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An indigenous design of Integrated Automated Current Weather Instruments System (IACWIS) for aeronautical meteorological observations

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सार – भारत में विमानन उपयोग की चरघातांकी वृद्धि के मद्देनजर वैज्ञानिक मौसम उपकरणों के आधुनिकीकरण की तत्काल आवश्यकता है। आधुनिकीकरण के एक भाग के रूप में शोधकर्ताओं द्वारा हवाई जहाज के उतरने के क्षेत्र में पवन की दिशा और गति, तापमान और ओसांक का नियमित मॉनीटरन करने के लिए एकीकृत स्वचालित तात्कालिक मौसम उपकरण प्रणाली (आई. ए. सी. डब्ल्यू. आई. एस.) के अभिकल्पन और उसका विकास करने का प्रयास किया गया है। चूँकि यह प्रणाली अंकीय है अतः यह पवन की दिशा और गति के लिए वेक्टर औसतन आँकड़ों के अभिग्रहण तथा आगे और विश्लेषण आदि के लिए सुविधाजनक है। इस प्रणाली के सफल फील्ड परीक्षणों के उपरांत इसे देश के सात अंर्तराष्ट्रीय हवाई अड्डों (बेंगलुरू, कालीकट, दीव, हैदराबाद, लखनऊ, नागपुर और नई दिल्ली) में लगाया गया है। यह प्रणाली अंर्तराष्ट्रीय नागर विमानन संगठन (आई. सी. ए. ओ. 2004) की अपेक्षाओं और विश्व मौसम विज्ञान संगठन (डब्ल्यू. एम. ओ. 1992) द्वारा स्वीकृत पवन आँकड़ों और वेक्टर औसतन के अनुरूप प्रचालनात्मक रूप से सटीक है। इस शोध पत्र में प्रणाली की अभिकल्पन क्षमताओं और उसमें विस्तार की संभावनाओं को प्रस्तुत किया गया है।

ABSTRACT. There is an urgent need for modernisation of aeronautical meteorological instruments considering the exponential growth of aviation industry in India. As a part of modernization, an attempt has been made by the authors to design and develop an Integrated Automated Current Weather Instruments System (IACWIS) for the continuous monitoring of wind direction and speed, temperature and dew point at the touchdown zone of the runway. This system being digital has a lot of advantages such as vector averaging for wind direction and wind speed, data archival and amenable for further analysis etc. The system after successful field trials has been installed at seven international airports in the country (Bangalore, Calicut, Diu, Hyderabad, Lucknow, Nagpur and New Delhi). The system meets the operationally desirable accuracy requirements of International Civil Aviation Organisation (ICAO, 2004) and vector averaging of wind data as recommended by World Meteorological Organisation (WMO, 1992). The system design capabilities and scope for expansion have been presented in this paper.

Key words − IACWIS, ICAO, WMO, Sensors, Aviation.

1. Introduction

The most basic requirements in the field of aviation meteorology are the availability of reliable and representative observations at aerodromes. Essential data for take-off and landing are wind direction, wind speed, RVR, visibility, cloud ceiling height, temperature, dew point and pressure. The existing analog Current Weather Instruments Systems (CWIS) functioning at various airports suffer from multiple drawbacks such as the need for many multiple core cables for transmission of the analog signal and greater time consuming routines for the operation, maintenance and calibration of such a system.

Scalar averaging in widely fluctuating winds results in errors due to skewed direction distribution. As the wind is a vector, a vector-averaging technique should be used to report two and ten-minutes averages at aerodrome meteorological stations (AMS) and aerodrome meteorological offices (AMO). Vector-averaging is possible by digital processing of wind data. This paper is an attempt to provide insight of an integrated automated current weather instruments system (IACWIS) for the continuous monitoring of wind direction, wind speed, temperature and dew point at the touch down zone of the runway. IACWIS requires only few cores of cable for its operation and does not require frequent maintenance.

TABLE 1

Advantages of IACWIS over conventional analog CWIS

Properties	Analog systems	IACWIS
Data transmission	Multi core cable required to transmit the data from field to met briefing room	Only 4 cores in the cable are required to transmit the data
Wind averaging	Scalar averaging resulting in probable error	Vector averaging representing reliable mean values
Linearity	Lot of analog hardwares required to eliminate nonlinear characteristics of the sensor in the desired range.	It is easy to linearise the non linear characteristics at any range through software modification
Data validation	No accuracy in the validation due to subjectivity	Accurate and easy methods of data validation through software
External interference	All external interferences affect the data quality	Data quality is not affected by the external interference
Hygroclip (combined sensor)	No provision to use hygroclip	Provision to use hygroclip, thermistor and dew cell
Units of wind speed	Extra hardware is required to display wind speed in desired units	Provision to select different units of wind speed such as knots, mps and kmph
Hard copy	Strip chart recorders are required for data storage	Graphical print outs can be obtained using low cost dot matrix printer
Data storage	No long term data storage	Long term data storage by interfacing a PC
Slave display	Only two or three slave displays are allowed to connect the system	Maximum 31 slave displays can be interfaced with the systems at different locations

These digital systems also have inbuilt lightning surge dissipators. The relative merits of IACWIS over CWIS have been tabulated in Table 1.

