μP BLIS

A REPORT FOR ECE 453

AND

THE SPACE SCIENCE AND ENGINEERING CENTER

DEC. 15, 1976

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The Boundary Layer Instrumentation System (BLIS) is an integrated weather instrument designed by the Space Science Engineering Center, University of Wisconsin, for use during the GATE meteorology experiments in the equatorial Atlantic during the summer of 1974. The system is designed to measure wind speed, wind direction, wind tilt (vertical components), temperature, humidity, and barometric pressure.

The system is currently built using random logic. Because of the complexity of the package, a high chip count (about 50) is required. Inherent with the hard wired approach is the large number of interconnections which increases failure rates and the inflexibility.

By redesigning the system with a microprocessor a large number of benefits are possible. First, the chip count would be reduced which would tend to increase reliability and also reduce the amount of time required to assemble a unit. A second benefit would be the flexibility obtained by the ability to redefine the system simply by changing the program stored in PROM. New resistance or capacitance sensors could be added as required to a spare input port on the sonde, and the program could be changed to accommodate it.

Because of the great computational power of the micro-processor, features not possible with hard-wired logic are feasible. Two very useful additions would be the ability of the package to transmit data in standard engineering units, and self-calibration.

As a part of ECE 453, a feasibility study has been done to see what is possible in the way of improving the BLIS system using a microprocessor. The National Semiconductor PACE system was chosen because of its availability and the development system owned by the electrical engineering department.

The μP BLIS is built around the PACE processor board. The PACE is a 16 bit microprocessor. The memory was a standard National Semiconductor 1K x 16 PROM board. No RAM was required because of the 10 word hardware stack built into the MPU, which was used as a scratch pad.

The old system transmits the data in digital format, so the present sensors have a digital type output. Because of the large effort that went into their initial design, it was decided to use the present sensors and to build an interface between them and the PACE.

It was decided that the μP BLIS would also be designed to meet the following specifications:

1) Sensor Accuracy would be at least equivalent to the current system (see Appendix I).

2) The output of the μP BLIS would be compatible with the present BLIS ground equipment.

3) All data would be in engineering units.

4) The system would be self-calibrating.

Because the system is self calibrating, the reference channels in the present system need not be transmitted. This gives a 25% increase in the sampling rate.

HARDWARE

SENSORS

The μP BLIS uses the same sensors as used on the regular BLIS system. A brief description of the sensors will be given here; for more information refer to Ref. 1.

Temperature and Humidity

Temperature and humidity measurements are made by using transducers that change their resistances with respect to the temperature or humidity. Thermistors are used for temperature; hygristors, a carbon coated film, are used for humidity. These resistances determine the frequency of an RC oscillator known as the Resistance Oscillator (RO). Each transducer is switched in at the appropriate time and gated to a binary counter. The resulting count is parallel loaded to the bus for analysis in software.

In addition to the hygristor, humidity can be measured by an index determined by the difference between two thermistors, one of which is kept moist by a wick leading to a water tank built into the package.

Pressure Measurements

Pressure measurements are made in a way similar to temperature, except that the capacitance is varied instead of the resistance. The pressure sensor is an aneroid barometer connected to a small metal plate. This plate is parallel and closely spaced to a fixed plate. An increase (decrease) in pressure will cause the plates to move and thus decrease (increase) the capacitance between them. As in the RO, the Capacitance Oscillator (CO) output is counted and loaded onto the bus.

Wind Speed and Direction

The sensor for measuring the wind is the WINDAV; short for Wind Direction and Velocity. The WINDAV consists of a main shaft connected at one end to three wind cups. At the other end is a thin disk. Etched through this disk are 180 slots in an outer ring and a single slot inside. These are called the Resolver and Once Around (OA) respectively.

Light from LEDS shines through the slots in the disk and is detected by photo-transistors. As the disk spins with the wind cups, the transistors are turned on and off by the interrupted light beams. Wind speed is measured by counting Resolver pulses. The wind speed is a linear function of counts, which are converted to meters/second by the MPU.

One of the wind cup arms is made of μ-metal, a metal with very high permeability. This draws the nearby field from the Earth's magnetic field into the center of the shaft. Mounted inside of the shaft is a non-rotating magnetic-diode (MD). The current through the diode is a function of the magnetic field through it. As the cups turn, the magnetic field causes a sinusoidal output from the MD.

The positive sloped zero crossing of the MD signal corresponds to the μ-metal arm pointing to the Earth's north magnetic pole. At this time the PACE starts counting each of the resolver pulses. This counting continues until the μ-metal arm is pointing in the same direction as the package. The final count is the direction that the package is pointing in degress.

Wind Tilt

The sonde is designed to point into the wind, and this includes the vertical components caused by up and down drafts. As the sonde responds to these vertical components a pendulum will pivot on the shaft at its top.

The pendulum has slots etched through it in the form of a Gray Code of the angle. A photo-transistor LED combination detects this code which is loaded onto the bus.

Sensor Interface

The PACE bus is a sixteen bit bus multiplexed between data and addresses. Since only 1K of memory is required, bits 11 through 15 may be used as 'one hot' decoders thus reducing the logic needed for decoding. Bit 14 selects the sensor bank, while bits 0-2 select the proper sensor.

When one of the sensors is selected, bits 0-2 are latched in IC-J. The latched signals are fed into IC-K which is a one-of-eight decoder. The decoded signal switches the proper sensor into the proper sensor oscillator. Bits 0-2 are also inputted to IC-C. This multiplexes the RO, CO or Resolver (RESV) into the counter consisting of IC-D through F. When the counting period is completed (timed in a software loop), the count is parallel loaded into TRI-STATE latches comprised of IC-G through I. During a read instruction this is inputed by the PACE.

When TILT information is desired, FLAG 12 is pulsed which loads the parallel data into the counter. The data is then loaded into the TRI-STATE latches for transfer onto the bus.

The switching between the aneroid and reference in the CO is done by means of a latching relay. Pulses to drive the relay are producted by means of a monostable (IC-U). When one of the pressure elements are selected by IC-K the relay latches in the proper position.

The signal from the OA and MD are fed onto Jump Condition 13 and 14. When wind direction is measured, the program will respond to these conditions to properly control the counting of the RESV pulses.

Output

The PACE in this system uses no RAM, so the only time a write instruction occurs is when it is outputting data to its only output port. Because of this

decoding is not required of the output port. Whenever a write statement is executed the Output Data Strobe (ODS) is pulsed. This latches the data into the 16 bit shift register comprised of IC-L and IC-M.

A NE555 timer acts as the clock for the output circuitry. The shifted data is NORed with the clock and fed to a 741 for level shifting. The output of the 741 is a three level wave form from which 1's, 0's and the clock can be extracted by the BLIS Ground Station. A counter consisting of IC-P and IC-T keep track of the number of bits that have been transmitted. When the shift registers have been emptied the proper condition will appear on the jump condition Number 15. The PACE will by this time have the next data word ready and output it. Under low wind conditions or a failure of the WINDAV the PACE could find itself in an infinite loop. To prevent this, the interrupts are enabled. If th time comes when the output buffer should be loaded with the wind direction data, the counter will cause an interrupt pulling the PACE out of the loop. The PACE will output an error code telling the ground station that a malfunction has occurred. The PACE will continue to transmit other channels.

The software for the micorprocessor-based BLIP consists of;

1. INIT - an initialization routine executed on power-up.

2. MAIN - the main program loop which processes raw sensor data using the subroutines listed below and outputs directly usable values in engineering units.

3. DELAY - a 225 ms. wait loop used in accumulating sensor counts.

4. MUL - a fixed point multiplication routine which takes 2-16 bit operands and returns a 32 bit product.

5. DIV - a fixed point division routine which takes a 32 bit dividend and a 16 bit divisor and returns a 16 bit rounded quotient.

6. CCRCT - a routine which corrects several of the sensor readings for temperature drift of the associated electronic components before processing.

7. INTERP - a routine which performs a linear interpolation for determining wet and dry bulb temperatures, relative humidity and barometric pressure.

Since nearly all of the routines are linear, flowcharts have not been included, and since the program listing has been profusely commented I have chosen rather to give a brief verbal description of each routine.

1. INIT

This routine is executed on power up. It disables all interrupts except level 2, which is used to abort the wind direction measurement when the wind speed is very low. INIT also sets BYTE = 0 for 16 bit data operation and readies the BLIP's 12 bit counter for counting.

