Digital ReadOut For GMRT Servo Encoders

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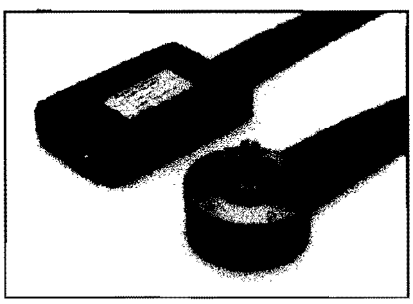
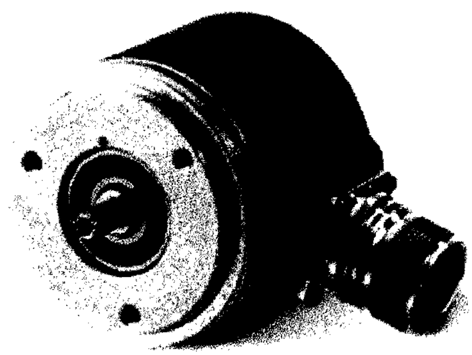




CONTENTS

1. AIM : To design a handheld instrument for reading of GMRT servo system encoders at elevation and azimuth encoder platforms

The specific aim of the project is to design a handheld instrument with Microcontroller and LCD screen with :

i. Interface to 17 bit absolute Teledyne Encoder. [Model A25S]

ii. Interfacing of 17bit absolute Heidenhain Encoder with SSI & EnDat01 Protocols. [Model ROC417]

iii. Interfacing of 20bit Heidenhain Encoder with EnDat01 protocol. [Model RCN 220]

iv Interfacing of FPS system Incremental Encoder. [Model ROD50 ,2048ppr]

2. INTRODUCTION :

Giant Meterwave Radio Telescope (GMRT) is an array of 30 fully steerable parabolic dishes of 45m diameter each spread over a distance of 25km. GMRT is one of the most powerful Radio Telescopes in the world operating in the frequency range of 50-1500 Mhz.

GMRT antennae are mounted in Altitute-Azimuth (ALT-AZ) fashion. Each of the axes uses 17bit Absolute Encoder for position feedback of the axes to precisionly track the cellestial objects.

The servo system of GMRT is getting upgraded from previous Teledyne Encoders to Heidenhain Encoders (EnDat01) . Also, during maintenance, these encoders are removed in case of misallignment of axis shaft to encoder shaft.

To fix the encoder, dish is taken to known marked position and then encoder is set to the marked reading. For eg. In Elevation axis, dish is positioned towards zenith and locked ; which indicates 90deg position for elevation. After this, encoders are adjusted to the reading 90deg and fastened to shaft with flexible coupling. In azimuth axis, dish is taken to marked position of AZ-Mech. Lock (225deg/135deg) and then encoder reading is adjusted accordingly.

The encoder platform for EL axis is located around 22m height in a dificult to access position as seen in following fig 1. The AZ axis encoder is located at a height of 10m in another difficult position where barely 2-3 persons can stand.

These encoders are connected to ground based servo system through RS-422 differential lines with cable lengths varying from 15-25m.

To adjust the encoder , person located at encoder platform has to take help from ground based person who reads the console of Servo system [fig 2] and then shouts to another person standing outside concrete tower. This person again shouts towards encoder platform to communicate the reading.

This crude form of feedback for adjusting encoder at height 22m from ground is painstaking. Hence, a requirement for handheld Digital Readout with accuracy of 17bit came into picture.

3.TYPES OF ENCODER AT GMRT:

The various types of encoders at GMRT are as follows:

1)Teledyne Encoder [Model A25S] :

This 17 bit absolute encoder is being used since commissioning of GMRT. The reading of encoder starts with transmission of INT signal which converts rotary position to digital format.

After sending CLK as shown in fig 3, data is sent on serial differential lines with MSB bit first and thereafter LSBs. Also parity bit is sent at the end.

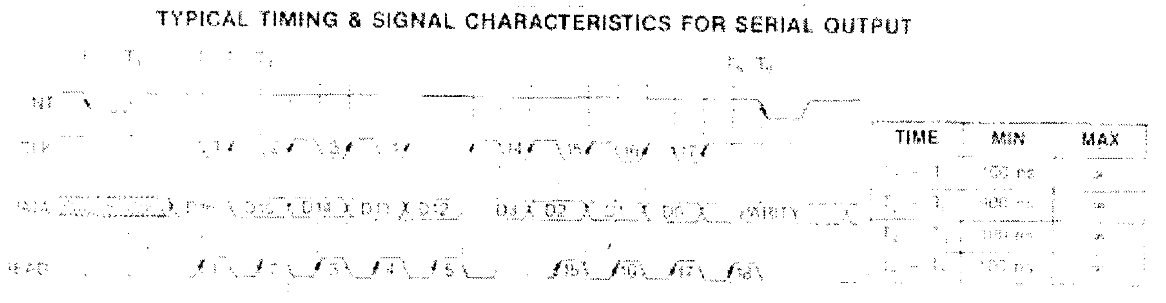


Fig 3. Waveforms for Teledyne Encoder

2)Heidenhain 17 bit & 20 bit Encoders with EnDat01 protocols

[Model nos. ROC417-EnDat01 & RCN 220 respectively]

As shown in figure 4., these absolute encoders use duplex communication for data transmission. The transmission of data starts by asserting CLK signal to low ; which stores the rotary position value. After 2T time, MODE bits for reading the encoder are to be transmitted. After 2T time interval, Encoder sends START and ALARM bits, which signify the health of Encoder. Thereafter, data bits and CRC bits are to be sent by Encoder in synchronism with CLK . Data and Mode bits share the same line.

