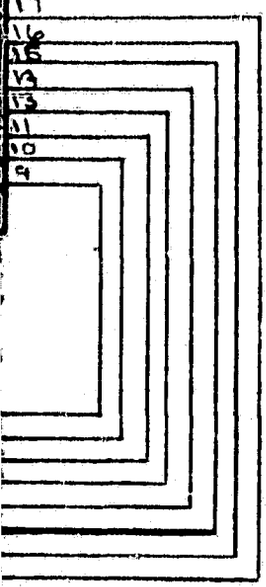
TECHNOLOGY INCORPORATED
LIFE SCIENCES DIVISION
HOUSTON, TEXAS 77058

DRAWN BY	DATE	TITLE
M. H. UTLEY	10-6-79	8080 A. BASED CARDIOTACHOMETER CPU
DESIGN ENG. J. A. DONALDSON	11-14-79	
PROJ. ENG. W. G. CROSIER	11-14-79	DWG. NO. MPCT-2010-S
		SHEET 1 OF 3



FOLDOUT FRAME

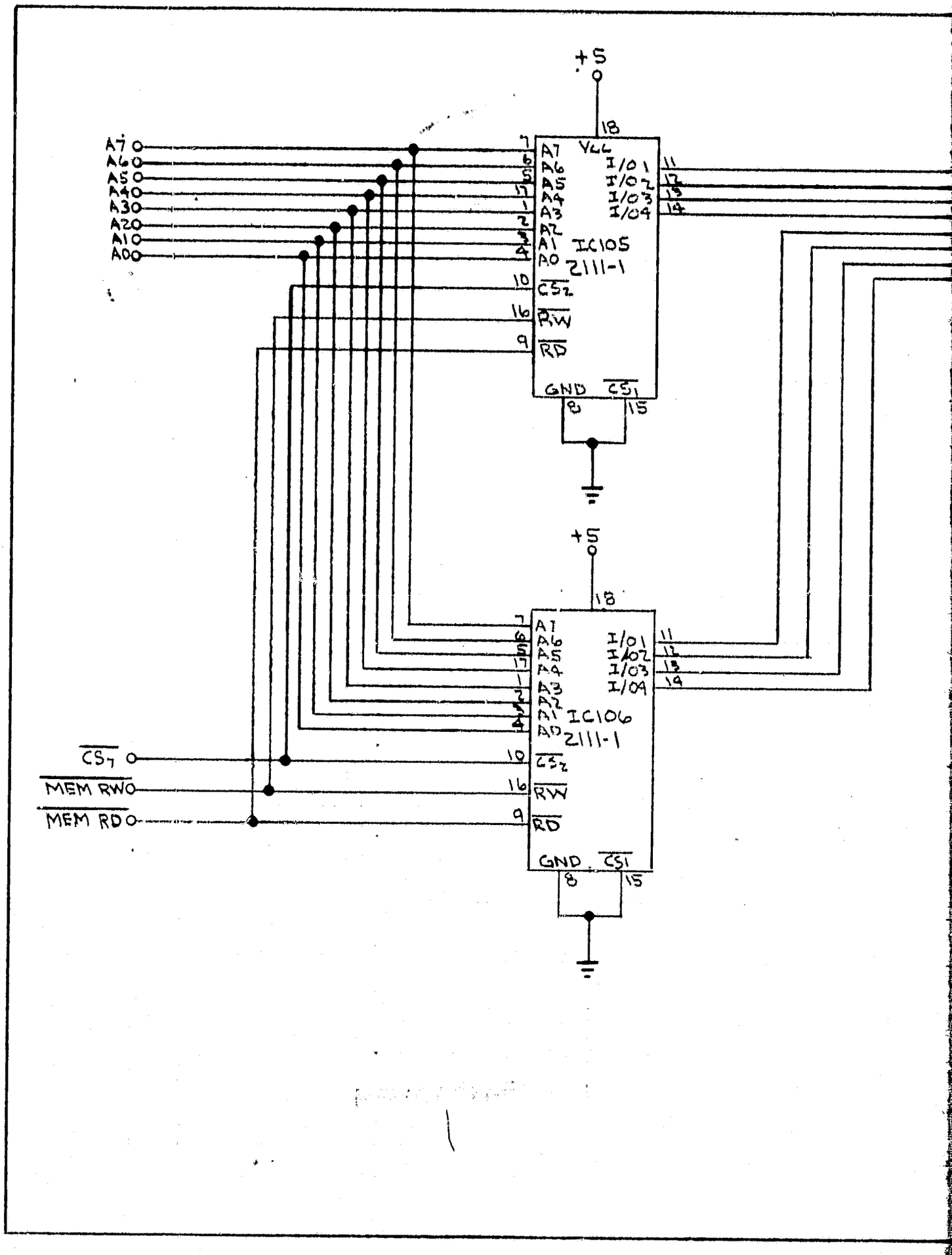
* SEE NOTE #1

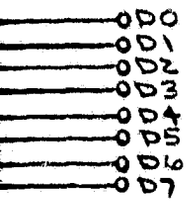


NOTES: (1) FOR FUTURE EXPANSION.