2. MAIN is a routine which does these tasks sequentially in an endless loop:

a. ROCNT - get count from resistance oscillator using reference resistor for subsequent correction of WB, DB and HYGR counts.

b. Output synch word (16 1's) to transmitter output buffer.

c. WB - get count from resistance oscillator using wet bulb thermistor; call CCRCT to correct count; call INTERP to calculate wet bulb temperature; and output result to transmitter output buffer.

d. DB - similar to WB except for use of dry bulb thermistor.

e. RH - similar to WB except for use of hygristor.

f. COCNT - get count from capacitance oscillator using reference capacitor for subsequent correction of ANRD count.

g. Output BLIP ID word to transmitter output buffer.

h. PRESS - get count from capacitance oscillator using aneroid capacitor cell; call CCRCT to correct count; call INTERP to calculate barometric pressure; and output result to transmitter output buffer.

i. WS - count the number of resolver pulses from the anemometer during the DELAY interval; multiply this count by a constant to convert to meters/sec.; and output result to transmitter output buffer.

j. WD - count the number of resolver pulses from the anemometer from the occurance of the SONC pulse to the occurance of the OA pulse. This count is equal to half the number of degrees of the wind direction. Multiply this count by 200 to convert the count to the proper format. Here, as was mentioned earlier, a level 2 interrupt is used to abort the wind direction measurement if the transmitter output buffer goes empty. This condition will arise when the wind speed is so low that more than 1/4 sec. elapses between the SONC pulse and the OA pulse. In this event, an error code is output.

k. TILT - The tilt is encoded using a 6-bit gray code. This code is read directly using the parallel load capability of the BLIP's 12 bit counter. This code is then used as an index into a lookup table to convert to a degrees-minutes format.

1. JMP to ROCNT and start sequence over.

3. DELAY

This routine uses a large number stored in PROM, called DLY, in an AISZ loop to generate a delay of 225 ms. This delay is used in accumulating counts from the resistance and capacitance oscillators and from the anemometer resolver.

4. MUL

This routine takes 2 positive 16 bit operands, the multiplier in RØ and the multiplicand in R1. A repeated addition algorithm is used rather than a shift-and-add algorithm because the multiplier will always be rather small. The multiplier is complemented first. The multiplication loop consists of incrementing the negative multiplier and testing for zero, indicating the end of the multiplication. The multiplicand is added to R2 and any carrys out of R2 are added to R3. Thus a 32 bit product is formed in R3,R2.

5. DIV

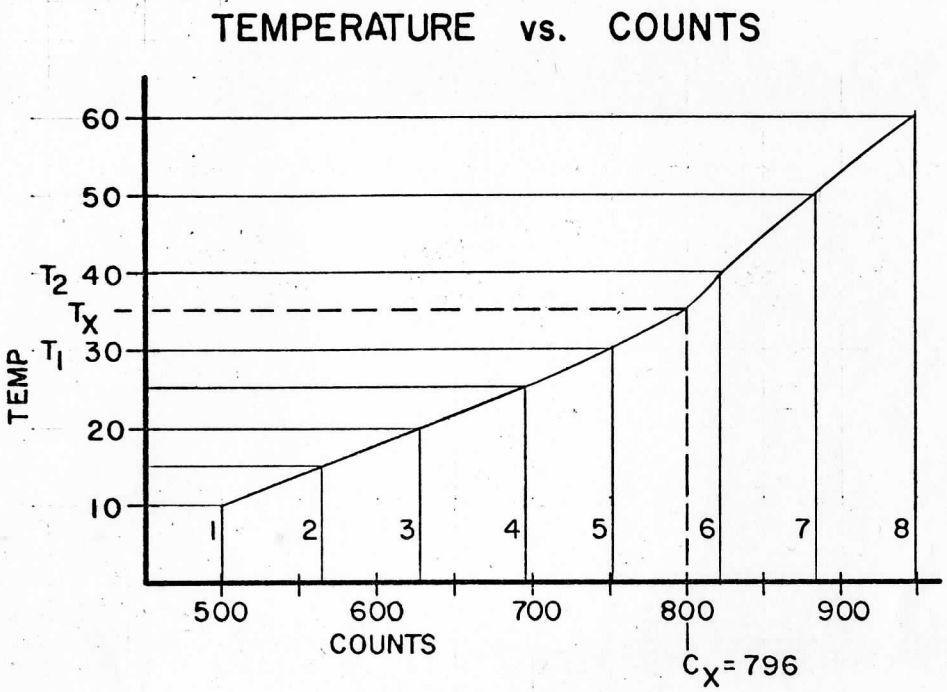
This routine takes 2 positive operands, a 32 bit dividend in R3,R2 and a 16 bit divisor in RØ. A repeated subtraction algorithm is used rather than a shift-subtract-restore algorithm because the divisor will always be large. The divisor is negated first. The division loop consists of incrementing the quotient and adding the negative divisor to the low word of the dividend. When there is no carry the low word of the dividend is decremented. When there is no carry from this operation the division is done. To decide whether to round up the quotient or not, the value in R2, which = the remainder - divisor, is multiplied by 2 using a left shift. The divisor is added to this quantity yielding 2(remainder - divisor) + divisor = 2 x remainder - divisor. If this quantity is positive, then the remainder is greater than 1/2 x divisor and the quotient is rounded up by 1.

6. CCRCT is a count correction routine which is used to compensate for temperature drift in the resistance oscillator (RO) and capacitance oscillator (CO). A precision reference resistor and capacitor called ROREF and COREF are used on every pass through the main program loop. When the BLIP is calibrated on the ground, a count is taken for 1 DELAY interval using ROREF and COREF. These calibration counts, called ROCAL and COCAL respectively, are stored in PROM. During program execution a count is taken using ROREF, called C_R. Then a count is taken using the wet bulb thermistor (BWTH), called C_O. The correction made by CCRCT is:

$$C_X = C_O + \frac{[C_C - C_R] \times C_O}{C_C}$$

where C_X is the corrected count, C_O is the WBTH count, C_C is the calibration count ROCAL in PROM, and C_R is the ROREF COUNT. This is a simple % difference correction. The same procedure is used for the dry bulb thermistor, hygristor and aneroid capacitor.

7. INTERP is the routine which does the actual conversion from counts to wet or dry bulb temperature, relative humidity or barometric pressure. Since the curves of the above parameters vs. counts are nonlinear, piecewise linearized approximations to the curves are stored in PROM. They values of points along the curve (every 64 counts) are stored in successive locations in PROM in lookup table fashion. The 0^{th} location in the table contains the number of counts corresponding to the 1st point on the curve, used for normalization. Linear interpolation is used to find values on the curves between points in PROM. A sketch will serve to illustrate the method used:



TABLE

LOC		CONTENT
C_{min} =	0	500
	1	10
	2	14
	3	20
	4	26
	5	32
	6	39
	7	50
	8	62

If CCRCT returned C_X = 796 counts, INTERP would calculate the corresponding temperature as follows:

1. Subtract C_{min} from C_X to normalize $C_X - C_{min} = C_N$, 796-500 = 296

2. Shift C_N right 6 places, 296 = 100 101000 to separate CN_{0-5} from CN_{6-15}. CN_{6-15} CN_{0-5}

3. Look up T_2 (the stored value just greater than T_X) by adding CN_{6-15}, right justified, to the Table base address and indexing by 2. In this example this is loc. (CN_{6-15} + 2) = loc. (4+2) = loc. 6 yielding T_2 = 39°.

4. Look up T_1 (the stored value just less than T_X) as above but indexing by 1. This yields loc. 5 with T_1 = 32°.

With T_2, T_1 and CN_{0-5}, T_X can be found by:

$$T_X = T_1 + \frac{(T_2 - T_1)CN_{0-5}}{64}$$, the familiar y = b + mx.

Since the points in the table are all separated by 64 counts, the division is a simple right shift of 6 places. In this example:

$T_2 - T_1 = 39° - 32° = 7°$

$(T_2-T_1)Cn_{0-5} = 7° \times 40 = 280$

$(T_2-T_1)Cn_{0-5}/64 = 4$

$T_X = T_1 + 4 = 32 + 4 = 36°$

Calculations of dry bulb temperature, relative humidity and barometric pressure follow the same procedure.

General Comments on BLIP Software

1. The accuracy of the INTERP calculation depends primarily on the number of points along the Temperature, Relativity, Humidity or Pressure vs. Counts curves stored in PROM. We arbitrarily chose to store points every 64 counts so we could fit all software and lookup tables in 512 words or PROM.

