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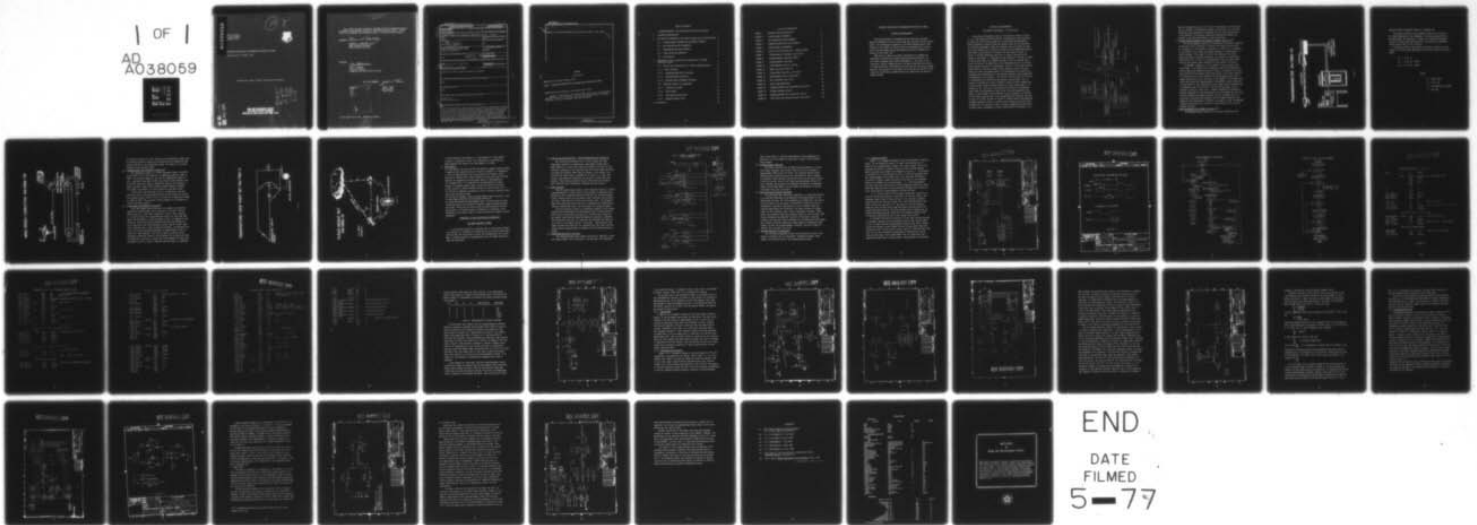
ROME AIR DEVELOPMENT CENTER GRIFFISS AFB N Y  
AUTOMATED WEATHER DATA DISSEMINATION FEASIBILITY MODEL.(U)  
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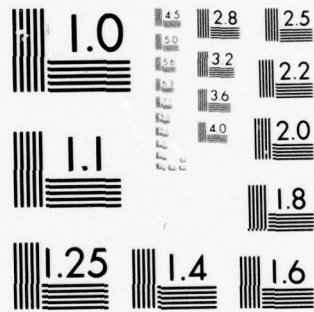
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RADC-TR-76-332  
In-house Report  
February 1977



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AUTOMATED WEATHER DATA DISSEMINATION FEASIBILITY MODEL

Captain Brian L. Masson, USAF

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AIR FORCE SYSTEMS COMMAND  
GRIFFISS AIR FORCE BASE, NEW YORK 13441

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) This report describes a study conducted to determine the feasibility of developing an inexpensive microprocessor-based system to accept raw weather data from Air Force inventory sensors and process this data for display. A feasibility model was built at RADC with an Intel Model 8080 microprocessor and attempts were made to interface with the following sensors: the AN/GMQ-13 Rotating Beam Ceilometer, the AN/GMQ-10 Transmissometer, the AN/TMQ-11 Temperature/Dew Point Sensor, and the AN/GMQ-20 Wind Instrument. This report details the		

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## AUTOMATED WEATHER DATA DISSEMINATION FEASIBILITY MODEL

### 1. INTRODUCTION/BACKGROUND

The present method of disseminating and displaying terminal weather information on an Air Force base does not meet the Air Force's needs. This problem was recognized at the GEEIA Meteorological Conference in July 1968<sup>1</sup> and the Air Force's requirements for an Automated Terminal Weather Dissemination/Display System (ATWDDS) were detailed in AFCS ROC 7-69.

RADC has performed an in-house investigation of methods for automation and potential problems associated with automation. At this time it appears that recent developments in the areas of A/D conversion, digital communications, and data processing could result in a more versatile, cost-effective system than was previously thought possible. The purpose of this report is to outline the results of the study and to describe an ATWDDS feasibility model that has been designed by RADC.

2.

THE NEED FOR AUTOMATION;  
THE PRESENT SYSTEM AND ITS DEFICIENCIES

The system configuration used for illustration, shown in figure 1, is in use today at Griffiss AFB NY. Configuration varies from base to base, but the Griffiss system can be considered representative. Data originates at sensors along the runway, which will be described in following paragraphs. There are identical sets of sensors on each end of the runway, all of which are cabled into the Remote Observation Site (ROS), which houses an indicator for each type of sensor. A switch in the ROS determines which set of sensors (one end of the runway or the other), is connected to the indicators. The ROS is linked to the outside world via a BAUDOT teletype circuit to Carswell AFB, and to the rest of the home base via an electrowriter net. An electrowriter system consists of a transmitter, which is a roll-paper writing tablet with an electrical output, and a receiver, which is an automatically driven roll-paper tablet. The transmitter and receiver are connected with telephone wire, and anything written on the transmitter is reproduced on the receiver. The Griffiss electrowriter net consists of transmitters at the ROS and Base Weather Station (BWS), and receivers at the BWS and 9 other locations such as the SAC command post and the control tower. Anything written on either transmitter is reproduced on all receivers. The system is used mainly to disseminate sensor data and observations from the ROS. The wind speed/direction sensor is also cabled into the BWS and 5 other locations via the ROS. Each of these locations has a wind speed/direction indicator identical to that at the ROS. The BWS is linked to Carswell AFB by approximately 4 BAUDOT teletype circuits. A closed circuit television system links the BWS with 13 locations on base, including command posts and pilots briefing rooms. Viewgraphs or charts placed before the camera at the

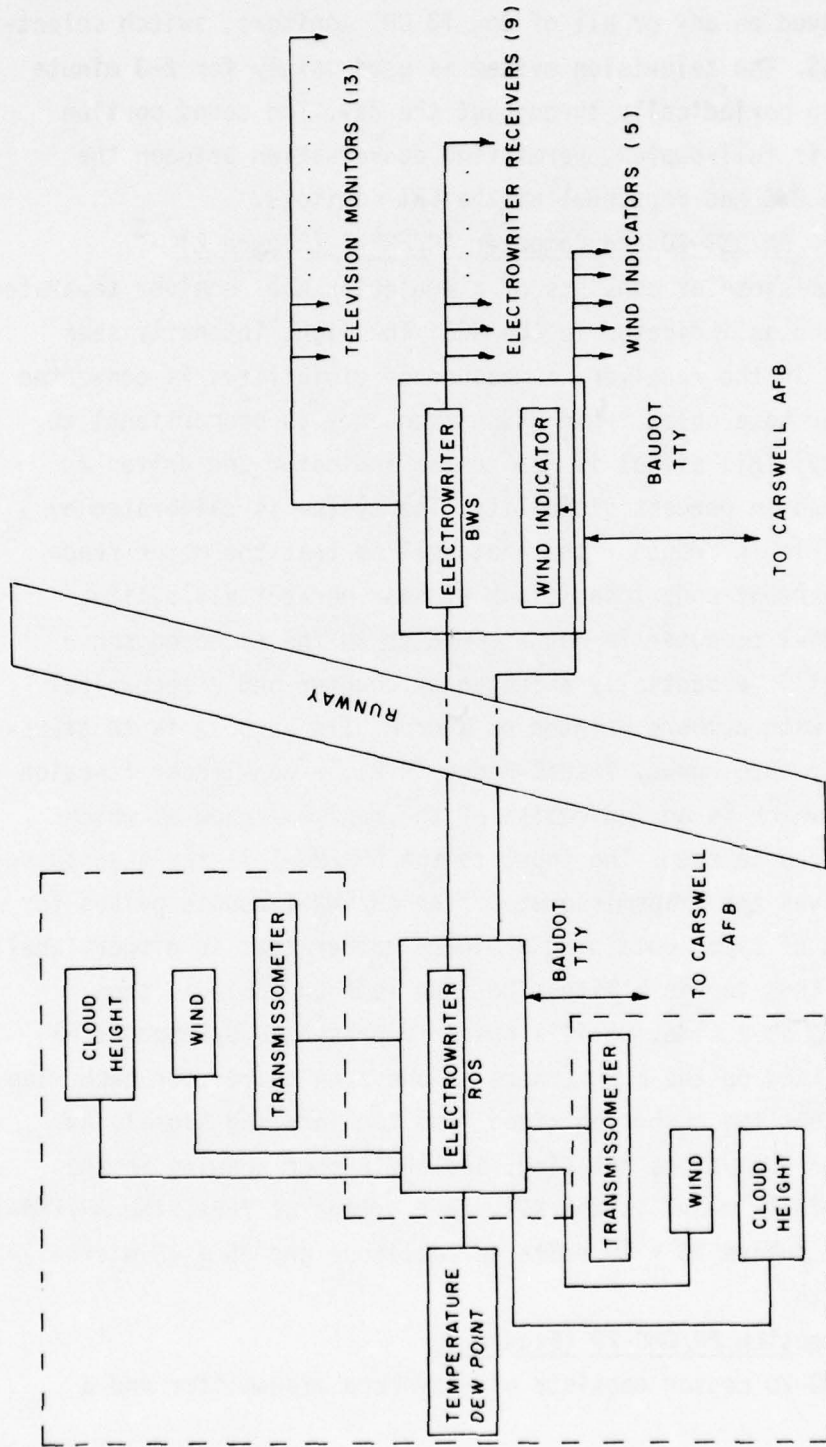


Figure 1

BWS are displayed on any or all of the 13 CRT monitors, switch selectable at the BWS. The television system is used mainly for 2-3 minute briefings given periodically throughout the day. The sound portion of the system is full-duplex, permitting conversation between the briefer at the BWS and personnel at the CRT monitors.

#### 2.1 Transmissometer AN/GMQ-10 and Computer AN/FMN-1 (Figure 2)<sup>2,3</sup>

The transmissometer consists of a projector and receiver separated by 500 feet, and an indicator in the ROS. The light intensity seen by a photocell in the receiver, a measure of visibility, is converted in the receiver to a pulse train whose frequency is proportional to light intensity. This signal is fed to the indicator and drives a meter calibrated in percent visibility. The system is calibrated by adjusting an iris in front of the photocell so that the meter reads close to 100 percent under conditions of near perfect visibility.