Authors have designed and developed an IACWIS at the Electronics laboratory of Deputy Director General of Meteorology (Surface Instruments), India Meteorological Department, Pune. The system after successful field trials has been installed at seven international airports in the country (Bangalore, Calicut, Diu, Hyderabad, Lucknow, Nagpur and New Delhi). Fig. 1 shows the locations of CWIS and IACWIS. IACWIS meets the accuracy requirement of International Civil Aviation Organisation (ICAO, 2004) and vector averaging of wind data recommended by World Meteorological Organisation (WMO, 1992)

2. System description

The complete system of IACWIS consists of the following major sub-systems as shown in Fig. 2. The main units are field units and Indoor units.

Field units comprises (*i*) sensors (*ii*) signal conditioner unit (*iii*) data digitizer and (*iv*) cable modem or radio modem (transmit) and the Indoor units consists of (*i*) cable modem (receive), (*ii*) data acquisition system, (*iii*) digital displays, (*iv*) printers and (*v*) personal computer or work stations.

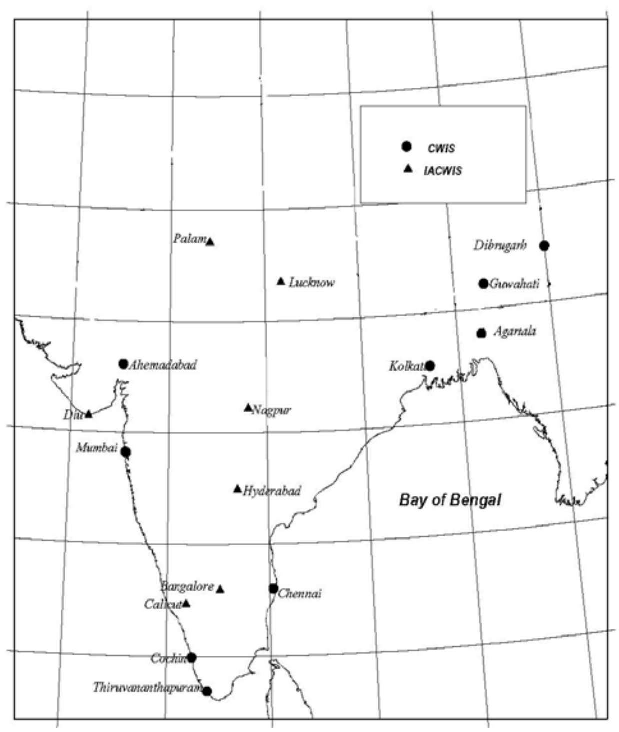


Fig. 1. Location of Current Weather Instruments System (CWIS) and Integrated Automated CWIS (IACWIS) in India