2. In using the present BLIS ground station, which has a 5 digit decimal readout, we decided on a fixed output format for the software of 2 significant digits to the right of the decimal point. This meets or exceeds the expected accuracy of the calculations. This format does lead to a problem with the barometric pressure, which has a range from 850.00 to 1040.00mb requiring a 6 digit display and 17 bits. Our solution was to subtract 800 mb. from all readings so the transmitted values would be in the range from 50.00 to 240.00 mb.

CONCLUSIONS

In building an actual system certain items would have to be changed before it would be practical. One of the biggest problems would be power. The PACE/BLIS uses approximately 7.5 watts. This is of course too much for a battery powered system. The hardware would be built with CMOS logic instead of the TTL used in PACE/BLIS. Additional power would be saved by using a CMOS MPU. Low power PROM would be needed, but additional power could be saved by applying power to it only during read cycles.

The execution of the software is entirely hardware bound. Total processing time for a temperature or pressure reading (which uses the longest routine) is on the order of 1 msec, while 224 msec are spent in a wait loop while accumulating sensor counts. An 8 bit micro-processor using double precision would have negligible effect on the performance of a system using a similar hardware design.

The MPU could easily control a more complex interface. By using an external timing clock instead of delay loops, and extra counters in the interface, a large increase in sampling rate could be obtained. The 220 msec sampling period per sensor is required for high resolution, but if more than one measurement were made at one time the data rate could be increased.

The software was designed as a main program calling subroutines. The purpose of this was to make changing the functions as simple as possible. Each sensor has its own modular block of code. If it was desired to add or delete sensors or the order of sampling, only the very simple main program would need changing, plus the addition or deletion of the subroutines. Also it would be easy to substitute better subroutines as these where developed. By using software designed this way, a custom package could be used for each experiment with only minor software changes.

REFERENCES

1. Boundary Layer Instrumentation Package; "Measurands, Sensors, Configurations of the Subsystem, and Field Use Comments," Space Science and Engineering Center, University of Wisconsin. March 18, 1974.

2. Boundary Layer Instrumentation System (BLIS) Sonde; A User Manual, Space Science and Engineering Center, University of Wisconsin. February, 1976.