The AN/FMN-1 computer is not a computer in the accepted sense of the term. It is essentially a frequency counter and a mechanical look-up table with numbers printed on a drum. Its purpose is to translate visibility into Runway Visual Range (RVR), a non-linear function of visibility which is an indication of the maximum range at which runway lights can be seen. The input to the AN/FMN-1 is the same pulse train that drives the transmissometer. The AN/FMN-1 counts pulses for a fixed length of time, obtaining a binary number that is proportional to frequency, thus to visibility. The drum look-up table is then rotated, a step at a time, until a number represented by conductive material deposited on the drum (there is one such number for each step position) matches the number obtained from the incoming signal. At this point, the drum stops rotating, and the number showing in the window on the front panel is the RVR, in hundreds of feet. The AN/FMN-1 requires input pulses  $15 \pm 10$  volts in amplitude and  $35 \pm 15$  microseconds in width.

#### 2.2 Wind Speed/Direction AN/GMQ-20 (Figure 3)<sup>4</sup>

The AN/GMQ-20 sensor consists of a synchro transmitter and a

# TRANSMISSION METER AN/GMQ-10

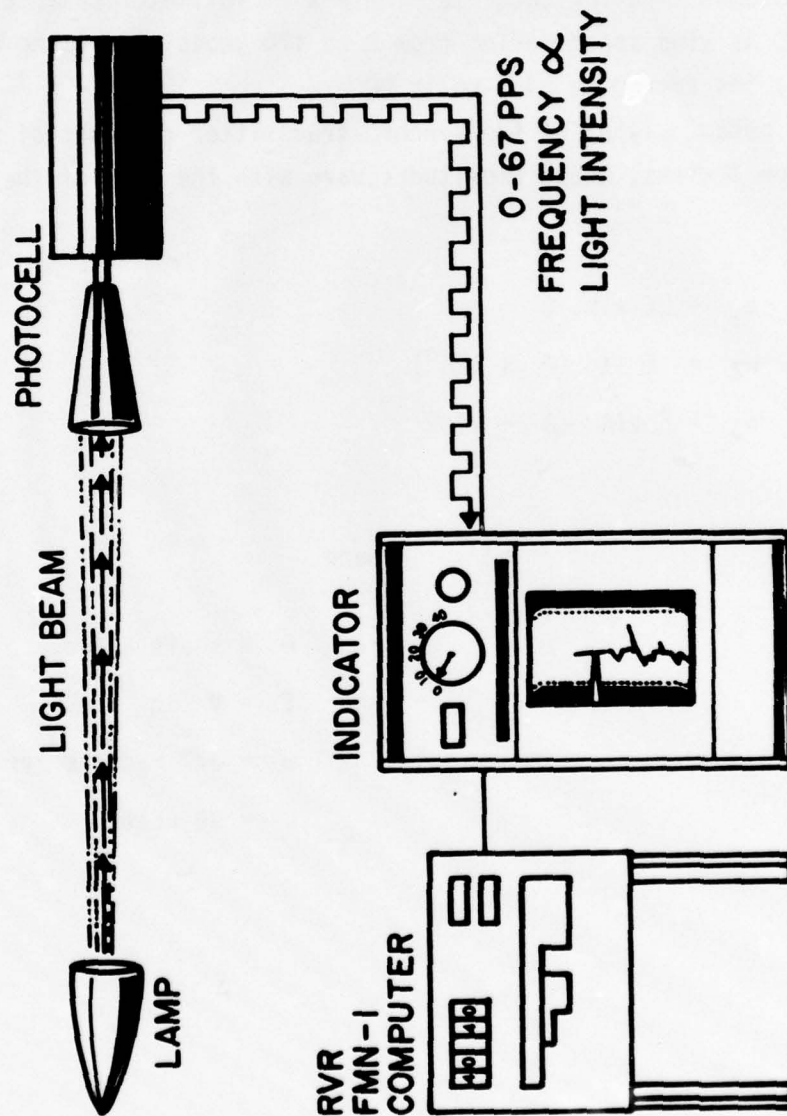


Figure 2

propeller-driven tachometer housed in a weather van.

The angular velocity of the propeller shaft, and in turn the DC voltage generated by the tachometer, is directly proportional to the wind speed. The indicator is simply a DC voltmeter calibrated in knots. As wind speed varies from 0 to 120 knots, the tachometer output varies from 0 to 14.7 volts DC.

The output signal of the synchro transmitter consists of 60 Hz signals on 3 wires, whose amplitudes vary with the sine of the shaft angle.

$$e_1 = E \sin \theta$$

$$e_2 = E \sin (\theta + 120^\circ)$$

$$e_3 = E \sin (\theta + 240^\circ)$$

where

$$\theta = \text{shaft angle}$$

$$E = V \sin \omega t$$

$$\omega = 377 \text{ radians per second}$$

$$V = 90 \text{ volts}$$

# WIND SPEED / DIRECTION AN/GMQ - 20

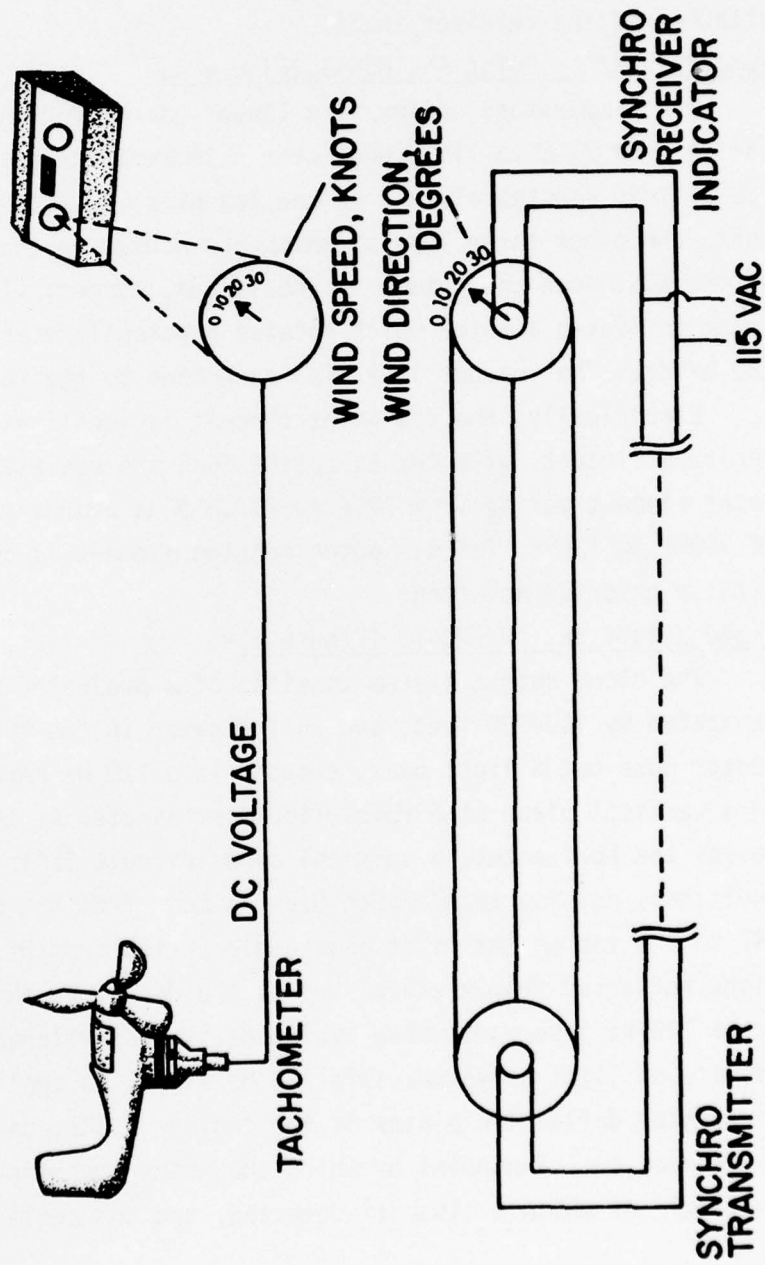


Figure 3

The synchro receiver is a unit similar to the transmitter, whose shaft is forced by the 60 Hz signals on the three lines to assume the same angular position as the transmitter shaft. The readout is a pointer attached to the receiver shaft.

### 2.3 Temperature/Dew Point AN/TMQ-11 (Figure 4)<sup>5</sup>

The temperature sensor is a linear thermistor whose resistance varies from 77.6 to 119.6 ohms over a temperature range of -80°F to 130°F. This sensing element is one leg of a wheatstone bridge circuit, the other three legs of which are housed in the indicator unit at the ROS. When the bridge is unbalanced, current flow through a meter activates a motor which rotates a potentiometer to balance the bridge. The readout is a dial connected to the motor shaft.

Electrically, the dew point circuit is identical to the temperature circuit, with the exception that the resistance of the dew point element varies from 77.6 to 117.6 ohms over a temperature range of -80°F to 120°F. The dew point sensing element is surrounded by a lithium chloride solution.

### 2.4 Cloud Height Set AN/GMQ-13 (Figure 5)<sup>6</sup>

The cloud height system consists of a projector and detector separated by 400-900 feet, and an indicator in the ROS. The projector puts out a light beam, chopped at a 120 Hz rate, rotating in a vertical plane at 5 revolutions per minute. As the light beam passes the horizontal, a vertical sweep circuit is triggered in the indicator, causing an electron beam to move from the bottom of a CRT to the top as the light beam angle varies from 0° to 90°. When light reflected from a cloud strikes the detector, the detector puts out a 120 Hz sine wave whose amplitude is proportional to the intensity of light detected. This 120 Hz signal is applied to the horizontal deflection plates of the indicator CRT, causing the trace to broaden out. The point at which the trace broadens out thus gives the angle at which a cloud is detected, and the angle is translated