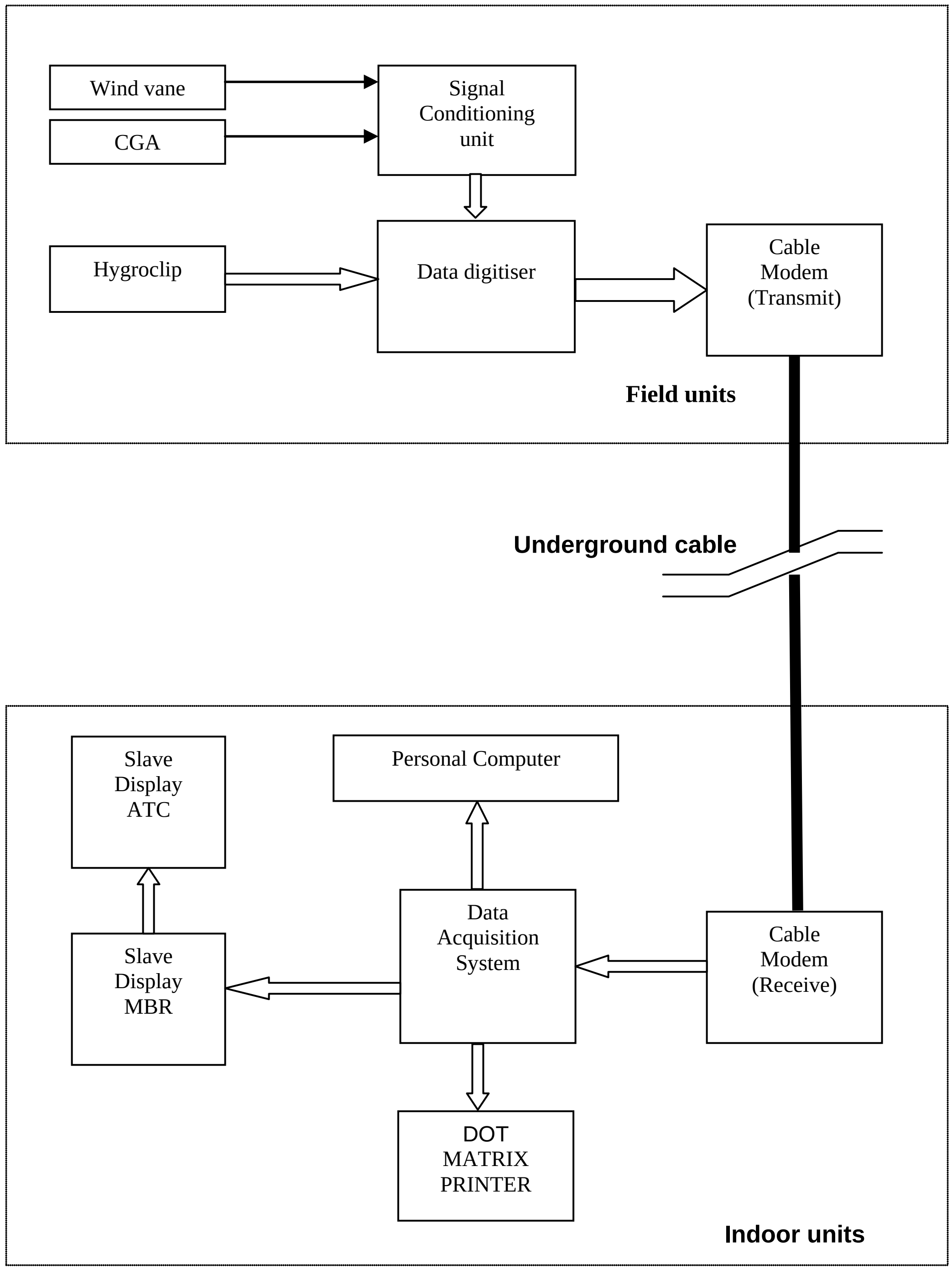


Fig. 2. Complete system of IACWIS

2.1. *Sensors*

In IACWIS sensors with different output forms can be interfaced. In the present system the sensors utilized are (a) Potentiometric wind vane for wind direction (b) Cup generator anemometer for wind speed and (c) Hygroclip for both temperature and humidity. The first two are IMD make sensors. Hygroclip (Rotronics make) is a combined sensor used for temperature and humidity measurement in all the seven IACWIS stations.

Potentiometric wind vane – The sensor used for measurement of wind direction is an IMD-make potentiometric wind vane. The potentiometer in the wind

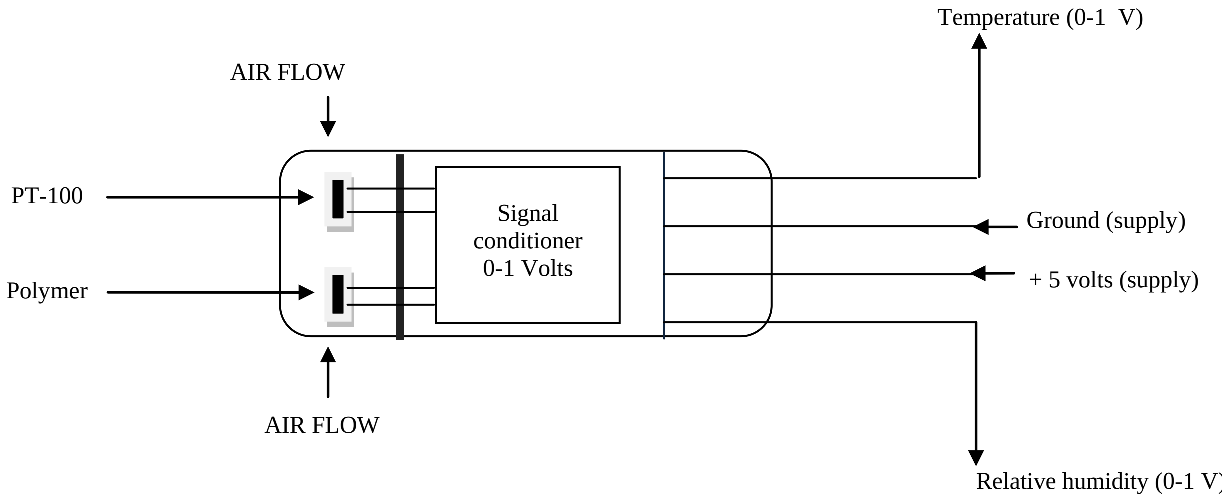


Fig. 3. Schematic diagram of Hygroclip

vane is a servo-micro torque potentiometer and has a maximum resistance of 10 kilo-ohms (KΩ) over an end gap of about 4 degrees. The potentiometer is coupled to the wind vane shaft so as to give a resistance output increasing linearly with the increasing of wind direction. Thus 0 KΩ corresponding to the north, 2.5 KΩ for east, 5 KΩ for south, 7.5 KΩ for west and the variation of 0-360 degree corresponds to 0 to 10 KΩ.