3. Pace Technical Description, National Semiconductor Corporation, June, 1975.

Appendix I

MEASUREMENT SPECIFICATIONS

Temperature	±0.1°C
Pressure	±0.5 mb
Humidity	±1%
Wind Speed	±0.5 m/sec
Wind Direction	±2°
Wind Tilt	±0.5°

```
END PASS 1
    1        0000                R0=0
    2        0001                R1=1
    3        0002                R2=2
    4        0003                R3=3
    5        0002                PSIGN=2
    6        0007                CRYF=7
    7        0008                LINK=8
    8        0009                IEN=9
    9        000A                CRY=10
   10        000B                NSIGN=11
   11        0000      .ASECT
   12                  .TITLE    INIT
   13 0000 3900 A      START:    PFLG    IEN             ;DISABLE ALL INTRPTS
   14 0001 1809 A                JMP     INIT
   15 0002 1809 A                JMP     INIT
   16 0003 18BC A                JMP     OWD
   17        0009                .=.+5
   18 0009 3100 A      INIT:     PFLG    1               ;DISABLE INTRPT 1
   19 000A 3280 A                SFLG    2               ;ENABLE INTRPT 2
   20 000B 3300 A                PFLG    3               ;DISABLE INTRPT 3
   21 000C 3400 A                PFLG    4               ;DISABLE INTRPT 4
   22 000D 3500 A                PFLG    5               ;DISABLE INTRPT 5
   23 000E 3A00 A                PFLG    10              ;WORD LENGTH=16 BITS
   24 000F 3C00 A                PFLG    12              ;COUNTER IN COUNT MODE
   25 0010 1865 A                JMP     POCNT           ;JMP TO MAIN PROGRAM
   26                  .TITLE    DEFNS
   27 0011 0000 A      BUF:      .WORD   0
   28 0012 3039 A      ID:       .WORD   X'3039
   29 0013 4000 A      RESV:     .WORD   X'4000
   30 0014 4001 A      ANRD:     .WORD   X'4001
   31 0015 4002 A      COREF:    .WORD   X'4002
   32 0016 4003 A      ROREF:    .WORD   X'4003
   33 0017 4004 A      WBTH:     .WORD   X'4004
   34 0018 4005 A      DBTH:     .WORD   X'4005
   35 0019 4006 A      HYGR:     .WORD   X'4006
   36 001A 4007 A      AUX:      .WORD   X'4007
   37 001B 1000 A      ROCAL:    .WORD   X'1000
   38 001C 1000 A      COCAL:    .WORD   X'1000
   39 001D 1000 A      WSMULT:   .WORD   X'1000
   40 001E 012C A      WBTBL:    .WORD   X'012C
   41 001F 0154 A      DBTBL:    .WORD   X'0154
   42 0020 017C A      RHTBL:    .WORD   X'017C
   43 0021 01A4 A      PRTBL:    .WORD   X'01A4
   44 0022 0001 A      ONE:      .WORD   1
   45 0023 FFFF A      MONE:     .WORD   -1
   46 0024 2E3F A      DLY:      .WORD   X'2E3F
   47                  .TITLE    TLTTBL
   48 0025 04B7 A      TLTTBL:   .WORD   1207            ;TILT VALUES IN
   49 0026 046C A                .WORD   1132            ;DEGREES AND MINUTES
   50 0027 04DB A                .WORD   1243            ;WIND UP,
   51 0028 0526 A                .WORD   1318            ;00000 TO 01800 DEGREES
   52 0029 03FE A                .WORD   1022            ;WIND DOWN,
   53 002A 0421 A                .WORD   1057            ;10000 TO 11800 DEGREES
   54 002B 03B3 A                .WORD    947
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 55 002C 0390 A          .WORD  912
 56 002D 05E0 A          .WORD 1504
 57 002E 0604 A          .WORD 1540
 58 002F 0595 A          .WORD 1429
 59 0030 0549 A          .WORD 1353
 60 0031 0673 A          .WORD 1651
 61 0032 0650 A          .WORD 1616
 62 0033 06C0 A          .WORD 1728
 63 0034 070C A          .WORD 1804
 64 0035 0220 A          .WORD  544
 65 0036 026B A          .WORD  619
 66 0037 01FE A          .WORD  510
 67 0038 01B3 A          .WORD  435
 68 0039 02D8 A          .WORD  728
 69 003A 028E A          .WORD  654
 70 003B 0323 A          .WORD  803
 71 003C 0346 A          .WORD  838
 72 003D 00FC A          .WORD  252
 73 003E 00DA A          .WORD  218
 74 003F 0146 A          .WORD  326
 75 0040 0191 A          .WORD  401
 76 0041 006D A          .WORD  109
 77 0042 008F A          .WORD  143
 78 0043 0023 A          .WORD   35
 79 0044 0000 A          .WORD    0
 80 0045 2BC7 A          .WORD 11207
 81 0046 2B7C A          .WORD 11132
 82 0047 2BEB A          .WORD 11243
 83 0048 2C36 A          .WORD 11318
 84 0049 2B0E A          .WORD 11022
 85 004A 2B31 A          .WORD 11057
 86 004B 2AC3 A          .WORD 10947
 87 004C 2AA0 A          .WORD 10912
 88 004D 2CF0 A          .WORD 11504
 89 004E 2D14 A          .WORD 11540
 90 004F 2CA5 A          .WORD 11429
 91 0050 2C59 A          .WORD 11353
 92 0051 2D83 A          .WORD 11651
 93 0052 2D60 A          .WORD 11616
 94 0053 2DD0 A          .WORD 11728
 95 0054 2E1C A          .WORD 11804
 96 0055 2930 A          .WORD 10544
 97 0056 297B A          .WORD 10619
 98 0057 290E A          .WORD 10510
 99 0058 28C3 A          .WORD 10435
100 0059 29E8 A          .WORD 10728
101 005A 299E A          .WORD 10654
102 005B 2A4F A          .WORD 10831
103 005C 2A56 A          .WORD 10838
104 005D 280C A          .WORD 10252
105 005E 27EA A          .WORD 10218
106 005F 2856 A          .WORD 10326
107 0060 28A1 A          .WORD 10401
108 0061 277D A          .WORD 10109
109 0062 279F A          .WORD 10143
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0063 2738 A                 .WORD 10036
0064 2710 A                 .WORD 10000

                    .TITLE  MAIN
0065 CC16 A  ROCNT: LD      R3,ROREF        ;R3=INDEX REG
0066 C300 A         LD      R0,(R3)         ;SWITCH ROREF TO R0
0067 3B00 A         PFLG    11              ;CLR COUNTER
0068 14C6 A         JSR     DELAY           ;WAIT
0069 C300 A         LD      R0,(R3)         ;ROREF COUNT, CR
006A 51FF A         LI      R1,-1           ;SYNCH WORD=ALL ONES
006B 4FFF A  OSYNCH: BOC    15,OSYNCH       ;WAIT FOR BUFFER EMPTY
006C D411 A         ST      R1,BUF          ;OUTPUT SYNCH WORD
006D CC17 A  WB:    LD      R3,WBTH         ;R3=INDEX REG
006E C700 A         LD      R1,(R3)         ;SWITCH WB THERM TO R0
006F 3B00 A         PFLG    11              ;CLR COUNTER
0070 14C6 A         JSR     DELAY           ;WAIT
0071 C700 A         LD      R1,(R3)         ;WB COUNT, C0
0072 C81B A         LD      R2,ROCAL        ;R0 CAL UNT, CC
0073 6000 A         PUSH    R0              ;SAVE CR
0074 14EA A         JSR     CCRCT           ;CORRECT C0
0075 CC1E A         LD      R3,WBTBL        ;WB TABLE BASE ADD
0076 14FA A         JSR     INTERP          ;CALC WB TEMP
0077 6400 A         PULL    R0              ;RESTORE CR FOR DB
0078 4FFF A  OWB:   BOC     15,OWB          ;WAIT FOR BUFFER EMPTY
0079 D411 A         ST      R1,BUF          ;OUTPUT WB TEMP
007A CC18 A  DB:    LD      R3,DBTH         ;R3=INDEX REG
007B C700 A         LD      R1,(R3)         ;SWITCH DB THERM TO R0
007C 3B00 A         PFLG    11              ;CLR COUNTER
007D 14C6 A         JSR     DELAY           ;WAIT
007E C700 A         LD      R1,(R3)         ;DB COUNT, C0
007F C81B A         LD      R2,ROCAL        ;R0 CAL COUNT, CC
0080 6000 A         PUSH    R0              ;SAVE CR
0081 14EA A         JSR     CCRCT           ;CORRECT C0
0082 CC1F A         LD      R3,DBTBL        ;DB TABLE BASE ADD
0083 14FA A         JSR     INTERP          ;CALC DB TEMP
0084 6400 A         PULL    R0              ;RESTORE CR FOR RH
0085 4FFF A  ODB:   BOC     15,ODB          ;WAIT FOR BUFFER EMPTY
0086 D411 A         ST      R1,BUF          ;OUTPUT DB TEMP
0087 CC19 A  RH:    LD      R3,HYGR         ;R3=INDEX REG
0088 C700 A         LD      R1,(R3)         ;SWITCH HYGR TO R0
0089 3B00 A         PFLG    11              ;CLR COUNTER
008A 14C6 A         JSR     DELAY           ;WAIT
008B C700 A         LD      R1,(R3)         ;HYGR COUNT C0
008C C81B A         LD      R2,ROCAL        ;R0 CAL COUNT, CC
008D 6000 A         PUSH    R0              ;SAVE CR
008E 14EA A         JSR     CCRCT           ;CORRECT C0
008F CC20 A         LD      R3,RHTBL        ;RH TABLE BASE ADD
0090 14FA A         JSR     INTERP          ;CALC RH
0091 6400 A         PULL    R0              ;RESTORE CR
0092 4FFF A  ORH:   BOC     15,ORH          ;WAIT FOR BUFFER EMPTY
0093 D411 A         ST      R1,BUF          ;OUTPUT RH
0094 CC15 A  COCNT: LD      R3,COREF        ;R3=INDEX REG
0095 C300 A         LD      R0,(R3)         ;SWITCH COREF TO C0
0096 3B00 A         PFLG    11              ;CLR COUNTER
0097 14C6 A         JSR     DELAY           ;WAIT
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 165 0098 C300 A          LD    R0,(R3)       ;COREF COUNT, C0
 166 0099 C412 A          LD    R1,1D         ;BLIP ID #
 167 009A 4FFF A  01D:    BOC   15,01D        ;WAIT FOR BUFFER EMPTY
 168 009B D411 A          ST    R1,BUF        ;OUTPUT BLIP ID #
 169 009C C014 A  PRESS:  LD    R0,AIRD       ;R3=INDEX REG
 170 009D C780 A          LD    R1,(R3)       ;SWITCH ANEROID TO C0
 171 009E 3B00 A          PFLG  11            ;CLR COUNTER
 172 009F 14C6 A          JSR   DELAY         ;WAIT
 173 00A0 C700 A          LD    R1,(R3)       ;ANRD COUNT, C0
 174 00A1 C81C A          LD    R2,COCAL      ;C0 CAL COUNT, CC
 175 00A2 14EA A          JSR   CCRCT         ;CORRECT C0