# TEMPERATURE / DEW POINT SET AN/TMQ-II

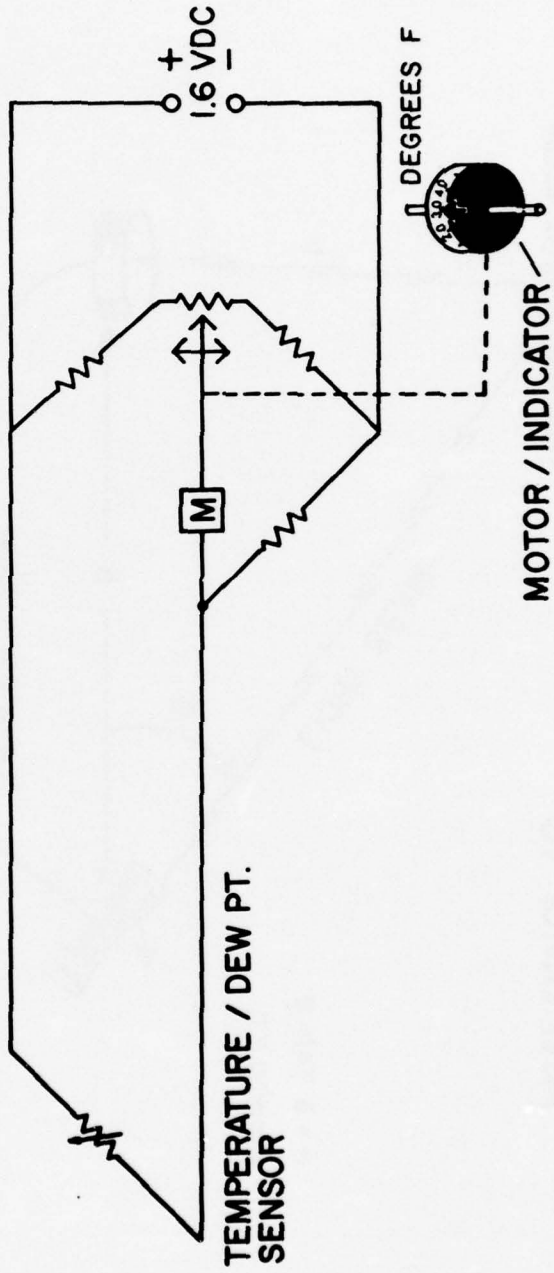
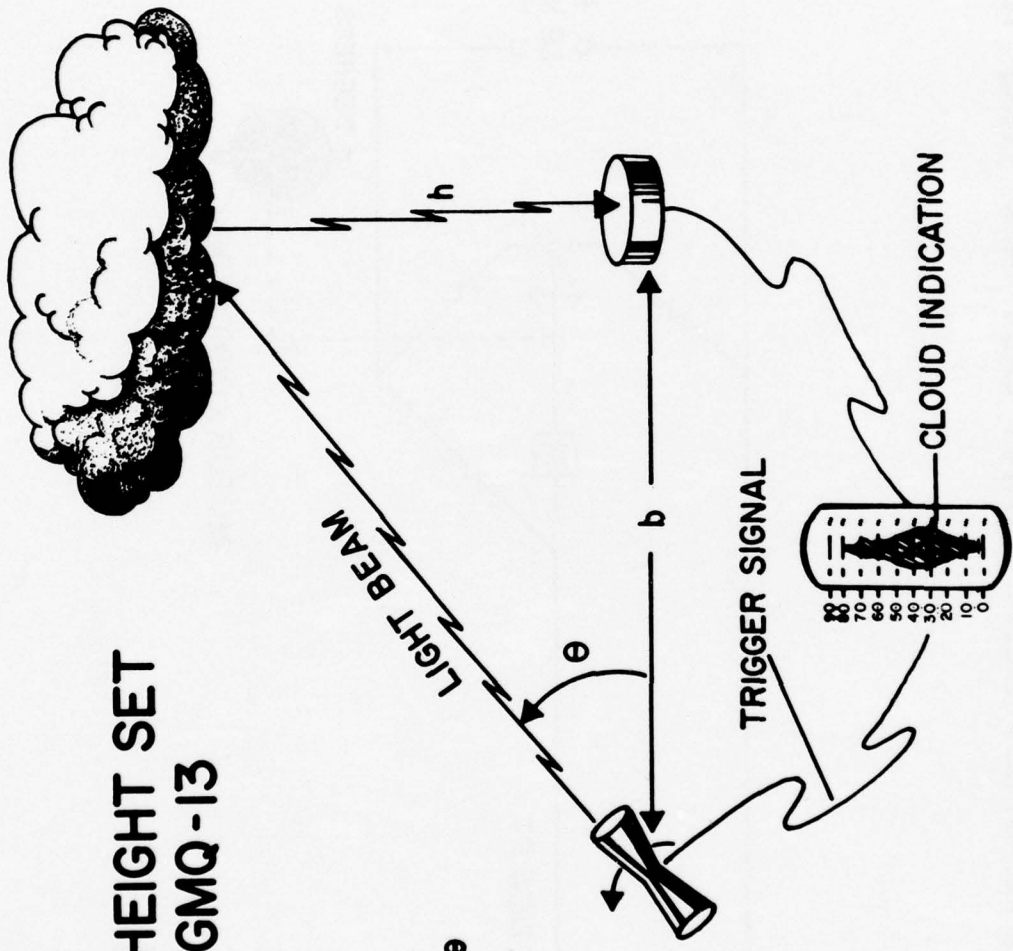


Figure 4

# CLOUD HEIGHT SET AN/GMQ-13



$$h = b \tan \theta$$
$$b \approx 500 \text{ FT.}$$

Figure 5

to cloud height by the formula  $h = b \tan \theta$  where  $h$  = cloud height in feet,  $b$  = baseline in feet. This translation is performed by a human operator who looks up the cloud height in a table.

## 2.5 Deficiencies

- (1) Time Delays: The time lag from the instant a weather sensor detects a change to the instant the key air traffic controller is informed of it (via the electrowriter) can be as great as ten minutes. Dissemination of weather data to the outside world must wait until the ROS observer has punched an accurate paper tape on a teletypewriter.
- (2) Erroneous Data: It is possible for the ROS observer to make mistakes in preparing paper tapes, and the writing on an electrowriter receiver is often illegible (nines are read as zeros, etc.).
- (3) The ROS is expensive to maintain, since it requires sanitary facilities, heat and back-up power.
- (4) The ROS is crowded, since it houses several large indicators. Lack of space makes operation and maintenance difficult.
- (5) Cable Maintenance and Replacement Costs: The meteorological cable connecting sensors and indicators requires frequent trouble-shooting and repair, mainly due to the fact that the cable generally carries analog data. In an analog system, information is contained in the amplitude of the signal, which is highly sensitive to changes in cable parameters.

## 3. APPROACHES TO DIGITIZATION AND DISSEMINATION

### THE RADC FEASIBILITY MODEL

It now appears possible to eliminate most of the present system's shortcomings by performing A/D conversion at each sensor, doing away with the ROS, and installing a control and dissemination unit at the BWS. To examine methods for accomplishing this, the RADC feasibility model was developed.

### 3.1 Control and Processing Unit - Block Diagram Analysis (Figure 6).

The control and Processing unit is built around the INTEL Corporation Intellec 8 microprocessor development system with a model 8080 CPU. A 70-pin cable from the interface card slot of the Intellec 8 connects to the interface card file which houses the logic to accept and condition data from all sensors in the system. The circuitry for each sensor is mounted on its own 4" x 5" card, providing a high degree of modularity at the cost of some extra components. These interface modules receive their data over twisted pairs from the data transmitters collocated with the sensors.

#### 3.1.1 Wind Interface

The wind speed signal appears at the interface module as a delta-sigma modulated bit stream, which can be treated as repetition rate modulation with a maximum frequency of 255 Hz. The interface module counts incoming pulses for one second, then interrupts the processor and sets a flag (one bit of port 9) by raising WSF. The processor reads the accumulated count from port 8, automatically resetting the flag and clearing the count, and the process is allowed to repeat.

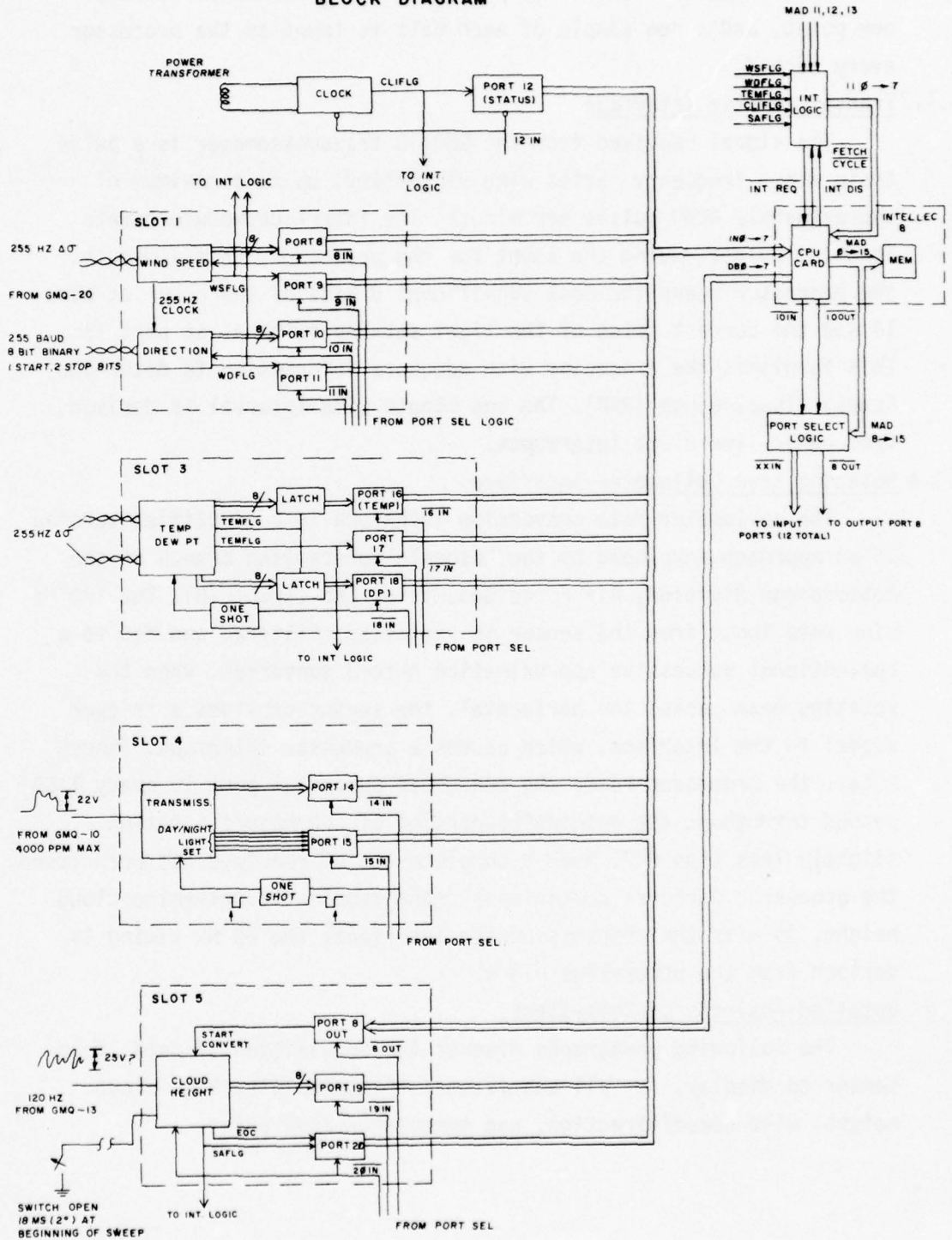
The wind direction signal is a continuous stream of 8 bit binary numbers each representing an instantaneous value of wind direction, each having its own start and stop bits. The data rate is 255 bits per second. Each time the interface module has received a complete 8 bit byte with stop bits, it interrupts the processor and sets one bit of port 11 as status flag by raising WDF. The processor then reads the data byte from port 10, resetting the flag. Thus, the processor receives approximately 25 samples of wind direction data per second.

#### 3.1.2 Temperature/Dew Point Interface

The temperature/dew point signals received are identical to the wind speed signals and are handled in the same way. The repetition

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Fig. 6 - CONTROL & PROCESSING UNIT  
BLOCK DIAGRAM



rate of the signal is directly proportional to the temperature or dew point, and a new sample of each data is input to the processor every second.

### 3.1.3 Transmissometer Interface

The signal received from the GMQ-10 transmissometer is a pulse train whose frequency varies with visibility, up to a maximum of approximately 4000 pulses per minute. The interface module counts incoming pulses, saving the count for the processor. Once a minute, the processor reads the most significant 8 bits of the count at port 14 and the current value of the light setting switches at port 15. This furnishes the processor with adequate information to determine Runway Visual Range (RVR). The one minute time interval is derived from power-line clock interrupts.