Cup generator anemometer − The sensor used for wind speed measurement is the IMD make three-cup anemometer. The sensor is basically an alternating voltage generator using six pole magnets as the rotor and a suitable stator coil winding. The frame carrying the three cups spaced at 120° rotates the anemometer rotor shaft with the wind, thereby inducing alternating voltage in the stator coils. The frequency of the alternating voltage output of the anemometer can be calculated using the relation:

$$F = (N \times P)/120$$

Where N – No. of revolutions/minute (r.p.m)
P – No. of poles of magnets

The r.m.s value of AC voltage generated can be calculated by using the equation derived from Farday's law of electromagnetic induction:

$V_{r.m.s} = n \times S \times H \times \sqrt{2} \times \pi \times F$, where n is the number of turns in the stator coil, S is its area of cross section and H is the flux density of the magnet.

The rpm values of the AC voltage at the output of the anemometer vary linearly with wind speed over a range of 0-100 knots. The r.p.m *versus* wind speed and output voltage *versus* r.p.m are linearly related. The output of anemometer at different wind speed have been tabulated below:

Wind speed (knots)	10	20	30	40	50	60	70	80	90	100
CGA output in r.m.s value of ac	0.82	1.84	2.83	3.80	4.77	5.72	6.69	7.60	8.74	9.67

Hygroclip − Hygroclip is a combined sensor for both temperature and relative humidity. The basic sensor for relative humidity is a thin polymer, which is having the property to absorb moisture from the air and changes its electrical permittivity in proportion to the relative humidity. The polymer is placed between the parallel plate capacitor as a dielectric. The basic sensor for the temperature is Pt-100 whose resistance is 100 ohms at 0°C. and the resistance increases linearly with the increase in temperature. Hygroclip requires 5 V DC power at field. It has a measuring range of 0-100% for relative humidity and -40° C to + 60° C for temperature. Its output is 0-1 volts DC. The output voltages of Hygroclip at different temperatures and relative humidity have been tabulated below:

Temperature (°C)	*Output Voltage (mv)*	*Relative humidity(%)*	*Output Voltage (mv)*
-40	0	0	0
-20	200	20	200
+20	600	40	400
+40	800	60	600
+50	900	80	800
+60	1000	90	900

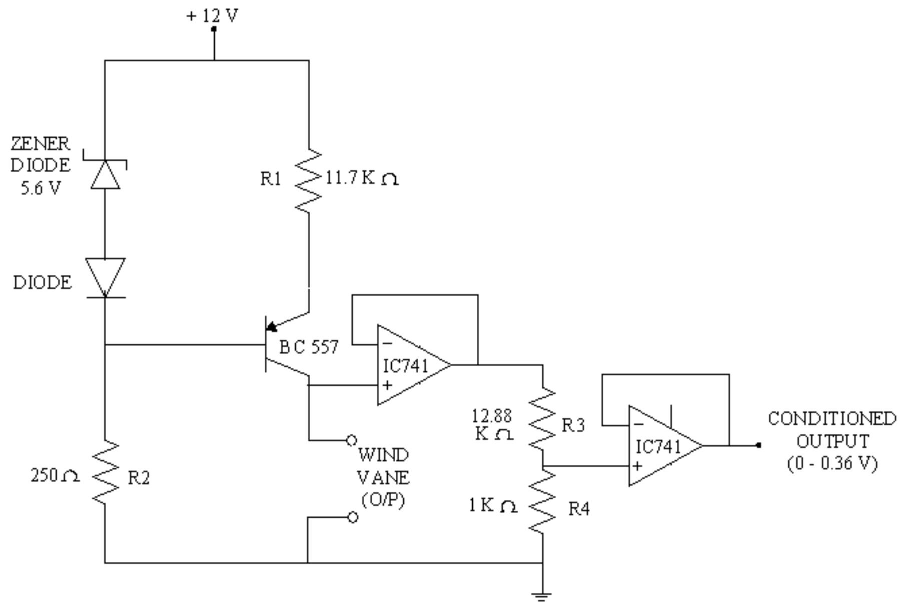


Fig. 4. Signal conditioner for wind direction

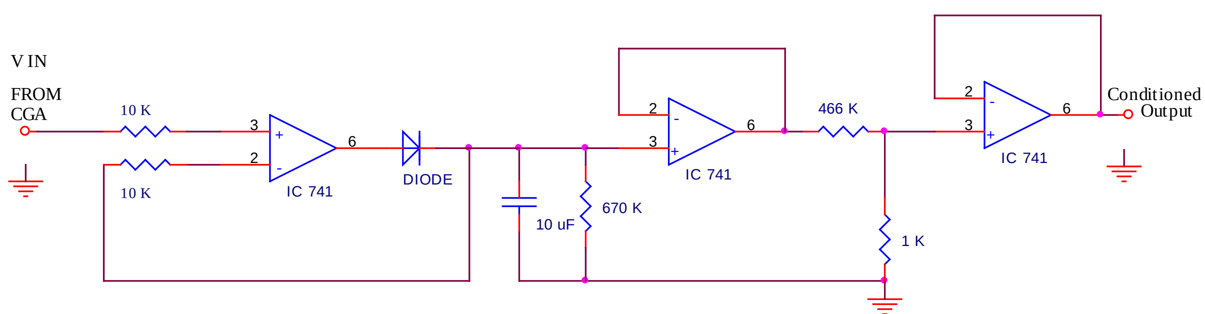


Fig. 5. Signal conditioner for wind speed

Dew point can be calculated by using the following formula for 1000 hPa level stations (WMO, 1992)