 176 00A3 CC21 A          LD    R3,PRTBL      ;PRESS TABLE BASE ADD
 177 00A4 14FA A          JSR   INTERP        ;CALC PRESSURE
 178 00A5 4FFF A  OPRESS: BOC   15,OPRESS     ;WAIT FOR BUFFER EMPTY
 179 00A6 D411 A          ST    R1,BUF        ;OUTPUT BAR PRESSURE
 180 00A7 CC13 A  WS:     LD    R3,RESV       ;R3=INDEX REG
 181 00A8 C300 A          LD    R0,(R3)       ;SWITCH RESV TO COUNTER
 182 00A9 3B00 A          PFLG  11            ;CLR COUNTER
 183 00AA 14C6 A          JSR   DELAY         ;WAIT
 184 00AB C300 A          LD    R0,(R3)       ;RESV COUNT
 185 00AC C41D A          LD    R1,WSMULT     ;WS MULTIPLIER
 186 00AD 14CD A          JSR   MUL           ;PROD IN R2
 187 00AE 4FFF A  OWS:    BOC   15,OWS        ;WAIT FOR BUFFER EMPTY
 188 00AF D811 A          ST    R2,BUF        ;OUTPUT WS
 189 00B0 CC13 A  WD:     LD    R3,RESV       ;R3=INDEX REG
 190 00B1 C700 A          LD    R1,(R3)       ;SWITCH RESV TO COUNTER
 191 00B2 52FF A          LI    R2,-1         ;LOW WS ERROR INDICATOR
 192 00B3 3980 A          SFLG  IEN           ;ENABLE INTRPT
 193 00B4 4DFF A  WSONC:  BOC   13,WSONC      ;WAIT FOR SONC PULSE
 194 00B5 3B00 A          PFLG  11            ;CLR COUNTER
 195 00B6 4EFF A  WOA:    BOC   14,WOA        ;WAIT FOR ONCE AROUND
 196 00B7 C700 A          LD    R1,(R3)       ;RESV COUNT
 197 00B8 2902 A          SHL   R1,1,0        ;MULTIPLY BY 2
 198 00B9 5064 A          LI    R0,100        ;MULTIPLY BY 100
 199 00BA 14CD A          JSR   MUL           ;PROD IN R2
 200 00BB 3900 A          PFLG  IEN           ;DISABLE INTRPT
 201 00BC 4FFF A  OWD:    BOC   15,OWD        ;WAIT FOR BUFFER EMPTY
 202 00BD D811 A          ST    R2,BUF        ;OUTPUT WD
 203 00BE CC13 A  TILT:   LD    R3,RESV       ;R3=INDEX REG
 204 00BF 3C80 A          SFLG  12            ;LOAD TILT INTO COUNTER
 205 00C0 CE00 A          LD    R2,(R3)       ;TILT CODE
 206 00C1 3C00 A          PFLG  12            ;COUNTER TO COUNT MODE
 207 00C2 C225 A          LD    R0,TLTTBL(R2) ;LOOK UP TILT IN TABLE
 208 00C3 4FFF A  OTILT:  BOC   15,OTILT      ;WAIT FOR BUFFER EMPTY
 209 00C4 D011 A          ST    R0,BUF        ;OUTPUT TILT
 210 00C5 1865 A          JMP   ROCNT         ;START MAIN PROG OVER
 211                    .TITLE  DELAY
 212 00C6 6000 A  DELAY:  PUSH  R0            ;SAVE R0
 213 00C7 C024 A          LD    R0,DLY        ;WAIT LOOP COUNTER
 214 00C8 7000 A          CAI   R0,0          ;COMPLEMENT
 215 00C9 7801 A  DWAIT:  AISZ  R0,1          ;IF COUNTER=0, DONE
 216 00CA 18C9 A          JMP   DWAIT         ;ELSE, WAIT
 217 00CB 6400 A          PULL  R0            ;RESTORE R0
 218 00CC 8000 A          RTS   0             ;RETURN
 219                    .TITLE  MUL
```

```
220 00CD 6000 A  MUL:    PUSH  R0          ;SAVE MPR
221 00CE 5200 A          LI    R2,0        ;CLR R2
222 00CF 5300 A          LI    R3,0        ;CLR R3
223 00D0 7800 A          CAI   R0,0        ;COMPLEMENT MPR
224 00D1 7001 A  MLOOP:  AISZ  R0,1        ;INC -MPR, IF=0, RETURN
225 00D2 18D4 A          JMP   MADD
226 00D3 18D9 A          JMP   MRST
227 00D4 6A40 A  MADD:   RADD  R1,R2        ;ADD MPD TO PROD ACC
228 00D5 4A01 A          BOC   CRY,MPADC   ;IF CRY=1,
229 00D6 18D1 A          JMP   MLOOP
230 00D7 EC22 A  MPADC:  ADD   R3,ONE      ;THEN INC HI PROD ACC
231 00D8 18D1 A          JMP   MLOOP
232 00D9 6400 A  MRST:   PULL  R0          ;RESTORE MPR
233 00DA 8000 A          RTS   0           ;RETURN
234                      .TITLE DIV
235 00DB 6000 A  DIV:    PUSH  R0          ;SAVE DVR
236 00DC 7001 A          CAI   R0,1        ;NEGATE DVR
237 00DD 51FF A          LI    R1,-1       ;INIT QT=-1
238 00DE E422 A  DLOOP:  ADD   R1,ONE      ;INC QT
239 00DF 6A00 A          RADD  R0,R2       ;SUB DVR FROM LOW DVD
240 00E0 4AFD A          BOC   CRY,DLOOP   ;IF NO CRY,
241 00E1 EC23 A          ADD   R3,MONE     ;THEN DEC HI DVD
242 00E2 4AFB A          BOC   CRY,DLOOP   ;IF NO CRY, THEN DIV DONE
243 00E3 2A02 A          SHL   R2,1,0      ;2(REMAINDER-DVR)
244 00E4 7001 A          CAI   R0,1        ;MAKE DVR POSITIVE
245 00E5 6880 A          RADD  R2,R0       ;2(REM-DVR)+DVR=
246 00E6 4B01 A          BOC   NSIGN,DRST  ;2*REM-DVR, IF POSITIVE,
247 00E7 E422 A          ADD   R1,ONE      ;THEN ROUND UP QT
248 00E8 6400 A  DRST:   PULL  R0          ;RESTORE DVR
249 00E9 8000 A          RTS   0           ;RETURN
250                      .TITLE CCRCT
251 00EA 6100 A  CCRCT:  PUSH  R1          ;SAVE C0
252 00EB 7001 A          CAI   R0,1        ;NEGATE CR
253 00EC 6880 A          RADD  R2,R0       ;(CC-CR)
254 00ED 6000 A          PUSH  R0          ;SAVE (CC-CR)
255 00EE 4201 A          BOC   PSIGN,CPCC  ;IF (CC-CR)<0,
256 00EF 7001 A          CAI   R0,1        ;THEN MAKE POSITIVE
257 00F0 6200 A  CPCC:   PUSH  R2          ;SAVE CC
258 00F1 14CD A          JSR   MUL         ;+(CC-CR)*C0 IN R3,R2
259 00F2 6400 A          PULL  R0          ;PULL CC
260 00F3 14DB A          JSR   DIV         ;(CC-CR)*C0/CC IN R1
261 00F4 6400 A          PULL  R0          ;PULL (CC-CR)
262 00F5 4201 A          BOC   PSIGN,CPCO  ;IF (CC-CR)<0,
263 00F6 7101 A          CAI   R1,1        ;THEN NEGATE QT
264 00F7 6400 A  CPCO:   PULL  R0          ;PUL C0
265 00F8 6900 A          RADD  R0,R1       ;(CC-CR)*C0/CC + C0
266 00F9 8000 A          RTS   0           ;RETURN
267                      .TITLE INTERP
268 00FA C300 A  INTERP: LD    R0,(R3)     ;CMIN
269 00FB 7001 A          CAI   R0,1        ;NEGATE CMIN
270 00FC 6900 A          RADD  R0,R1       ;CX-CMIN=CN
271 00FD 5206 A          LI    R2,6        ;SHIFT COUNTER
272 00FE 3800 A  IROR:   PFLG  LINK        ;CLR LINK
273 00FF 2503 A          ROR   R1,1,1      ;SHR CN INTO LINK
274 0100 2403 A          ROR   R0,1,1      ;SHR LINK INTO R0
```

```
 275 0101 7AFF A          AISZ  T2,-1          ;IF COUNTER=0, DONE
 276 0102 19FE A          JMP   IROR           ;ELSE, SHIFT AGAIN
 277 0103 8014 A          SHF   R2,10,0        ;R2=CN(0-5), R1=CN(6-15)
 278 0104 6BAC A          TALI  T1,DC          ;TABLE BASE ADD+INDEX
 279 0105 C702 A          LI    R1,2(T3)       ;LOOK UP T2 IN TABLE
 280 0106 CE01 A          LI    R2,1(T3)       ;LOOK UP T1 IN TABLE
 281 0107 6200 A          PUSH  R2             ;SAVE T1
 282 0108 7201 A          CAI   R2,1           ;NEGATE T1
 283 0109 6980 A          RADD  R2,R1          ;(T2-T1)
 284 010A 6100 A          PUSH  R1             ;SAVE (T2-T1)
 285 010B 4201 A          BOC   PSIGN,IMUL     ;IF (T2-T1)<0,
 286 010C 7101 A          CAI   R1,1           ;THEN MAKE POSITIVE
 287 010D 14CD A IMUL:    JSR   MUL            ;+(T2-T1)*CN(0-5)IN R3,R2
 288 010E 5006 A          LI    R0,6           ;SHIFT COUNTER
 289 010F 3800 A IDIV:    PFLG  LINK           ;CLR LINK
 290 0110 2703 A          ROR   R3,1,1         ;SHR HI PROD INTO LINK
 291 0111 2603 A          ROR   R2,1,1         ;SHR LINK INTO LOW PROD
 292 0112 78FF A          AISZ  R0,-1          ;IF COUNTER=0, DONE
 293 0113 19FB A          JMP   IDIV           ;ELSE, SHIFT AGAIN
 294 0114 4801 A          BOC   LINK,IRUP      ;IF LINK=1,
 295 0115 1901 A          JMP   IP
 296 0116 E422 A IRUP:    ADD   R1,ONE         ;THEN ROUND UP QT
 297 0117 6400 A IP:      PULL  R0             ;RESTORE (T2-T1)
 298 0118 4201 A          BOC   PSIGN,IP2      ;IF (T2-T1)<0,
 299 0119 7101 A          CAI   R1,1           ;THEN NEGATE QT
 300 011A 6400 A IP2:     PULL  R0             ;RESTORE T1
 301 011B 6900 A          RADD  R0,R1          ;T1+(T2-T1)*CN(0-5)/64=TX
 302 011C 8000 A          RTS   0              ;RETURN
 303      0000            .END  START
```

```
ANRD    0014  A     AUX     001A  A*    BUF     0011  A
CCPCT   00EA  A     COCAL   001C  A     COCNT   0004  A*
COREF   0015  A     CPCC    00F0  A     CPCO    0077  A
CRY     000A  A     CRYF    0007  A*    DB      007A  A*
DBTBL   001F  A     DBTH    0018  A     DELAY   00C6  A
DIV     00DB  A     DLOOP   00DE  A     DLY     0024  A
DRST    00E8  A     DWAIT   00C9  A     HYGR    0019  A
ID      0012  A     IDIV    010F  A     IEN     0009  A
IMUL    010D  A     INIT    0009  A     INTERP  00FA  A
IP      0117  A     IP2     011A  A     IPOR    00FE  A
IRUP    0116  A     LINK    0008  A     MADD    00D4  A
MLOOP   00D1  A     MONE    0023  A     MPADC   00D7  A
MRST    00D9  A     MUL     00CD  A     NSIGN   000B  A
ODB     0085  A     OID     009A  A     ONE     0022  A
OPRESS  00A5  A     ORH     0092  A     OSYNCH  006B  A
OTILT   00C3  A     OWB     0078  A     OWD     00BC  A
OWS     00AE  A     PRESS   009C  A*    PRTBL   0021  A
PSIGN   0002  A     R0      0000  A     R1      0001  A
R2      0002  A     R3      0003  A     RESV    0013  A
RH      0087  A*    RHTBL   0020  A     ROCAL   001B  A
ROCNT   0065  A     ROREF   0016  A     START   0000  A
TILT    00BE  A*    TLTTBL  0025  A     WB      006D  A*
WBTBL   001E  A     WBTH    0017  A     WD      00E0  A*
WOA     00B6  A     WS      00A7  A*    WSMULT  001D  A
WSONC   00B4  A
NO ERROR LINES
END PASS 2
SOURCE CHECKSUM = 234B
TURN PT PUNCH ON AND PUSH RUN
```