### 3.1.4 Rotating Beam Ceilometer Interface

The ceilometer data conversion technique is a simplified version of an approach developed by the Mesocale Forecasting Branch of the Meteorology Division, Air Force Geophysics Lab (AFGL/LYU). The 120 Hz sine wave input from the sensor is rectified, filtered and fed to a conventional successive approximation A-to-D converter. When the rotating beam passes the horizontal, the sensor provides a trigger signal to the interface, which causes a processor interrupt. Thereafter, the processor reads the converter output at port 19 every 1/60 second throughout the meaningful portion of the beam's rotation - slightly less than 90°. When a complete set of readings has been taken, the processor performs comparisons among samples to determine cloud height. As with the transmissometer interface, the 60 Hz timing is derived from the power-line clock.

## 3.2 Detailed Analysis of Subsystems:

The following paragraphs discuss the acquisition of data, from sensor to display, for all subsystems: transmissivity/RVR, cloud height, wind speed/direction, and temperature/dew point.

### 3.2.1 Transmissivity/RVR

Figure 7 is a schematic diagram of the transmissometer interface module. In the feasibility model, no signal conditioning unit is added to the transmissometer. Rather, the signal normally fed to the indicator at the ROS is applied directly to the interface module, where the pulses are clipped and reshaped by Q<sub>1</sub> and U<sub>1</sub>. If necessary or desirable in a future system, Q<sub>1</sub> and U<sub>1</sub> could be collocated with the transmissometer at the other end of the cable and followed by a line driver. Figure 7 shows the pulse at the input to the interface module as it appears on an oscilloscope. U<sub>1</sub>, a non-retriggerable one shot, puts out a 100 ms pulse, insuring against counting an input pulse more than once due to the pronounced overshoot and ringing present. (See figure 8, transmissometer interface timing).

U<sub>2</sub>, U<sub>5</sub> and U<sub>4</sub> form a 12 bit counter, whose most significant 8 bits are fed to the processor's input port 14. Once per minute, the processor reads a byte of data from port 14 by placing a negative-going pulse on the 14IN port select line. The trailing edge of this pulse is fed to a one-shot (U<sub>3</sub>) and used to clear the counters after the port has been read, preparing them to collect pulses for another one minute period. Since the maximum rate is 4000 pulses per minute (indicating maximum visibility), the highest possible count in the most significant 8 bits of the counter will be 250.

S1 through S4 perform the functions of the light setting switches on the FMN-1 computer and the day/night switch in the control tower. It will be seen from the transmissometer software flow chart (figure 9) and the program listing (figure 10) that the processor reads the switches at port 15 every time it reads a byte of visibility data from port 14, and uses the switch setting data to decide which look-up table to get runway visual range (RVR) from. For simplicity, the feasibility model uses 4 look-up tables, corresponding to 4 possible



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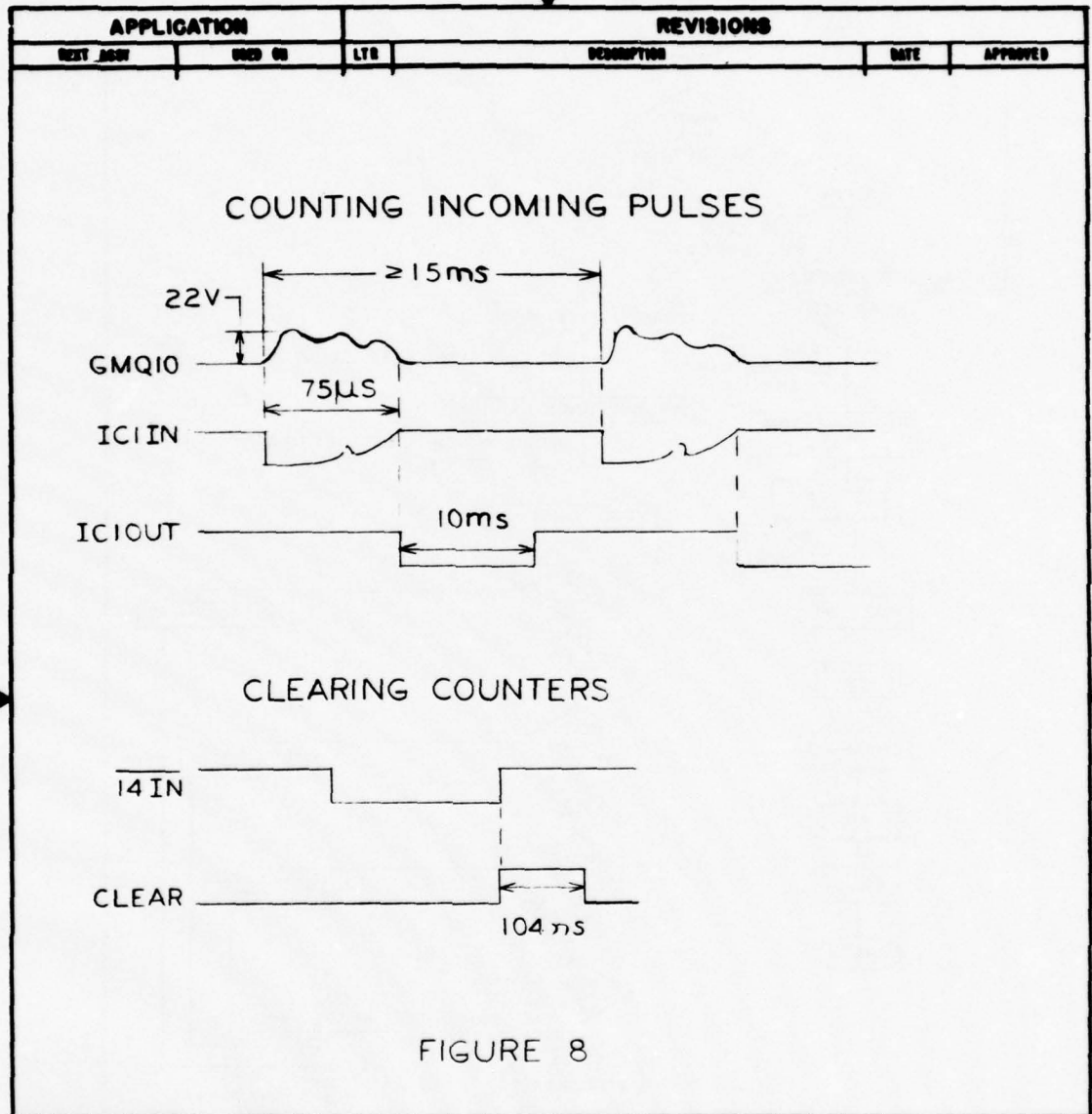
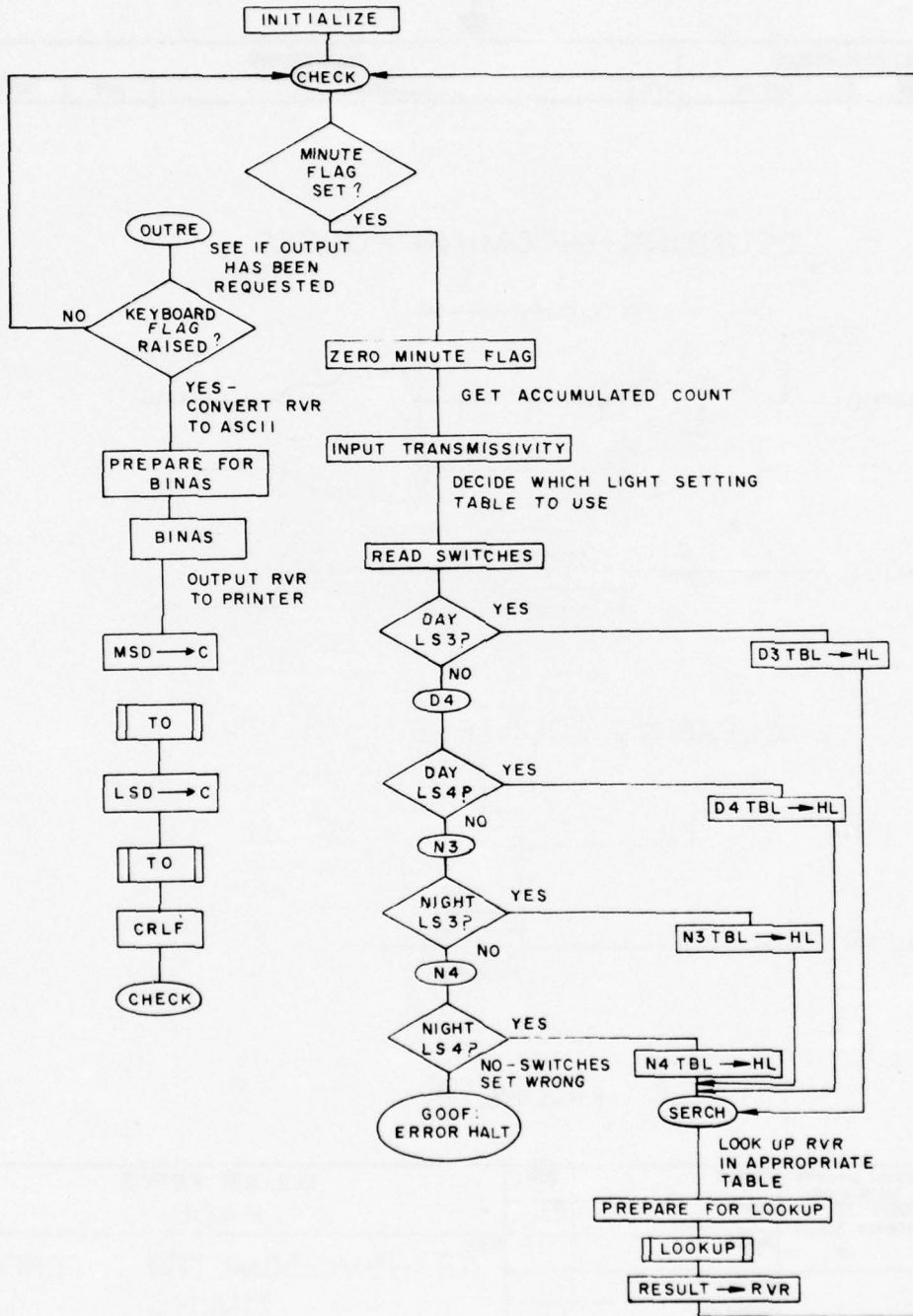