$$DP = 240.97 \times K / (17.502\text{-}K), \text{ where K is given by}$$

$$K = \ln (RH/100) + 17.502 \times DB/(240.97 + DB)$$

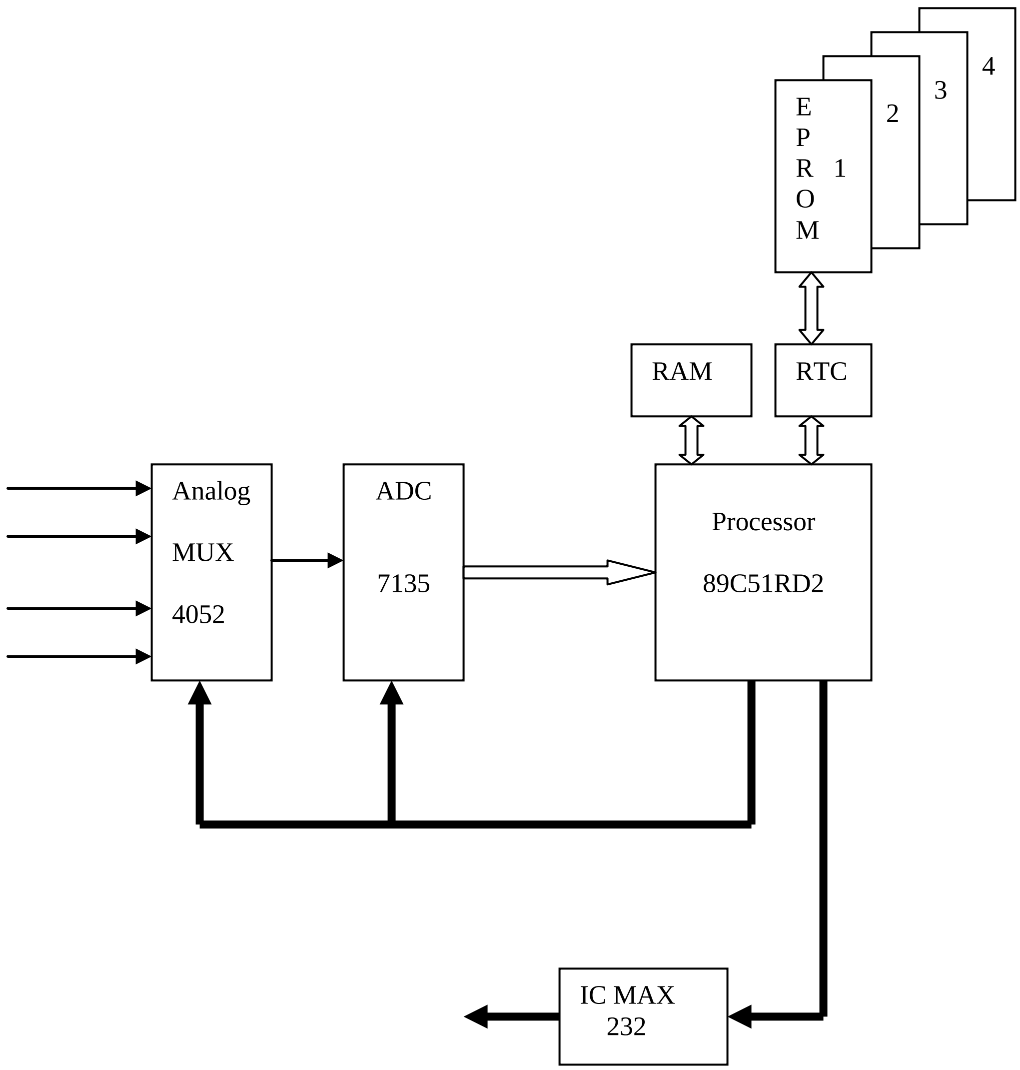
Where RH is the relative humidity in percentage, DB is the dry bulb temperature in degree centigrade, and DP is the dew point in degree centigrade. The formula may vary at different pressure levels (WMO, 1992). A schematic diagram of Hygroclip is shown in Fig. 3.

2.2. *Calibration of sensors*

Wind and temperature sensors can be calibrated at IMD Pune, before putting it in to field. Anemometer is calibrated using a wind tunnel and the temperature sensors are calibrated in a temperature chamber. Wind speed calibration is for a range of 0-125 kmph, temperature is for –60° C to + 150° C and humidity is for 10% to 95%. Periodic calibration at site can be done using hand held anemometers for wind speed and psychrometers for temperature and dew point. Wind vane can be calibrated by measuring its output resistance at various directions.