14 PIN AUGAT CONNECTOR PIN OUT

P1

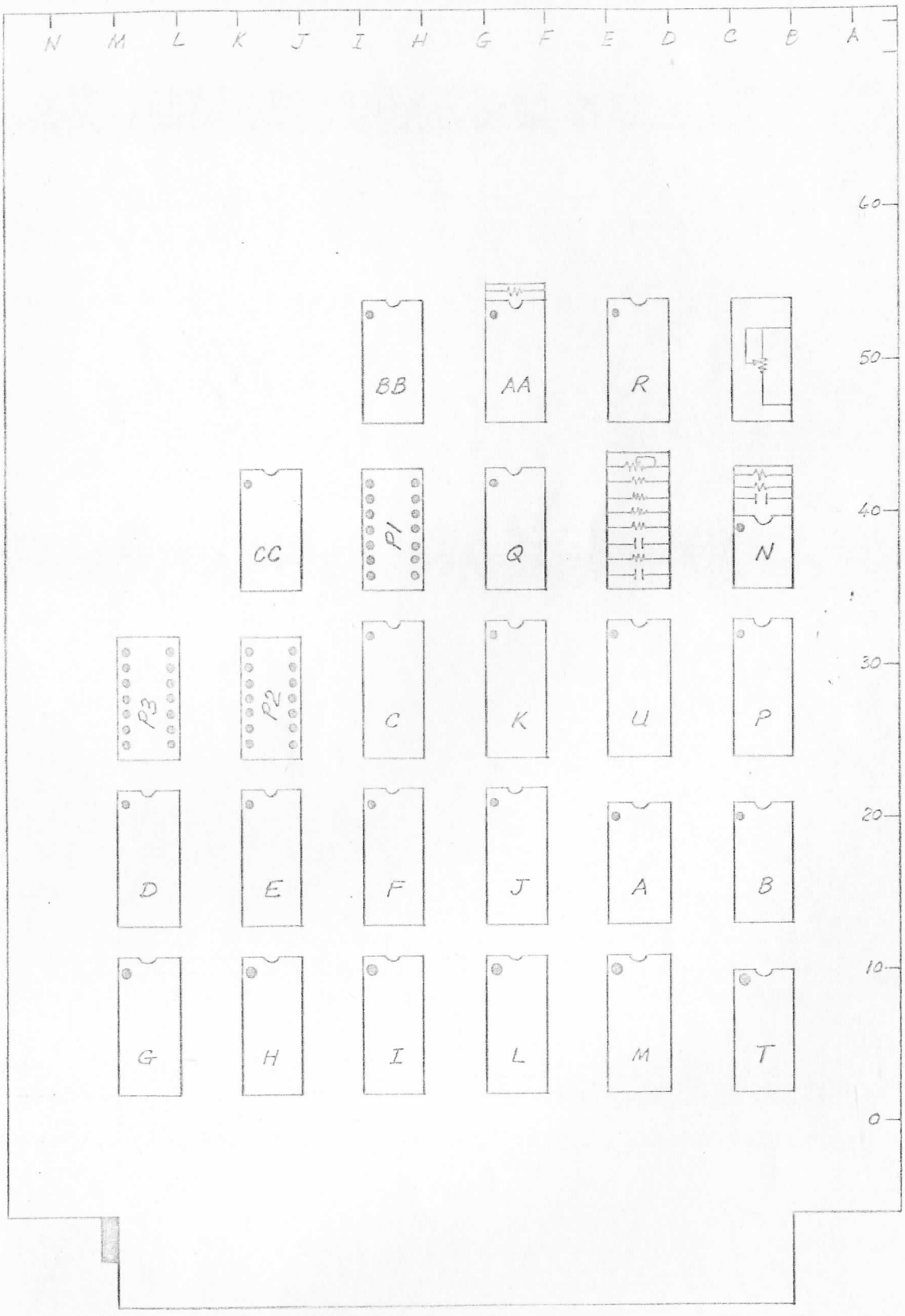
1	NINT
2	TILT BIT (LSB)
3	TILT BIT
4	TILT BIT
5	TILT BIT
6	TILT BIT
7	TILT BIT (MSB)
8-14	GND

P2

1	RL2
2	RL1
3	OA
4	MD
5	CO
6	RO
7	RO REF
8-14	GND

P3

1	+5V
2	-5V
3	RESV
4	AUX
5	HYGRISTOR
6	DRY BULB
7	WET BULB
8-14	GND



PROTO-BOARD IC LAYOUT

WIRE LIST FOR BLIS μP PAGE 1

SIGNAL NAME	ADD/ DELETE	FROM PIN		TO PIN	LEVEL	COLOR	COMMENTS
+5V			✓	B-20			
+5V			✓	H-32			
5V			✓	F-32			
5V			✓	D-32			
+5V			✓	B-32			
.5V			✓	F-42			
'5V			✓	B-39			
+5V			✓	D-49			
.5V			✓	F-53			
5V			✓	I-42			
ND			✓	M-3			
GND			✓	K-3			
ND			✓	I-3			
ND			✓	B-40			
GND			✓	G-3			
GND			✓	E-3			
ND			✓	C-3			
GND			✓	M-14			
GND			✓	K-14			
ND			✓	I-14			
WD			✓	G-14			
GND			✓	E-14			

WIRE LIST FOR BLIS μP PAGE 2

SIGNAL NAME	ADD/ DELETE	FROM PIN		TO PIN	LEVEL	COLOR	COMMENTS
GND	—		✓	C-14			
GND	—		✓	I-25			
GND	—		✓	I-26			
GND	—		✓	G-25			
GND	—		✓	E-25			
GND	—		✓	M-9			
GND	—		✓	C-25			
GND	—		✓	K-9			
GND	—		✓	G-36			
GND	—		✓	I-9			
GND	—		✓	C-39			
GND	—		✓	L-9			
GND	—		✓	J-9			
GND	—		✓	H-9			
GND	—		✓	G-31			
GND	—		✓	F-30			
5V	—		✓	E-47			
Q_A (D)	—	L-19	✓	L-8	1	W	LSB of Counter
Q_B (D)	—	L-18	✓	L-7	1	W	
Q_C (D)	—	L-17	✓	L-6	1	W	
Q_D (D)	—	L-16	✓	L-5	1	W	
Q_A (E)	—	J-19	✓	J-8	1	W	

WIRE LIST FOR BLIS μP PAGE 3

SIGNAL NAME	ADD/ DELETE	FROM PIN		TO PIN	LEVEL	COLOR	COMMENTS
Q_B (E)		J-18	✓	J-7	1	W	
Q_C (E)		J-17	✓	J-6	1	W	
Q_D (E)		J-16	✓	J-5	1	W	
Q_A (F)		H-19	✓	H-8	1	W	
Q_B (F)		H-18	✓	H-7	1	W	
Q_C (F)		H-17	✓	H-6	1	W	
Q_D (F)		H-16	✓	H-5	1	W	
CO (D)		L-20	✓	J-15	1	W	
LNB P(E)		K-15	✓	I-15	1	W	
NB T(E)		J-15	✓	K-15	2	BLUE	
CO (E)		J-20	✓	H-15	1	W	
CLR (D)		M-21	✓	K-21	1	W	
CL? (E)		I-21	✓	C-15	1	W	
CL? (F)		K-21	✓	I-21	2	Blue	
GND			✓	B-19			
5R		M-15	✓	L-15	1	W	
5R		B-18	✓	G-21	1	W	
5R		E-31	✓	D-26	1	W	
5R		L-15	✓	G-21	2	Blue	
R		B-18	✓	D-26	2	Blue	
CLK (D)		M-20	✓	K-20	1	W	
CLK (E)		I-20	✓	E-18	1	W	