FIGURE 8

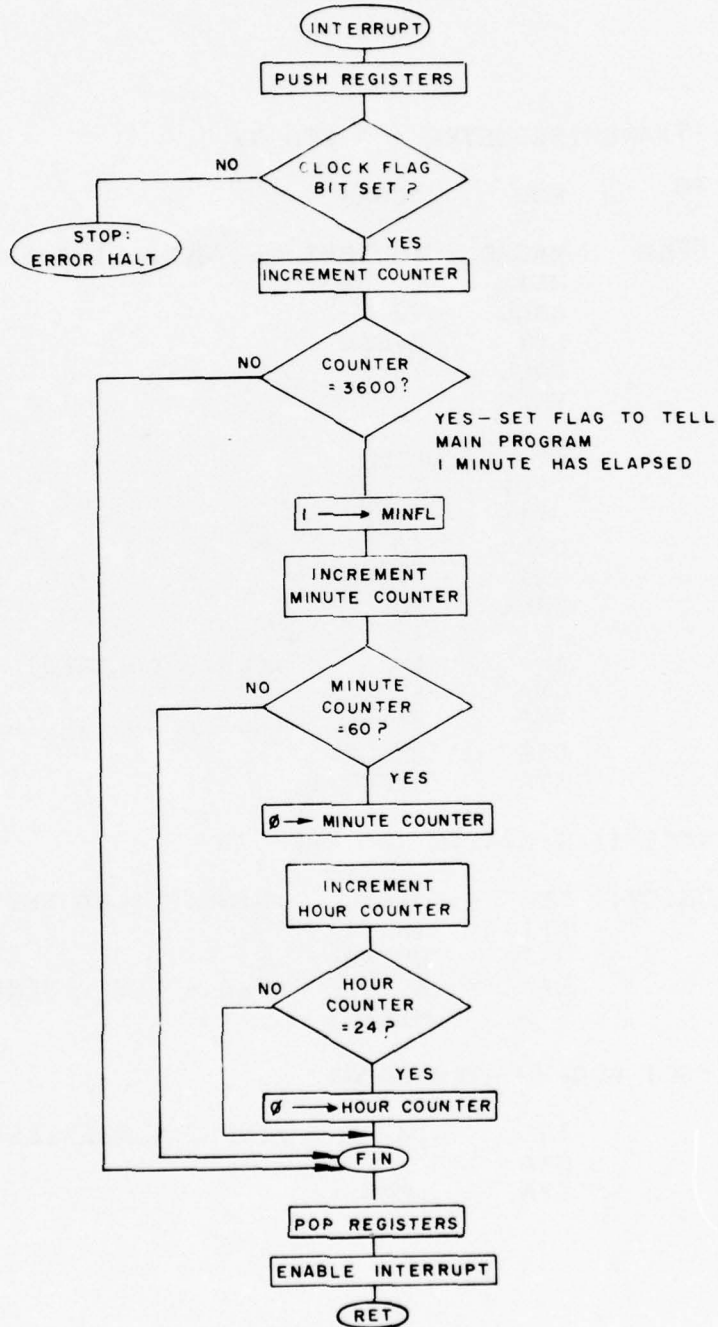
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	A.F. PROJ. ENGR. <i>[Signature]</i>	A.F. DESIGN ACTIVITY AUTHORITY D/L 762206	SIZE <b>A</b>	A.F. CODE IDENT. NO. 07877	DRAWING NO. X762207
	MATERIAL	SCALE	SHEET		

# TRANSMISSOMETER FLOW CHART

Fig. 9



# SERVICE CLOCK PULSE INTERRUPT



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;TRANSMISSOMETER - 3 FEB 76

```

3C3A      TO      EQU      3C3AH

          CRLF     MACRO    ;OUTPUT CAR RET, LINE FEED
          MVI      C,0DH
          CALL     TO
          MVI      C,0AH
          CALL     TO
          ENDM

0000      OTG      400H
          CRLF
0400 0E0D  MVI      C,0DH
0402 CD3A3C CALL     TO
0405 0E0A  MVI      C,0AH
0407 CD3A3C CALL     TO

040A DB0E      IN      14      ;CLEAR COUNTER
040C AF        XRA      A
040D 327300    STA      MINFL    ;CLEAR MINUTE FLAG & COUNTER
0410 327600    STA      BINCT
0413 327700    STA      BINCT+1

;SEE IF 1 MINUTE HAS ELAPSED

0416 3A7300    CHECK:  LDA      MINFL    ;MINUTE FLAG SET?
0419 FE01      CPI      1H
041B C26A04    JNZ     OUTRE
041E AF        XRA      A      ;YES - RESET MINUTE FLAG
041F 327300    STA      MINFL

;GET ACCUMULATED COUNT

0422 DB0E      IN      14      ;INPUT TRANSMISSIVITY
0424 2F        CMA
0425 327800    STA      TRANS
    
```

Figure 10

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;DECIDE WHICH LIGHT SETTING TABLE TO USE

0428	DE0F	IN	15	;READ LIGHT SETTING SWITCHES
042A	FE00	CPI	0H	;DAY LS 3?
042C	C23504	JNZ	D4	
042F	217900	LXI	H,D3TEL	;PREPARE TO SEARCH DAY 3 TABLE
0432	C35704	JMP	SEARCH	
0435	FE01	D4:	CPI	01H ;DAY LS 4?
0437	C24004	JNZ	N3	
043A	217F00	LXI	H,D4TEL	
043D	C35704	JMP	SEARCH	
0440	FE08	N3:	CPI	00H ;NIGHT LS 3?
0442	C24E04	JNZ	N4	
0445	218500	LXI	H,N3TEL	
0448	C35704	JMP	SEARCH	
044E	FE09	N4:	CPI	09H ;NIGHT LS 4?
044D	C25E04	JNZ	GOOF	
0450	C18E00	LXI	H,N4TEL	
0452	C35704	JMP	SEARCH	
0456	76	GOOF:	HLT	;SWITCHES SET WRONG

;LOOK UP RVR IN APPROPRIATE TABLE

0457	3A9700	SEARCH:	LDA	LNQTH	;PREPARE TO LOOK UP RVR
045A	47		MOV	E,A	
045B	3A7800		LDA	TRANS	
045E	119100		LXI	D,OUTLS	
0461	0B9504		CALL	LOOKP	
0464	329300		STA	RVR	
0467	031604		JMP	CHECK	

;SEE IF OUTPUT HAS BEEN REQUESTED

046A	DE01	OUTRE:	IN	1	;OUTPUT REQUEST?
046C	E601		ANI	1H	
046E	C21604		JNZ	CHECK	
0471	DE00		IN	0	;YES - CLEAR TTY FLAG

;CONVERT RVR TO ASCII

0473	3A9800		LDA	RVR	;PREPARE TO CONVERT TO ASCII
0476	219900		LXI	H,BFR	
0479	CDA604		CALL	FINAS	

;OUTPUT RVR TO PRINTER

047C 219A00		LXI	H, BFR+1	;OUTPUT 2 DIGITS
047F 4E		MOV	C, M	
0480 CD3A3C		CALL	TO	
0483 23		INX	H	
0484 4E		MOV	C, M	
0485 CD3A3C		CALL	TO	
		CRLF		
0488 0E0D		MVI	C, 0DH	
048A CD3A3C		CALL	TO	
048D 0E0A		MVI	C, 0AH	
048F CD3A3C		CALL	TO	
0492 C31604		JMP	CHECK	
0495 BE	LOOKP:	CMP	M	;LOOK UP RVR IN TABLE
0496 DAA304		JC	MATCH	
0499 05		DCR	B	
049A C29E04		JNZ	NOTFN	
049D 76		HLT		;NO MATCH FOUND
049E 23	NOTFN:	INX	H	
049F 13		INX	D	
04A0 C39504		JMP	LOOKP	
04A3 EB	MATCH:	XCHG		
04A4 7E		MOV	A, M	
04A5 C9		RET		
04A6 0664	BINAS:	MVI	B, 100	
04A8 CDB604		CALL	DIGIT	
04AB 060A		MVI	B, 10	
04AD CDB604		CALL	DIGIT	
04B0 0601		MVI	B, 1	
04B2 CDB604		CALL	DIGIT	
04B5 C9		RET		
04B6 3630	DIGIT:	MVI	M, 30H	
04B8 90	DI0:	SUB	B	
04B9 DAC004		JC	DI1	
04BC 34		INR	M	
04BD C3B304		JMP	DI0	
04C0 80	DI1:	ADD	B	
04C1 23		INX	H	
04C2 C9		RET		

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## ;SERVICE CLOCK PULSE INTERRUPT

```

0403          ORG      28H      ;COUNT A 60 HZ CLOCK PULSE
0025 C5      PUSH     E        ;ON INTERRUPT
0029 D5      PUSH     D
002A E5      PUSH     H
002E F5      PUSH     PSW
002C DB0C    IN        12
002E F601    ANI      01H      ;CLOCK BIT SET?
0030 C27200  JNZ      STOP      ;NO - CHECK OTHER FLAGS
0033 2A7600  LHLD     BINCT      ;YES - INCR BINARY COUNTER
0036 23      INX      H
0037 227600  SHLD    BINCT
003A 217600  LXI      H,BINCT ;COUNTER = -3600?
003D 7E      MOV      A,M      ;LSE
003E FE10    CPI      10H
0040 C26C00  JNZ      FIN
0043 23      INX      H        ;MSE
0044 7E      MOV      A,M
0045 FE0E    CPI      0EH
0047 C26C00  JNZ      FIN
004A 3600    MVI      M,0H      ;COUNTER = 3600 - 0 COUNTER
004C 2B      DCX      I
004D 3600    MVI      M,0H
004F 217300  LXI      H,MINFL ;MINUTE FLAG
0052 3601    MVI      M,1H
0054 217500  LXI      M,MIN     ;INCR 24 HOUR CLOCK
0057 34      INC     M
0058 7E      MOV      A,M
0059 FE3C    CPI      60        ;MIN = 60?
005B C26C00  JNZ      FIN
005E 3600    MVI      M,0      ;YES - 0 MIN
0060 217400  LXI      H,HOUR
0063 34      INC     H
0064 7E      MOV      A,M
0065 FE18    CPI      24        ;HOUR = 24?
0067 C26C00  JNZ      FIN
006A 3600    MVI      M,0      ;YES - 0 HOUR
006C F1      FIN:    POP     PSW
006D E1      POP     H
006E D1      POP     D
006F C1      POP     E
0070 FB      EI
0071 C9      RET
0072 76      STOP:  HLT

```

0073		MINFL:	DS	1	
0074		HOUR:	DS	1	
0075		MIN:	DS	1	
0076		PINCT:	DS	2	
0073		TRANS:	DS	1	
0079	437598AC	D3TEL:	DE	67,117,152,172,193,250	
007D	C6FA				
007F	2C7598AC	D4TEL:	DE	44,117,152,172,193,250	
0083	C6FA				
0085	05245275	N3TEL:	DE	5,36,82,117,163,250	
0089	A8FA				
008E	03183E5F	N4TEL:	DE	3,24,62,95,143,250	
008F	94FA				
0091	000E1822	OUTLS:	DE	0,14,24,34,50,99	
0095	3263				
0097	06	LNGTH:	DE	6	;LENGTH OF CHECK LIST
0098		RVP:	DS	1	
0099		EFR:	DS	3	
0000		END			

P=

switch settings. Each table has only 6 entries. In an operational system, there would be 6 tables with 20 entries each. The feasibility model processor is programmed to interpret the switch settings according to table 1.