2.3. *Signal conditioner*

The signal conditioning circuits for wind direction and wind speed are shown in Figs. 4 and 5 respectively. In the signal conditioning of wind direction, the potentiometric wind vane is connected at the output of a constant current driving device. The output is conditioned



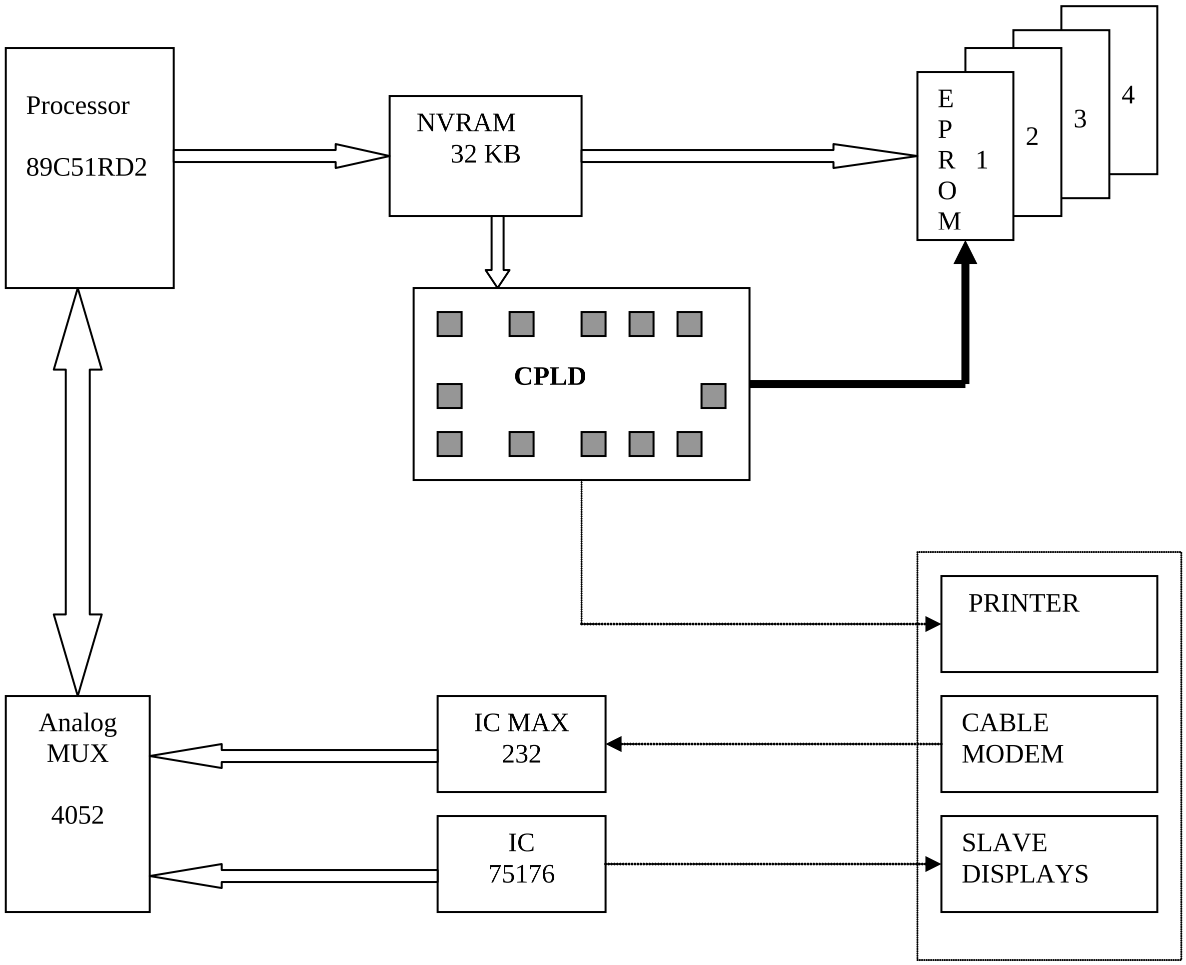
RAM →Random Access Memory, EPROM→ Erasable Programmable Read Only Memory,
RTC→ Real Time Clock, ADC→ Analog to Digital Converter

Fig. 6. Block diagram of the data digitiser

between 0 and 0.36 volts for the wind direction between 0 and 360°. In the case of wind speed, a peak to peak detector circuit is utilised.

2.4. *Data digitiser*

Data digitiser reads the analog output voltage from signal conditioning amplifier, digitises the data and converts the analog value to corresponding engineering units. The data flow through a data digitiser is shown in Fig. 6. The processor used, Philips 89C51RD2, is compatible with Intel 8051 series micro controllers. The components interfaced with the processor includes Analog multiplexer (IC 4052), Analog to Digital converter (IC 7135), 32KB Nonvolatile RAM, 512KB EPROM's (4 nos) and communication IC (MAX 232). Analog multiplexer selects one out of the four channels (wind direction, wind speed, temperature and dew point or humidity) under the control of the processor. Analog to Digital conversion is done by Dual slope integration technique. Here 7135 series ADC is used which generates 14 bits output, 20000 counts with resolution of 0.1 milli-volts to 2V range. The output is sent serially to the processor. In this unit also the processor sends Conversion ready pulse as per the program instructions. Philips 89C51RD2 micro controller is an 8-bit processor with 8-



EPROM→ Erasable Programmable Read Only Memory, NVRAM→ Nov Volatile Random Access Memory,
CPLD→ Complex Programmable Logic Device