FOLDOUT FRAME 2

TECHNOLOGY INCORPORATED LIFE SCIENCES DIVISION HOUSTON, TEXAS 77058		
DRAWN BY M.H. UTLEY	DATE 10-10-79	TITLE 8080A-BASED CARDIOTACHOMETER CPU
DESIGN ENG. J.A. DONALDSON	11-14-79	
PROJ. ENG. W. G. CROSIER	11-14-79	DWG. NO. MPCT-2010-S
		SHEET 2 OF 3

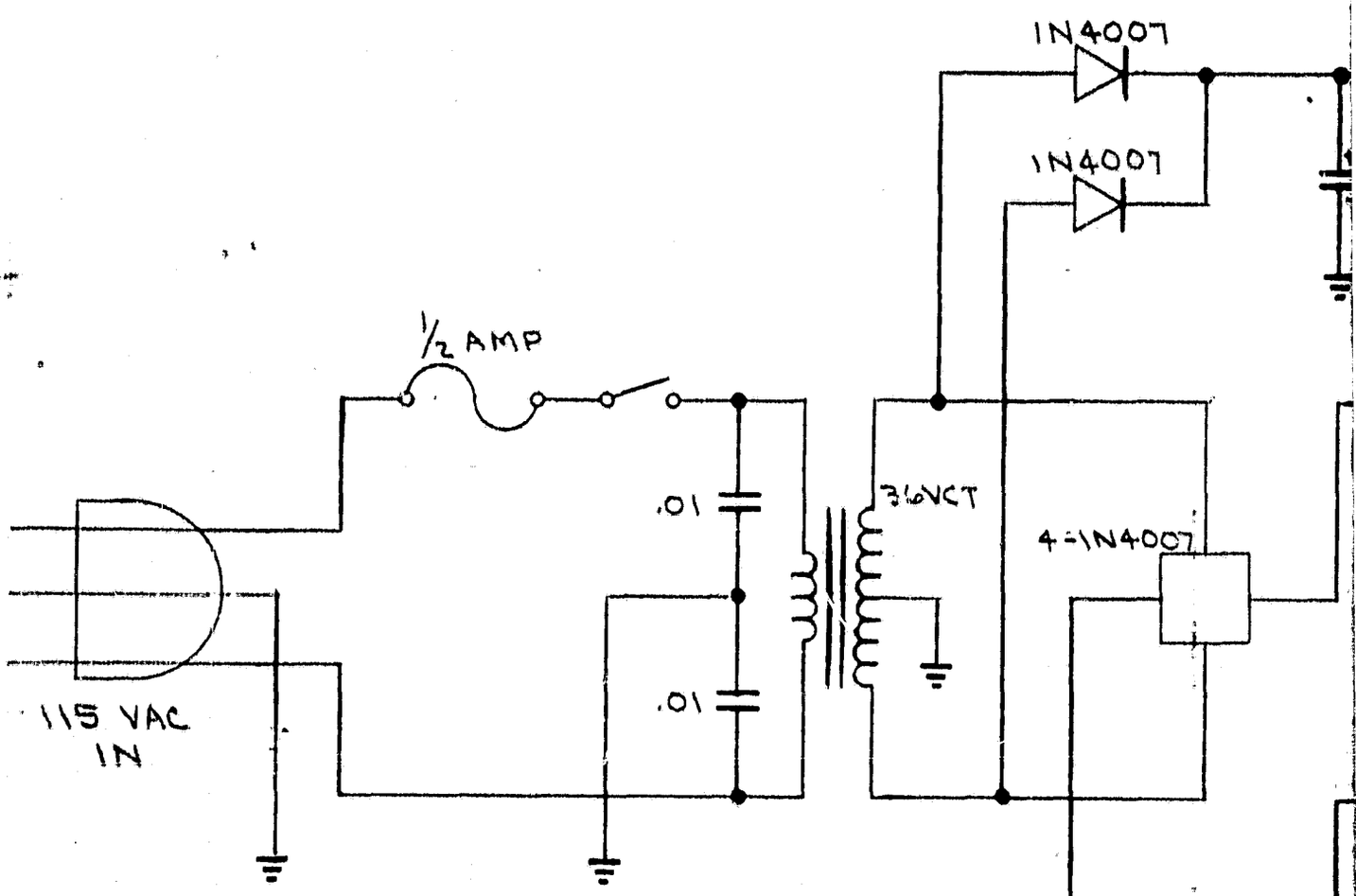

+5
18
A7
A6
A5
A4
A3
A2
A1
A0
VCC
I/O1
I/O2
I/O3
I/O4
IC105
2111-1
CS2
R/W
RD
GND
CS1
8
15
11
12
13
14
7
6
5
4
3
2
1
10
16
9
CS1
MEM RW
MEM RD
IC106