S1	S2	S3	S4	Light Setting	Day/Night
0	0	0	0	3	Day
0	0	0	1	4	Day
1	0	0	0	3	Night
1	0	0	1	4	Night

Table 1, Interpretation of Switch Settings

The one minute time interval for the transmissometer interface module is derived in software from the power line clock of figure 11. The 60 Hz signal on the secondary winding of the system's 12 volt power supply is shaped into a square wave by Q<sub>1</sub> and IC. The leading edge of the square wave sets D flipflop IC 2, raising CLIFLG to interrupt the processor. Upon recognizing the interrupt, the processor reads port 12, which also clears the D flipflop. As shown in the flow chart, figure 9, the processor increments a counter in memory every time it is interrupted by a clock pulse, and sets a "minute flag" when the count has reached 3600, indicating that one minute has elapsed. Similarly, the clock keeps track of real time in hours and minutes. While this feature is not used by the transmissometer routine, it is useful for such purposes as automatically appending real time to messages.

In the absence of interrupts, the main transmissometer routine continuously checks the minute flag and the keyboard flag (discussed below). Upon finding the minute flag set the processor reads the visibility and switch settings from ports 14 and 15, and immediately looks up the RVR in the appropriate table, each 8-bit entry of which



is an actual RVR value, in hundreds of feet. This value is then moved to buffer location "RVR" until it is retrieved for display.

The display used in the feasibility model is the page printer of the teletypewriter console, and output to the printer is initiated by depressing any key on the keyboard, raising the keyboard flag. When the processor finds the keyboard flag set, it retrieves the RVR from the buffer, converts it to ASCII via sub-routine "BINAS" and outputs the results to the printer.

### 3.2.2 Cloud Height

Figure 12 is a schematic diagram of the cloud height interface module. As the ceilometer beam passes the horizontal, the sync switch located in the RBC opens for approximately 18 ms, raising SAF and causing an interrupt, which tells the processor to take a reading from the A/D converter for each of the next 180 real time cloud interrupts. Thereafter, each time a real time clock interrupt occurs the processor provides a "start convert" signal to the A/D converter by outputting a "one" on output port 8, then waits to read the cloud height data until "end of convert" (EOC) is turned on by the converter. After all 180 readings have been taken and saved, the list of readings is examined to find the largest. From its position in the list, cloud height can be obtained by going to a look-up table similar to that used to determine RVR.

### 3.2.3 Wind Speed and Direction

Figure 13 is a schematic diagram of the wind speed and direction transmitter, collocated with the sensor. The RC clock (U 3) provides 225 Hz clock signals for both the speed and direction sections. Due to the clock signal reconstruction technique used at the receiver (figure 14), clock accuracy and stability is not critical. The output of the wind direction sensor (90 volt line-to-line synchro transmitter) is fed to a modular synchro-to-digital converter, the Astrosystems

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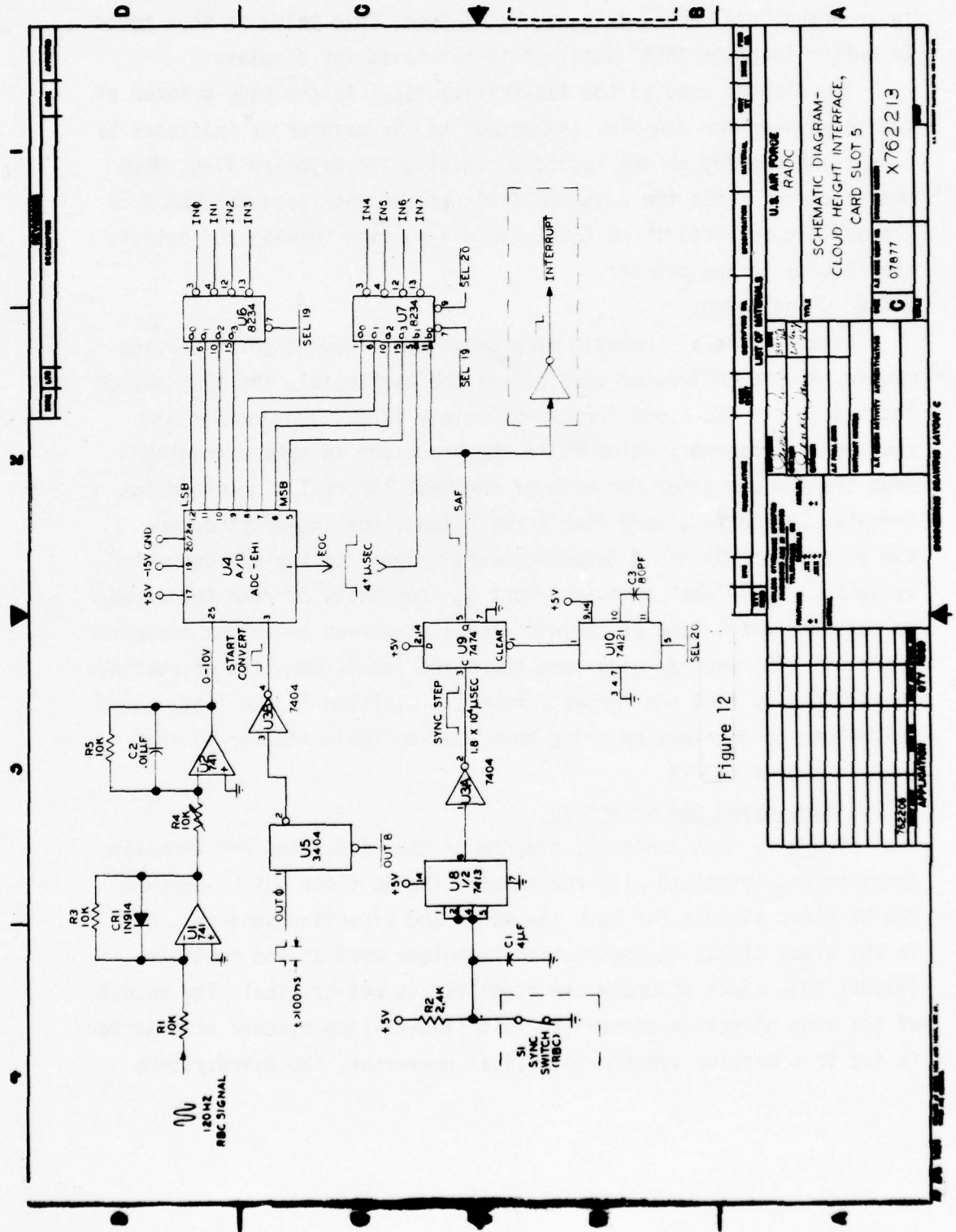
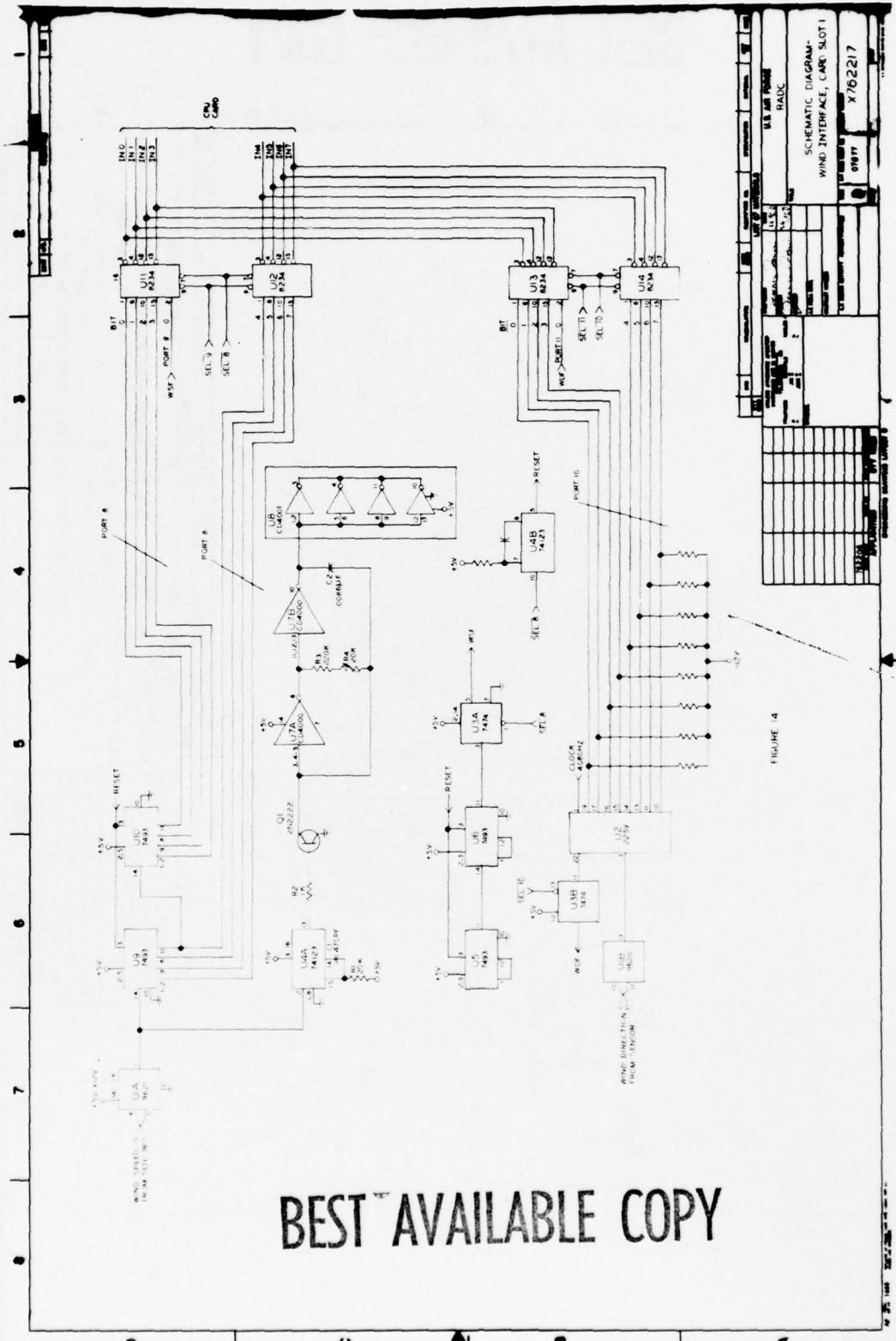


Figure 12

REV	DESCRIPTION	DATE	BY	CHKD	APP'D
1	INITIAL				
2	REVISION				
3	REVISION				
4	REVISION				
5	REVISION				
6	REVISION				
7	REVISION				
8	REVISION				
9	REVISION				
10	REVISION				
11	REVISION				
12	REVISION				
13	REVISION				
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100	REVISION				

U.S. AIR FORCE  
 SCHEMATIC DIAGRAM -  
 CLOUD HEIGHT INTERFACE,  
 CARD SLOT 5  
 X762213





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model M 6000. The parallel binary output of the converter is clocked out serially at a rate of 255 bits per second, with one start and two stop bits added to each reading. Thus there are 11 bits per character, including eight information bits, and approximately 25 characters are transmitted per second. The serial bit stream is fed to the twisted pair transmission line by a Fairchild 9621 differential line driver, and is received at the distant end by a 9620 line receiver. The differential line driver/receiver combination offers excellent protection from noise. The 9620 line receiver is specified to detect a signal of  $\pm 500$  millivolts in the presence of  $\pm$  volts of common mode noise. Since each digital reading consists of eight bits, there are  $2^8 = 256$  counts per shaft revolution, providing an accuracy of about  $\pm 1.5^\circ$ , which is comfortably adequate for this application.