Fig. 7. Block diagram of the data acquisition system

bit data bus and 16-bit address bus having an internal code memory of 64 KB. The processor linearise the data, sets the calibration factor and converts the humidity in to dew point. All the programs have been written in high-level language using 'C' language and the 'C' code is compiled to get Hex.file. "Philips flash programming utility" is used for downloading of Hex.file in to the processor. A 32 KB Non volatile RAM is doing 1 minute, 2 minute and 10 minute averaging of data and its storage. The averaging is decided by a real time clock (RTC). It has the decision capability of the completion of 1 minute, 2 minute and 10 minutes. Calibration parameters, configuration parameters, Baud rate etc. are stored in four numbers of 64 KB E^2PROM. The signal generated by the processor is in TTL level (Bit 1 $\rightarrow$ + 5 Volts, Bit 0$\rightarrow$ less than 0.8 Volts). It can be converted in to RS 232 signals (Bit 1 $\rightarrow$ + 5 Volts, Bit 0 $\rightarrow$ -5 Volts) by the communication IC MAX 232.

2.5. *Data acquisition system*

The Data acquisition system reads the transmitted data from the data digitiser. Fig. 7 shows the data flow diagram. The complete system of DAS includes a microprocessor, Non Volatile RAM, Flash memory, Analog MUX, IC MAX 232, Converter 75176 and a Complex Programming Logic Device (CPLD). The

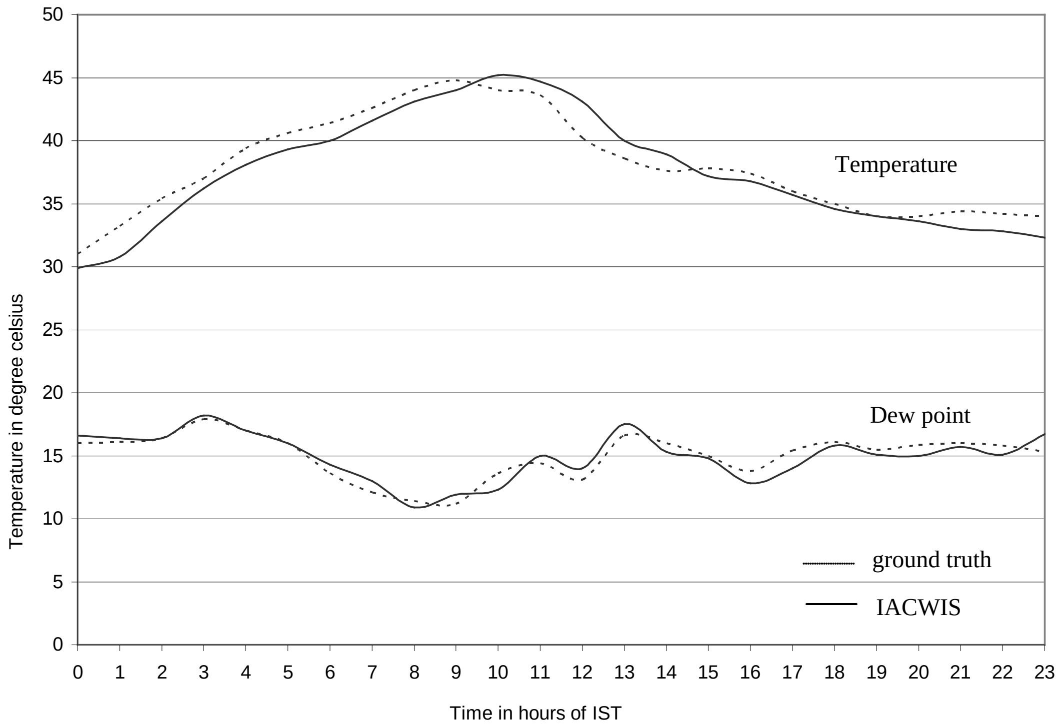


Fig. 8. Comparison of diurnal variation of temperature and dew point at Nagpur airport on 9 Jun 2005