WIRE LIST FOR BLIS μP PAGE 4

SIGNAL NAME	ADD/ DELETE	FROM PIN		TO PIN	LEVEL	COLOR	COMMENTS
CLK (F)		I-20	✓	K-20	2	Blue	
LD (D)		L-14	✓	J-14	1	W	
LD (E)		H-14	✓	E-19	1	W	
LD (F)		H-14	✓	J-14	2	Blue	
LD (F)		E-19	✓	B-14	2	Blue	
G1,2 (G)		L-3	✓	L-4	1	W	
G1,2 (H)		J-3	✓	J-4	1	W	
G1,2 (I)		H-3	✓	H-4	1	W	
		L-9	✓	L-4	2	Blue	
		J-9	✓	J-4	2	Blue	
		H-9	✓	H-4	2	Blue	
CLK (G)		M-4	✓	K-4	1	W	
CLK (H)		I-4	✓	F-14	1	W	
CLK (I)		E-15	✓	F-14	2	Blue	
		K-4	✓	I-4	2	Blue	
		M-10	✓	K-10	1	W	
		I-10	✓	C-19	1	W	
		I-10	✓	K-10	2	Blue	
		K-16	✓	K-17	1	W	
		I-16	✓	I-17	1	W	
		I-19	✓	I-18	1	W	
		I-17	✓	I-18	2	Blue	

WIRE LIST FOR BLIS μP PAGE 5

SIGNAL NAME	ADD/ DELETE	FROM PIN		TO PIN	LEVEL	COLOR	COMMENTS
GND	——	K-16	✓	K-14	2	Black	
GND	——	I-16	✓	I-14	2	Black	
IC (G)	——	H-30	✓	H-31	1	W	
	——	H-28	✓	H-29	1	W	
	——	H-30	✓	H-29	2	Blue	
	——	I-32	✓	H-31	2	Blue	
	——	I-31	✓	I-30	1	W	
	——	E-20	✓	I-28	1	W	
	——	C-17	✓	E-16	1	W	
C-2C (K)	——	G-32	✓	F-31	1	W	
	——	F-29	✓	G-20	1	W	
	——	G-30	✓	G-15	1	W	
	——	F-15	✓	H-25	1	W	
	——	G-32	✓	H-25	2	Blue	
	——	H-26	✓	G-30	2	Blue	
	——	H-27	✓	F-29	2	Blue	
	——	E-27	✓	E-36	1	W	
	——	D-36	✓	D-37	1	W	CAPACITOR 74123
	——	D-36	✓	E-26	2	Blue	
5V	——		✓	E-37		Red	
	——	E-38	✓	D-30	1	W	CAPACITOR 74123
	——	D-38	✓	D-39	1	W	

WIRE LIST FOR BLIS μP PAGE 6

SIGNAL NAME	ADD/ DELETE	FROM PIN		TO PIN	LEVEL	COLOR	COMMENTS
		D-38	✓	D-31	2	Blue	74123
-5V			✓	E-39		Red	
		C-38	✓	B-37	1	W	
		C-40	✓	C-41	1	W	
+5V			✓	C-36	1	Red	
+5V			✓	C-42	1	Red	
		B-42	✓	B-41	1	W	
		B-41	✓	B-38	2	Blue	
		C-40	✓	C-38	2	Blue	
		G-8	✓	E-8	1	W	
		C-7	✓	B-17	1	W	
		G-40	✓	G-37	1	W	
		C-37	✓	G-37	2	Blue	
		G-40	✓	B-17	2	Blue	
		E-8	✓	C-7	2	Blue	
		G-9	✓	E 9	1	W	
		D-14	✓	E-9	2	Blue	
		C-6	✓	C-9	1	W	
		E-31	✓	C-9	2	Blue	
		C-5	✓	D-15	1	W	
		B-16	✓	C-31	1	W	
		C-32	✓	C-4	1	W	

WIRE LIST FOR BLIS μP PAGE 7

SIGNAL NAME	ADD/ DELETE	FROM PIN		TO PIN	LEVEL	COLOR	COMMENTS
		D-3	✓	G-41	1	W	
		E-4	✓	G-38	1	W	
		G-42	✓	E-42	1	W	
		D-42	✓	D-43	1	W	
		D-43	✓	E-49	2	~~Blue~~ W	
		E-43	✓	D-48	1	W	PCM out
		G-39	✓	E-40	1	W	
		D-41	✓	D-40	1	W	
		D-41	✓	E-48	2	~~Blue~~ W	
GND			✓	E-41		Black	
		F3	✓	D-4	1	W	
		B-31	✓	C-8	1	W	

WIRE LIST FOR BLIS μP PAGE 8

I/O BUS and POWER CONNECTIONS

SIGNAL NAME	ADD/ DELETE	FROM PIN		TO PIN	LEVEL	COLOR	COMMENTS
DØ		F-5	✓	Pin 38	1	W	
D1		F-6	✓	Pin 40	1	W	
D2		F-7	✓	Pin 42	1	W	
DØ		G-18	✓	M-8	1	W	
D1		G-17	✓	M-7	1	W	
D2		F-17	✓	M-6	1	W	
DØ		F-5	✓	M-8	2	Blue	
D1		F-6	✓	M-7	2	Blue	
D2		F-7	✓	M-6	2	Blue	
D3		M-5	✓	F-8	1	W	
D4		G-8	✓	K-8	1	W	
D5		G-7	✓	K-7	1	W	
D6		G-6	✓	K-6	1	W	
D7		G-5	✓	K-5	1	W	
D8		D-5	✓	I-8	1	W	
D9		D-6	✓	I-7	1	W	
D10		D-7	✓	I-6	1	W	
D11		D-8	✓	I-5	1	W	
D3		M-5	✓	Pin 44	2	Blue	
D4		G-8	✓	Pin 48	2	Blue	
D5		K-7	✓	Pin 50	2	Blue	
D6		K-6	✓	Pin 52	2	Blue	

WIRE LIST FOR BLIS μP PAGE 9

SIGNAL NAME	ADD/ DELETE	FROM PIN		TO PIN	LEVEL	COLOR	COMMENTS
D7		K-5	✓	Pin 54	2	Blue	
D8		I-8	✓	Pin 37	2	Blue	
D9		I-7	✓	Pin 39	2	Blue	
D10		I-6	✓	Pin 41	2	Blue	
D11		I-5	✓	Pin 43	2	Blue	
D12		E-8	✓	Pin 47	1	W	
D13		E-7	✓	Pin 49	1	W	
D14		E-6	✓	E-17	1	W	
D14		E-6	✓	Pin 51	2	Blue	
D15		E-5	✓	Pin 53	1	W	
MD		K-28	✓	Pin 60	1	W	JC 13
OA		K-29	✓	Pin 57	1	W	JC 14
Xfer enter		Pin 59	✓	Pin 28	1	W	JC 15
Buffer Empty		C-4	✓	Pin 59	2	Blue	JC 15
IDS		C-20	✓	Pin 18	1	W	
IADS		C-18	✓	Pin 14	1	W	
F1		C-16	✓	Pin 22	1	W	BF 11
F2		B-15	✓	Pin 24	1	W	BF 12
+8		I-36	✓	G-26	1	W	
+3		I-37	✓	G-27	1	W	
+4		I-38	✓	G-28	1	W	
AUX-		I-39	✓	G-29	1	W	

WIRE LIST FOR BLIS µP PAGE 10

SIGNAL NAME	ADD/ DELETE	FROM PIN		TO PIN	LEVEL	COLOR	COMMENTS
RO REF+		K-25	✓	F-28	1	W	
RO +		K-26	✓	I-32	1	W	
CO +		K-27	✓	I-30	2	Blue	
RESV +		F-25	✓	I-29	1	W	
PRES +		F-26	✓	E-32	1	W	
CO REF +		F-27	✓	D-25	1	W	
RESV +		I-29	✓	I-40	2	Blue	
GND			✓	H-42 thru H-36			
GND			✓	J-31 thru J-25			
GND			✓	L-31 thru L-25			
+5V			✓	Pin 1			
+5V			✓	Pin 3			
+5V			✓	Pin 69			
+5V			✓	Pin 71			
GND			✓	Pin 2			
GND			✓	Pin 12			
GND			✓	Pin 11			
GND			✓	Pin 15			
GND			✓	Pin 72			
GND			✓	Pin 70			
GND			✓	Pin 35			
GND			✓	Pin 20			