The wind speed converter (figure 15) incorporates a novel concept in digital conversion and transmission - delta sigma modulation. The heart of the delta sigma converter is a dual slope integrator whose inputs are (1) the negative DC voltage from the GMQ-20 tachometer and (2) an internally generated positive reference voltage that is switched in and out periodically. Referring to figure 15, assume that initially the analog switch is open, the output of the integrator is low, and the input and output of the D flipflop are low. Clock pulses are not being gated to the output line. Since the tachometer output is negative the integrator will integrate in the positive direction, charging the capacitor to the polarity shown. When the comparator input passes ground potential, the state of the flipflop output Q changes on the next clock pulse. This has two results: (1) clock pulses will be gated to the line driver until the flipflop changes state again, (2) the reference voltage is switched into the integrator, causing it to integrate in the negative direction. When the input to the comparator goes negative, the gate to the line driver is closed, the reference



voltage is switched out, and the process repeats itself.

Consider a length of time T that is quite long relative to the time constants  $R_1C$  and  $R_2XC$ . Define  $N_c$  to be the number of clock pulses that occur in time T and  $N_D$  to be the number of clock pulses that are gated out as data during time T. (In time T, the flipflop goes through many on-off cycles. It turns out that

$$\frac{N_D}{N_c} = \frac{R_2xV_{tach}}{R_1xV_{ref}}$$

In fact, component values are calculated so that  $V_{ref}xR_1 = V_{full\ scale}$  and

$$N_D = \frac{V_{tach}}{V_{full\ scale}}$$

There are apparent sources of error. However, one of the strengths of delta sigma modulation is that most of these errors can be eliminated or, in fact, tend to cancel themselves out. Although

$$\frac{N_D}{N_c} \quad \text{depends}$$

on the values of  $R_1$  and  $R_2$ , note that

$$\frac{N_D}{N_c} \quad \text{is actually proportional}$$

to the ratio  $\frac{R_2}{R_1}$ . It is reasonable to expect that a 5% change in the

resistance of  $R_2$  brought about by environmental conditions would be accompanied by a like change in the value of  $R_1$ . Notice that the value of the capacitor is a "don't care" since it does not appear in the equation for  $\frac{N_D}{N_c}$

IC 2 of figure 13 is a Hybrid Systems DV 612, which contains all of the circuitry shown in figure 15 except C. In the receiving unit (figure 14) wind speed pulses are counted for a 1 second period similar to the transmissometer interface. However, the clock (IC 7) is synchronized by the incoming wind speed signal, eliminating the need for great accuracy and stability. the timing counter chain (U's 3,5,6)

(U's 3, 5, 6) interrupts the processor at every 256th clock pulse, and the processor reads a new byte of wind speed data.

The wind direction samples are received and serial-to-parallel converted by U 2, the Motorola Me 2259 terminal receiver (essentially the receiving half of a UART). The processor is interrupted to read a byte of data 25 times per second, every time a complete byte with stop bits has been received.

#### 3.2.4 Temperature/Dew Point

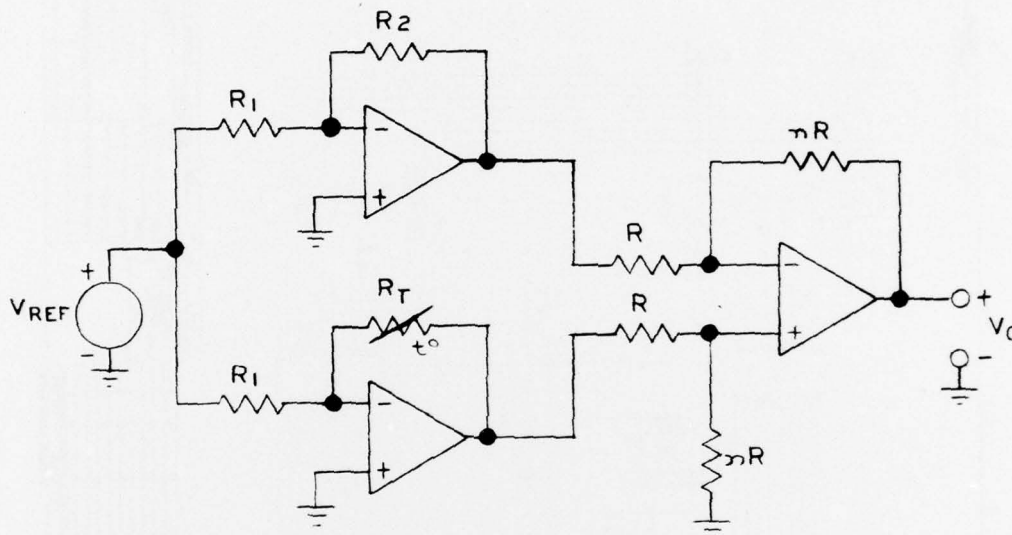
The temperature/dew point interface unit shown in figure 16 will not be discussed in detail, since it is very similar to the wind speed interface. However, the converter shown in figure 17, colocated with the sensor, bears some discussion. An effort was made to digitize the output of the TMQ-11 sensor, with unfavorable results. The temperature sensing thermistor in the TMQ-11 varies from 77.6 ohms to 119.6 ohms as temperature varies from  $-80^{\circ}\text{F}$  to  $130^{\circ}\text{F}$ . This is a change of 42 ohms for a temperature range of  $210^{\circ}\text{F}$ , or .2 ohms per degree F. One way to get a signal out of the sensor is to drive a constant current through it so that the voltage across the thermistor varies in proportion to its resistance. However, the current must be kept small to prevent heating of the thermistor. If a constant current of 5 ma is used, the output signal will swing  $5 \times 42 = 210$  millivolts over the temperature range of interest. To drive a delta sigma modulator or any other reasonable modulation scheme with any degree of accuracy requires an input signal swing of a few volts. To get a signal of 5 volts, we would need an amplifier with a gain of  $5 \text{ volts} / 210 \text{ millivolts} = 24$ .

Designing such an amplifier with sufficient accuracy would be extremely difficult, if not impossible. While it might be possible to digitize the output of the TMQ-11, the system would be expensive, inaccurate, and difficult to calibrate.



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APPLICATION			REVISIONS		
NEXT ASST	USED ON	LTR	DESCRIPTION	DATE	APPROVED



$$V_0 = -n \frac{V_{REF}}{R_1} [R_2 - R_T]$$

$R_T$  = LINEAR THERMISTOR

IF  $R_2$  = MAXIMUM VALUE OF  $R_T$ :

$$V_0 = n \frac{V_{REF}}{R_1} \Delta R_T$$

FIGURE 17

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON FRACTIONS DECIMALS ANGLES $\pm .XX \pm$ $\pm$ $\pm$ $\pm .XXX \pm$	REVISIONS DATE ENGINEER A.E. PROJ. ENGR. CONTRACT NO. A.E. DESIGN ACTIVITY AUTHENTICATION D/L 762206	<b>U.S. AIR FORCE</b> <b>RADC</b>  <b>SCHEMATIC DIAGRAM -</b> <b>BRIDGE SURROGATE CIRCUIT</b>
MATERIAL	SIZE <b>A</b>	A.E. CODE IDENT. NO. 07877
	SCALE	DRAWING NO. <b>X762208</b>
		SHEET

AF FORM 1652 SEP 63

PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE.

ENGINEERING DRAWING LAYOUT A VERTICAL

A better approach appears to be replacement of the TMQ-11 or replacement of the sensing elements in the TMQ-11. A likely replacement for the TMQ-11 is the temperature/dew point sensor designed by National Weather Service for their Remote Automated Meteorological Observation Station (RAMOS). The RAMOS sensor uses sensing elements from Yellow Springs Instrument Company - linear thermistors with a resistance change in the neighborhood of 130 ohms per degree C. A sensor of this type can be made part of a bridge-surrogate circuit\* as in figure 17.

An operating model that we built is shown in figure 18. The purpose of the forward-biased IN 914 diodes is to provide a  $V_{ref}$  of 2 diode drops, about 1.4 volts. This circuit, which proved to be extremely accurate, could be used with the component values shown for either the temperature or the dew point thermistor. The output is fed to a delta-sigma modulator for transmission to the temperature/dew point interface unit.

#### 4. CONCLUSIONS

The goals of automation, as addressed in this study, are twofold: first, to improve efficiency and reliability through automatic dissemination and display; second, to save development costs by retaining the existing sensors while reducing cable maintenance expense by replacing the existing cables. The results of the study indicate that the first of these goals can be completely met, while the second can be only partially achieved.

The most promising aspect of the automation effort is the processing, dissemination and display of data after it is digitized. A computer is good at performing easily defined tasks such as averaging a group of data samples, transcribing digital data into a format, and transmitting a message when queried. A microprocessor can perform all

\* For a detailed description of bridge-surrogate circuits, see Chapter VII of (8).

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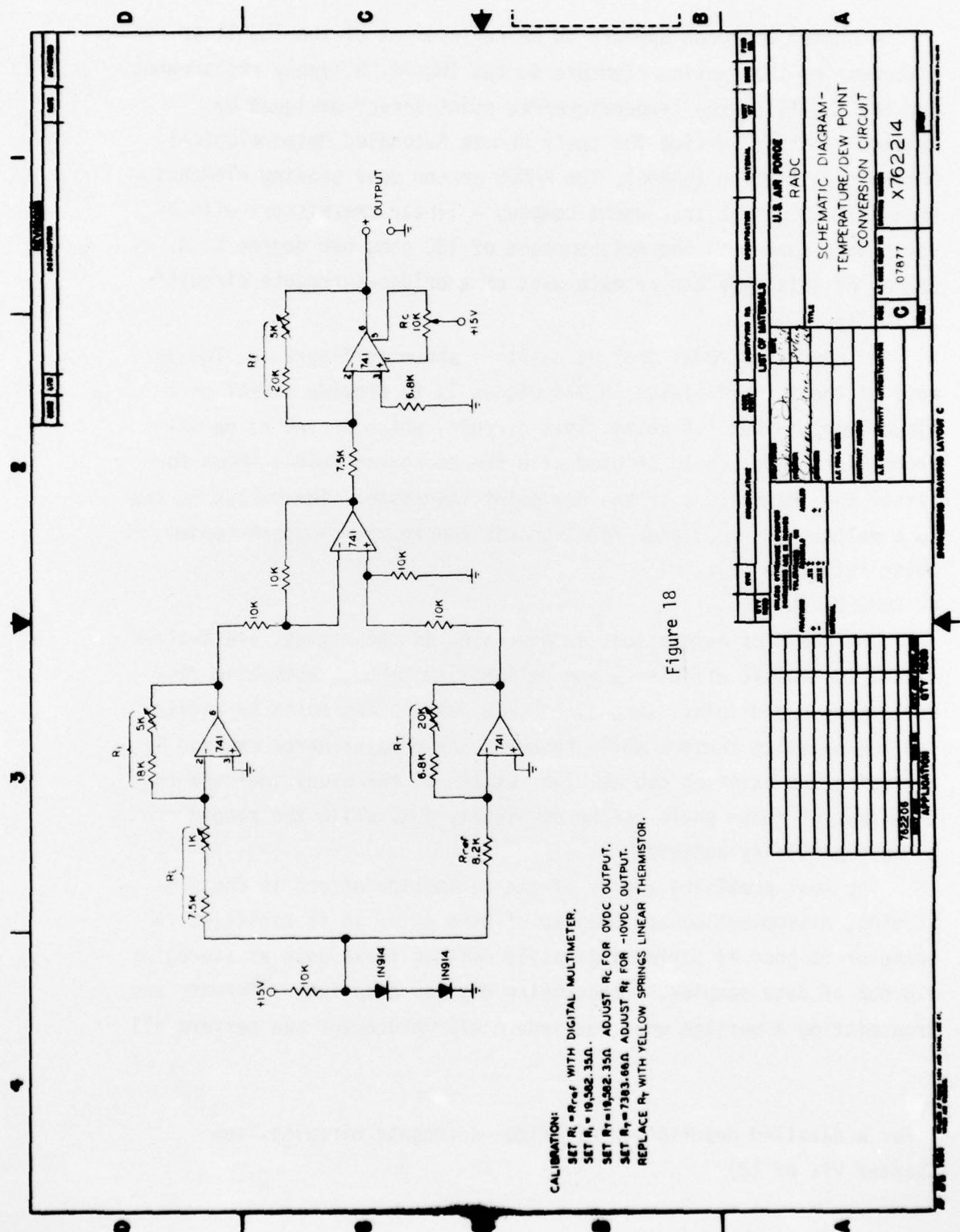