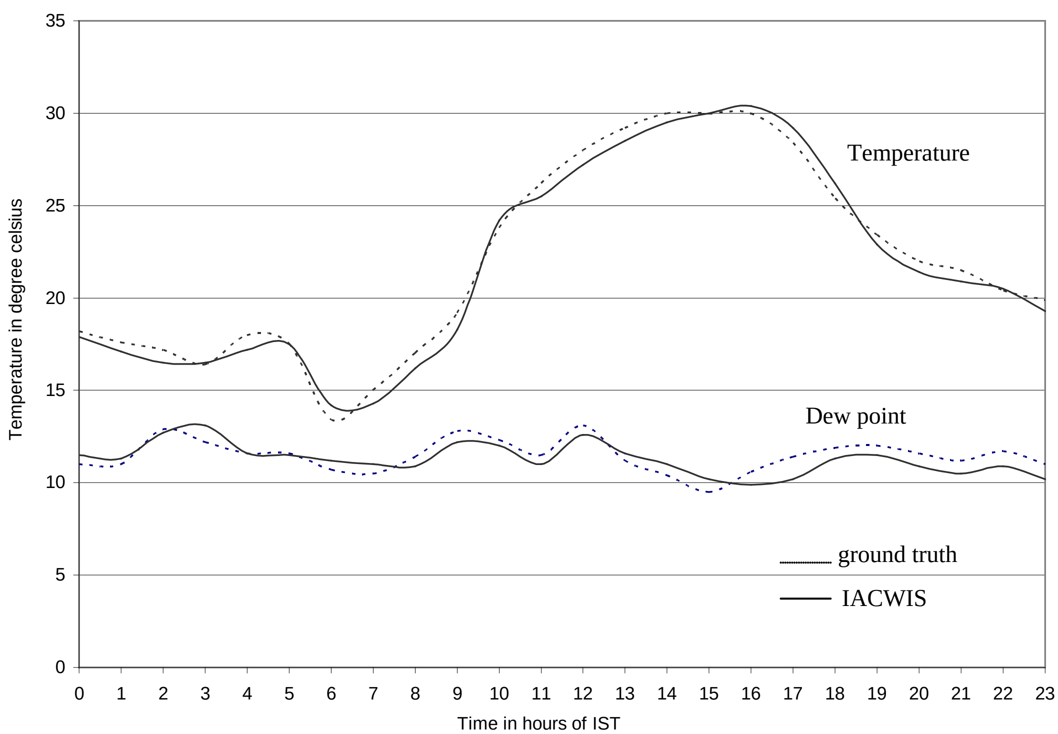


Fig. 9. Comparison of diurnal variation of temperature and dew point at Nagpur airport on 9 Jan 2007

TABLE 2

Accuracy of operation offered by IACWIS

Elements to be observed	Operationally desirable accuracy of measurement or observation as defined by ICAO (2004)	Accuracy attainable by IACWIS of India Meteorological Department
Wind direction	±10°	± 5°
Wind speed	±2 kmph (1 kt) up to 19 kmph (10 kts) ±10% above 19 kmph (10 kts)	± 2 kmph (1kt) up to 37 kmph (20 kts) ±5% above 37 kmph (20 kts)
Temperature	±1° C	±0.2° C
Dew point	±1° C	±0.2° C

received data, *i.e*., wind direction, wind speed, humidity, temperature, and dew point are read and stored in Non volatile memory (32 KB) for printing. One minute averaged values are stored in flash memory. Such data of approximately 30 days can be stored in the flash memory. Also, the received data is displayed on the 16 × 12 characters/numerals jumbo LCD display. The same data along with 2-minute average and 10-minute average values are transmitted to the slave displays as RS 422 signals. A complex programming logic device is used to assist the main processor while doing printing. It contains lot of latches and hardware logics to save the processing time. These latches keep the data till the printing is completed. Programs can specify the connections of these logic devices. The design tool is available free of cost in the website of embedded system academy (http://www.esacademy.com/). Chip selection of flash memory also done by CPLD. The data for one hour/three hour printing can be stored in a 32 KB Non volatile RAM. When the 1-hour/3 hour storage is completed, the data will be transferred to the CPLD alongwith computations of graphical format of data. Thirty days data can be stored in 512 KB × 4 flash memories with one-minute average of all parameters. The signal received through cable is RS 232 format signals, which can be converted into TTL logic by IC MAX 232. These logics can be processed and stored in flash memory. The processor extracts data from the flash memory and transmits through Analog MUX as RS 232 signal. Then IC 75176 converts the signal in to RS 422 format and sent to the slave displays.

2.6. *Cable modem*

The transmission of data from the runway site to the Met briefing room is in the form of RS 232 signals. The driver modem used here is Patton-short range modem which operates asynchronously point-to-point over 5 wires. No AC power or batteries required for its operation. It supports asynchronous RS-232 data rates to 115.2 Kbps over distances upto 15.0 miles.

3. Data quality

Integrated Automated Current Weather Instruments System (IACWIS) has a number of advantages over conventional analog current weather instruments system as shown in Table 1 and the attainable accuracy is listed in Table 2.

The daily hourly readings of temperature and dew point obtained from IACWIS in the months of June 2005 and January 2007 at Runway 32 of Sonagaon Airport, Nagpur are compared with the ground truth observations and shown in Figs. 8 and 9. There is a very good agreement between IACWIS and conventional analogue observations. However, the little difference between these two readings may be due to (*i*) distance between the observation locations (may about 3 km) (*ii*) different exposure conditions and (*iii*) comparatively minimum response time of the sensors in digital instrumentation.

4. Conclusion

The present system has been designed to take up four channels as described above. However the system can be upgraded to integrate channels like pressure for measurement of QNH, QFE, visibility, runway visual range, cloud base height, rainfall etc. The system can also be upgraded to transmit the data through Kalpana-I/Insat-3A through DRT by using a suitable transmitter. The system can be developed in to a current weather display, which can display the current values of weather parameters in a jumbo display and there is a provision for local forecast in a rolling display. This may be useful for all the regional and state wise Meteorological Centres to give an awareness of current weather to the public. One such system has been installed at Pushpa Gujral Science city, Jalandhar, Punjab.

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