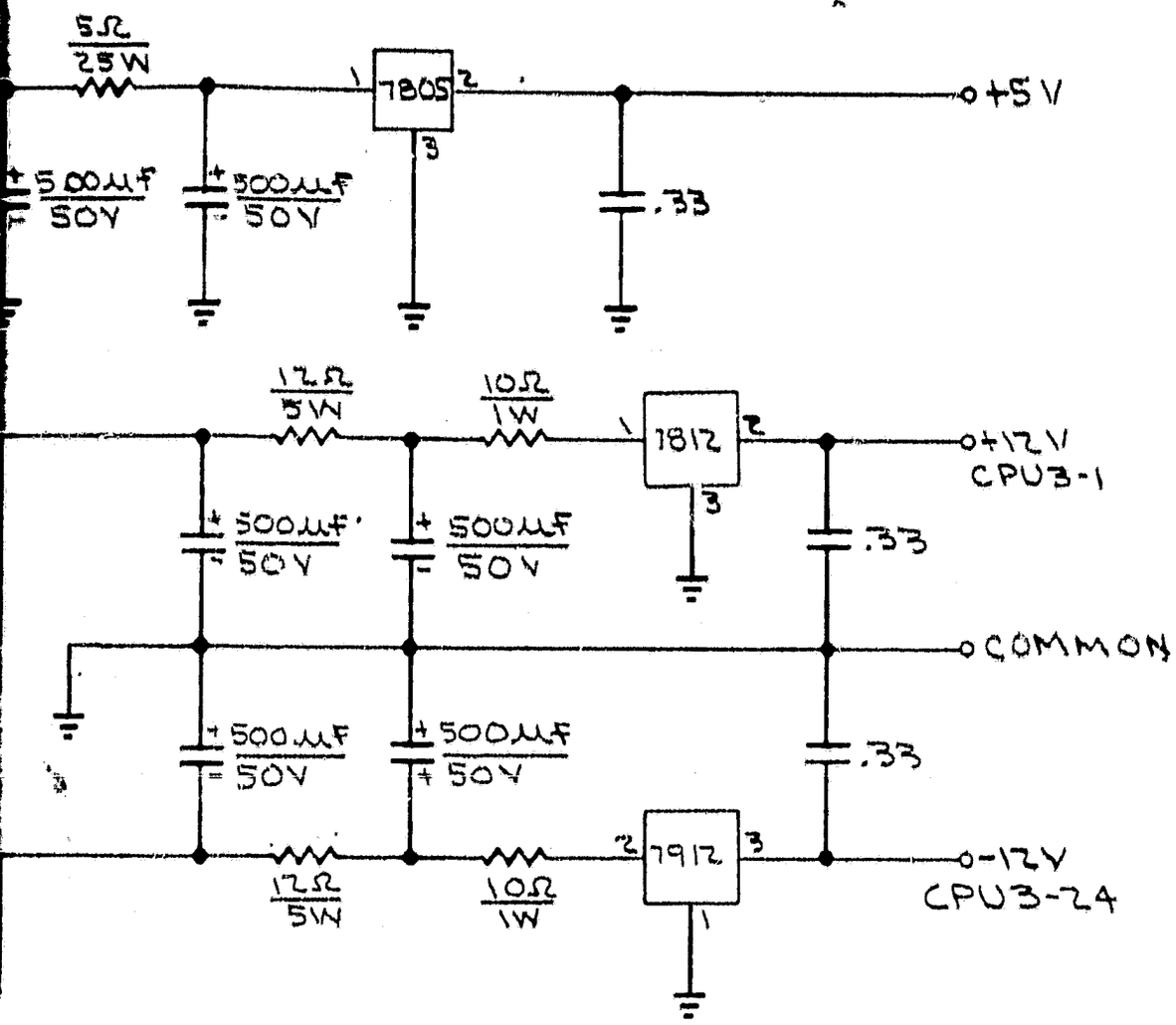
FOLDOUT FRAME

2

TECHNOLOGY INCORPORATED LIFE SCIENCES DIVISION HOUSTON, TEXAS 77058		
DRAWN BY M.H. UTLEY	DATE 10-1079	TITLE 8080A-BASED CARDIOTACHOMETER CPU
DESIGN ENG. J.A. DONALDSON	11-14-79	
PROJ. ENG. W.G. CROSIER	11-14-79	DWG. NO. MPCT-2010-S
		SHEET 3 OF 3



FOLDOUT FRAME



FOLDOUT FRAME

2

TECHNOLOGY INCORPORATED LIFE SCIENCES DIVISION HOUSTON, TEXAS 77058		
DRAWN BY M.H. UTLEY	DATE 10-13-79	TITLE 8080A - BASED CARDIOTACHOMETER POWER SUPPLY
DESIGN ENG. J.A. DONALDSON	11-14-79	
PROJ. ENG. W.G. CROSIER	11-14-79	DWG. NO. MPCT-7012-S
		SHEET 1 OF 1

APPENDIX G

APPENDIX G
SAMPLE OUTPUT