Figure 18

DATE	REV	DESCRIPTION	DESIGNED BY	CHECKED BY	DATE
LIST OF MATERIALS					
U.S. AIR FORCE RADC					
SCHEMATIC DIAGRAM - TEMPERATURE/DEW POINT CONVERSION CIRCUIT					
U.S. AIR FORCE				07877	
X762214				C	
PROCESSING DRAWING LAYOUT C					
APPLICATION					

all of these roles.

Digitizing the signal at the sensor to retain the existing sensor and permit replacement of cables was more successful with some sensors than others. In the instances where digitization at the sensor does not appear promising, it is generally because the existing sensor can not be functionally isolated from the existing indicator.

Sensors that fall into this category are the AN/GMQ-13 Rotating Beam Ceilometer, the AN/TMQ-11 Temperature/Dew Point Sensor, and the wind direction segment of the AN/GMQ-20 Wind Instrument. There doesn't appear to be any convenient way to digitize the RBC detector output signal at the sensor, because the digitization process requires timing from the computer (see para 3.2.2). It does not appear practical to digitize the output of the AN/TMQ-11 sensing unit, primarily because the sensing elements resistance variation over the temperature range is inadequate. A better approach would be adoption of a new sensor such as that used in the National Weather Service's RAMOS system (see para 3.2.4). The synchro-to-digital conversion technique used for the wind direction portion of the AN/GMQ-20 was partially successful, in that the signal produced by the wind direction converter can be transmitted over any type of cable. However, synchro-to-digital converters are fairly costly (\$300-400), and are normally specified for operation over commercial temperature range, necessitating some sort of temperature control for this application.

For sensors that can be functionally isolated from their indicators, digitization at the sensor seems feasible. Sensors of this type are the transmissometer and the wind speed segment of the AN/GMQ-20. Replacement of the transmissometers cable could be made possible quite easily by moving two or three components of the transmissometer interface out to the transmissometer as discussed in para 3.2.1. The wind speed sensor presents no special problems, since the

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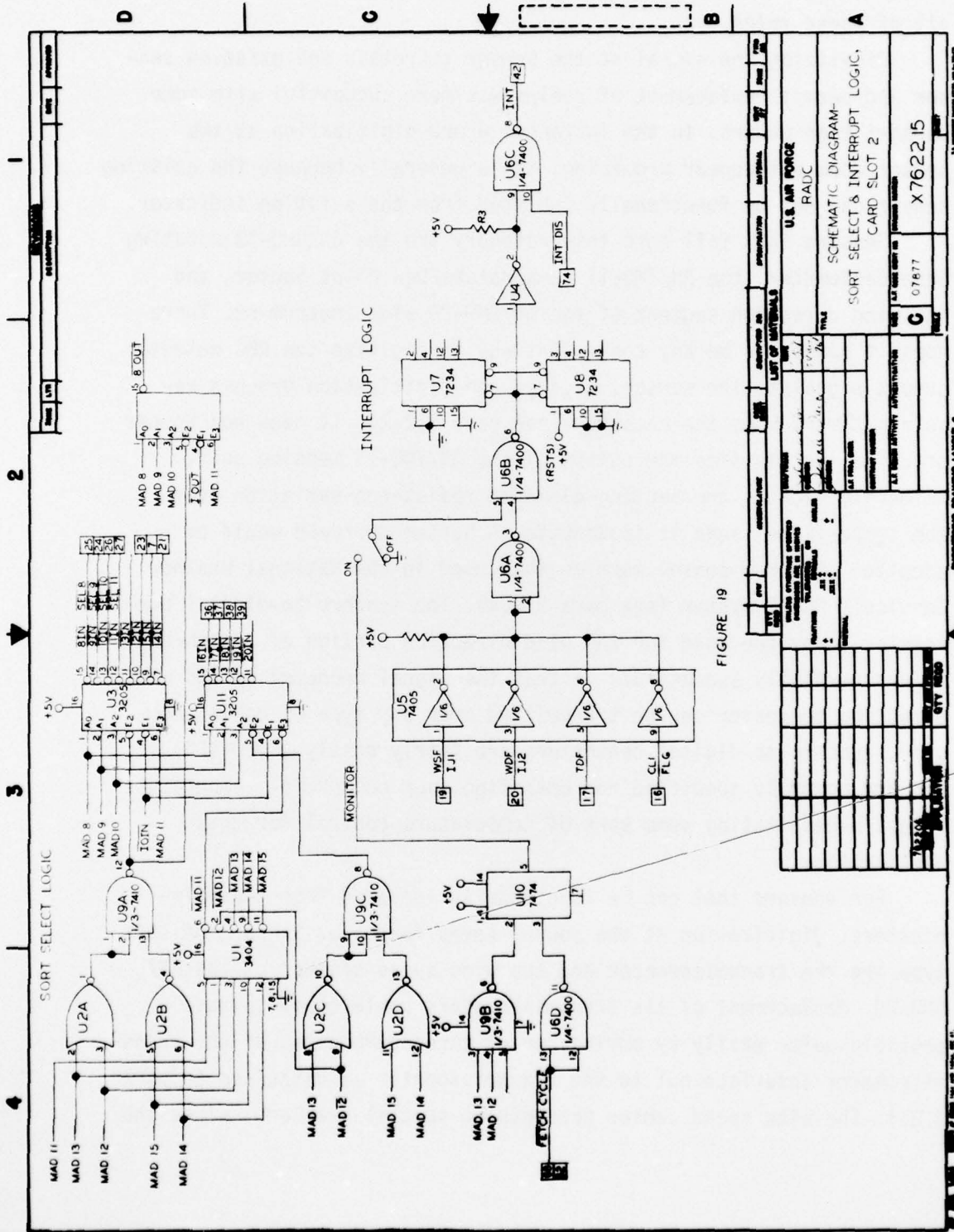


FIGURE 19

wind speed converter colocated with the sensor is simple and inexpensive, and its delta-sigma modulated output signal can be transmitted over any type of cable.

Perhaps the portion of the effort that shows the greatest promise of success is the elimination of the AN/FMN-1 Computer. The description of the transmissivity/RVR subsystem in para 3.2.1 shows that a microprocessor and a small amount of memory can do the job of the AN/FMN-1. In fact, this is a text-book microprocessor application that should result in significant cost savings.

The results of this study indicate that an automated, microprocessor-based system is feasible, and would provide major improvements, particularly in the area of dissemination and display. While it appears that some of the existing sensors could be made part of an automated system, the questions of whether to replace sensors or buy or develop new ones should be referred to AFGL/LYU, where these questions are being investigated further.

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## METRIC SYSTEM

### BASE UNITS:

Quantity	Unit	SI Symbol	Formula
length	metre	m	...
mass	kilogram	kg	...
time	second	s	...
electric current	ampere	A	...
thermodynamic temperature	kelvin	K	...
amount of substance	mole	mol	...
luminous intensity	candela	cd	...

### SUPPLEMENTARY UNITS:

plane angle	radian	rad	...
solid angle	steradian	sr	...

### DERIVED UNITS:

Acceleration	metre per second squared	...	m/s
activity (of a radioactive source)	disintegration per second	...	(disintegration)/s
angular acceleration	radian per second squared	...	rad/s
angular velocity	radian per second	...	rad/s
area	square metre	...	m
density	kilogram per cubic metre	...	kg/m
electric capacitance	farad	F	A·s/V
electrical conductance	siemens	S	A/V
electric field strength	volt per metre	...	V/m
electric inductance	henry	H	V·s/A
electric potential difference	volt	V	W/A
electric resistance	ohm	...	V/A
electromotive force	volt	V	W/A
energy	joule	J	N·m
entropy	joule per kelvin	...	J/K
force	newton	N	kg·m/s
frequency	hertz	Hz	(cycle)/s
illuminance	lux	lx	lm/m
luminance	candela per square metre	...	cd/m
luminous flux	lumen	lm	cd·sr
magnetic field strength	ampere per metre	...	A/m
magnetic flux	weber	Wb	V·s
magnetic flux density	tesla	T	Wb/m
magnetomotive force	ampere	A	...
power	watt	W	J/s
pressure	pascal	Pa	N/m
quantity of electricity	coulomb	C	A·s
quantity of heat	joule	J	N·m
radiant intensity	watt per steradian	...	W/sr
specific heat	joule per kilogram-kelvin	...	J/kg·K
stress	pascal	Pa	N/m
thermal conductivity	watt per metre-kelvin	...	W/m·K
velocity	metre per second	...	m/s
viscosity, dynamic	pascal-second	...	Pa·s
viscosity, kinematic	square metre per second	...	m/s
voltage	volt	V	W/A
volume	cubic metre	...	m
wavenumber	reciprocal metre	...	(wave)/m
work	joule	J	N·m

### SI PREFIXES:

Multiplication Factors	Prefix	SI Symbol
1 000 000 000 000 = 10 <sup>12</sup>	tera	T
1 000 000 000 = 10 <sup>9</sup>	giga	G
1 000 000 = 10 <sup>6</sup>	mega	M
1 000 = 10 <sup>3</sup>	kilo	k
100 = 10 <sup>2</sup>	hecto*	h
10 = 10 <sup>1</sup>	deka*	da
0.1 = 10 <sup>-1</sup>	deci*	d
0.01 = 10 <sup>-2</sup>	centi*	c
0.001 = 10 <sup>-3</sup>	milli	m
0.000 001 = 10 <sup>-6</sup>	micro	μ
0.000 000 001 = 10 <sup>-9</sup>	nano	n
0.000 000 000 001 = 10 <sup>-12</sup>	pico	p
0.000 000 000 000 001 = 10 <sup>-15</sup>	femto	f
0.000 000 000 000 000 001 = 10 <sup>-18</sup>	atto	a

\* To be avoided where possible.

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