WIRE LIST FOR BLIS μP PAGE 11

SIGNAL NAME	ADD/ DELETE	FROM PIN		TO PIN	LEVEL	COLOR	COMMENTS
PCM		D-48	✓	D-53	1	W	
GND			✓	E-53	1	~~Black~~ W	
+5V			✓	L-10			
+5V			✓	J-10			
+5V			✓	H-10			
+5V			✓	F-10			
+5V			✓	D-10			
+5V			✓	B-9			
+5V			✓	L-21			
+5V			✓	J-21			
+5V			✓	H-21			
+5V			✓	F-21			
+5V			✓	D-20			
(MSB) TILT BIT		K-18	✓	M-25	1	W	
TILT BIT		K-19	✓	M-26	1	W	
TILT BIT		M-16	✓	M-27	1	W	
TILT BIT		M-17	✓	M-28	1	W	
TILT BIT		M-18	✓	M-29	1	W	
(LSB) TILT BIT		M-19	✓	M-30	1	W	
DS		D-16	✓	Pin 17	1	W	
RL1		E-29	✓	K-30	1	W	
RL2		D-28	✓	K-31	1	W	

REVISIONS			
LTR.	DESCRIPTION	DATE	APPROVED

ANAROID
REF.
CAPACITIVE OSCILLATOR
REF.
THER. WB
THER. DB
HY
AUX.
RESISTIVE OSCILLATOR
TILT BITS
(LSB)
(MSB)
5R
74161 IC D
74161 IC E
74161 IC F
CAR
CLR
ICB 7404 F11
ICB 7404 F12
74151 IC C
D7 D6 D5 D4 D3 D2 D1 D0
STROBE
RESV
ICA 7400
ICA 7400
ICAA 7404
IC T 7474
IC AA 7404
100Ω
.002μF
IDS
7400 IC BB
IC G 74173
IC H 74173
IC I 74173
1D 2D 3D 4D C
1Q 2Q 3Q 4Q
M N CK
G_1 G_2
D_{14}
NADS
7474 IC CC
NC
ICA 7400
(LSB)
D_0 D_1 D_2 D_3 D_4 D_5 D_6 D_7 D_8 D_9 D_{10} D_{11}
I/O BUS
+5V
510K
270pF
IC U 74123 NC RL2
IC U 74123 NC RL1
74156 IC K
PRESSURE
CO - REF.
RO - REF.
WET BULB
DRY BULB
HYGRISTOR
AUXILARY
74175 IC J
3D 2D 1D
1Q 2Q 3Q
IC B 7404
MD JC 13
OA JC 14
BUFFER EMPTY JC 15

NOTES:
1) ——— = INTERCONNECTIONS BETWEEN SAME NUMBERED DRWGS.
2) ——▶ = CONNECTIONS TO/FROM SENSORS
3) ——▷ = CONNECTIONS TO/FROM PACE BUS

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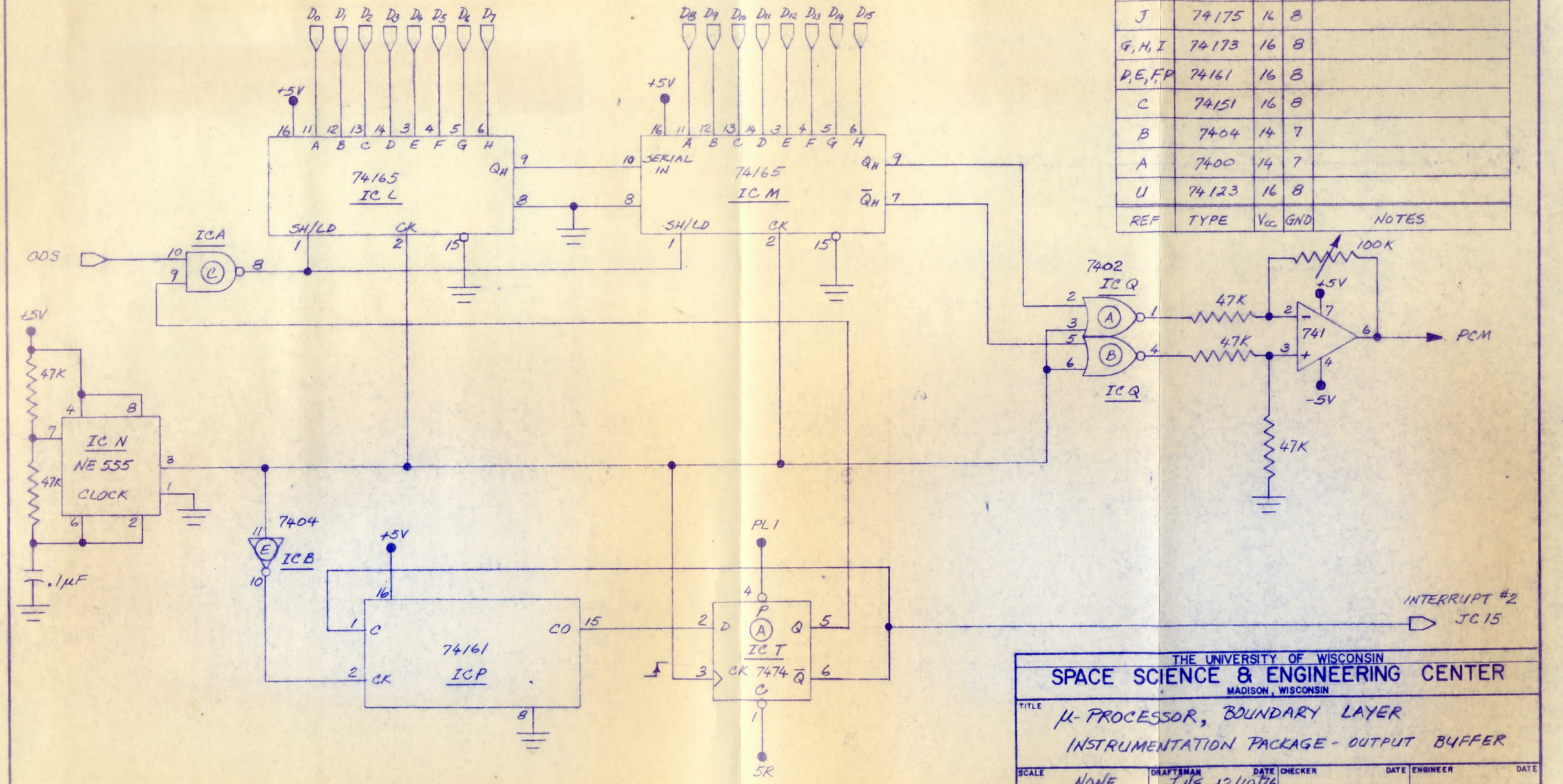
TITLE
μ-PROCESSOR, BOUNDARY LAYER INSTRUMENTATION PACKAGE - SENSOR INTERFACE

SCALE	DRAFTSMAN	DATE	CHECKER	DATE	ENGINEER	DATE
NONE	JE	12/10/76				
NEXT HIGHER ASSEMBLY			PRODUCT ASSURANCE	DATE	PROJECT APPROVAL	DATE
PROJECT NO. ECE 453	SIZE C	SHEET 1 OF 2	DRAWING NO. 453-001			

REF	TYPE	V_{cc}	GND	NOTES
R	HA2705	5		-5V TO PIN 4
Q	7402	14	7	
N	NE555	8	1	CLOCK - 64 HZ
L, M	74165	16	8	
K	74156	16	8	
J	74175	16	8	
G, H, I	74173	16	8	
D, E, F, P	74161	16	8	
C	74151	16	8	
B	7404	14	7	
A	7400	14	7	
U	74123	16	8	



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TITLE: μ-PROCESSOR, BOUNDARY LAYER INSTRUMENTATION PACKAGE - OUTPUT BUFFER

SCALE	DRAFTSMAN / DATE	CHECKER / DATE	ENGINEER / DATE
NONE	LVE 12/10/76		
APPROVAL / DATE	DESIGN ACTIVITY APPROVAL / DATE	ADDITIONAL APPROVAL / DATE	
PROJECT NO. ECE 453	SIZE B	SHEET 2 OF 2	DRAWING NO. 453-001