As shown in fig. 5, Heidenhain Encoder has many facilities for Encoder manufacturer, OEMs and end user such as storage of offset in encoder, checking health of encoder [such as voltage low/high, temperature high]. Also parameters like encoder sr. no, name of company can be stored in the encoder.

However, at GMRT, these encoders are used in reading mode only. RCN220 encoder is used at GMRT to validate 17 bit encoders.

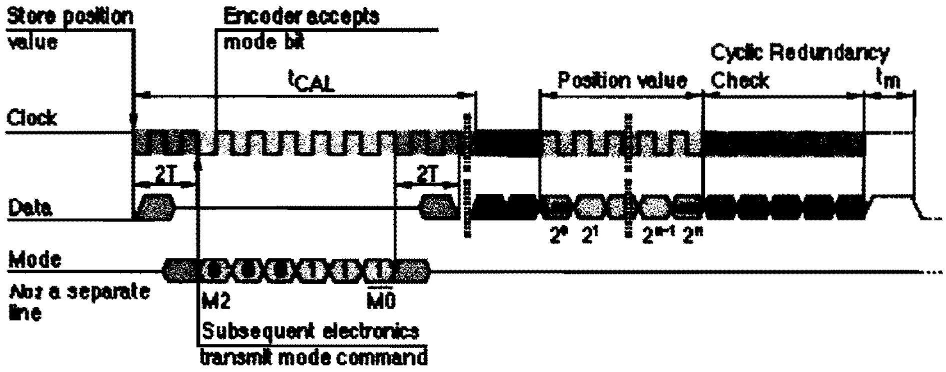
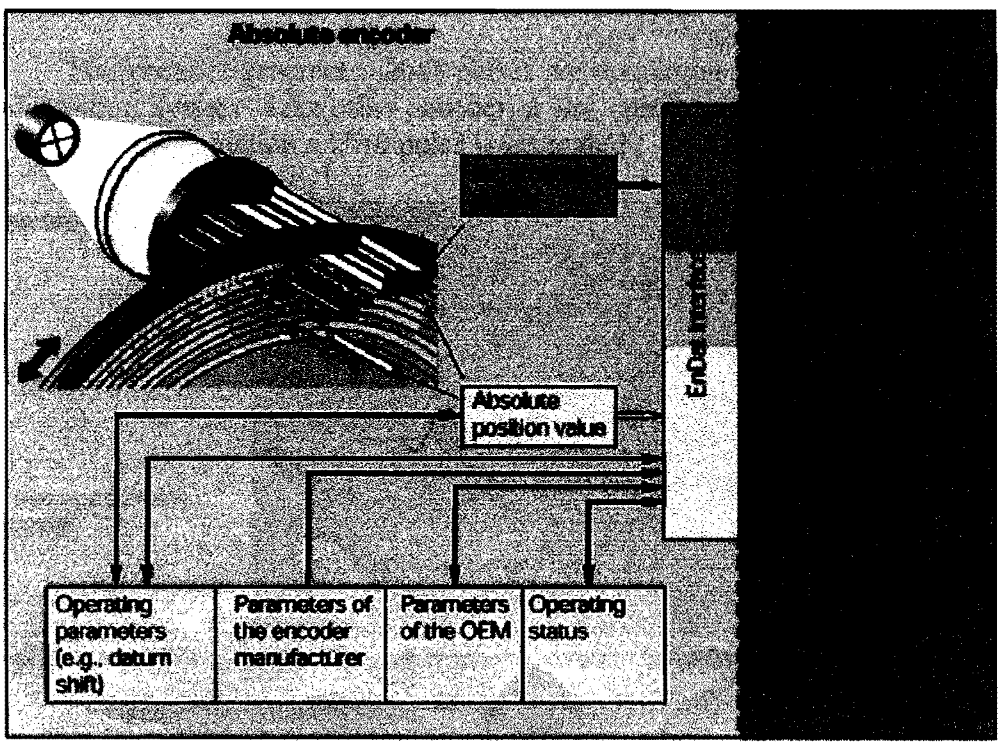


Fig. 4 : Timing Diagram for Heidenhain encoders with EnDat01 protocol.



Block diagram: Absolute encoder with EnDat interface

Fig. 5 : Heidenhain EnDat01 signals.

3)Heidenhain -17bit absolute with SSI protocol : [Model ROC417,SSI]

This encoder has similar interface like Teledyne encoder except that CLK lowering starts Rotary to Digital Conversion. This encoder is used at C04 antenna of GMRT.

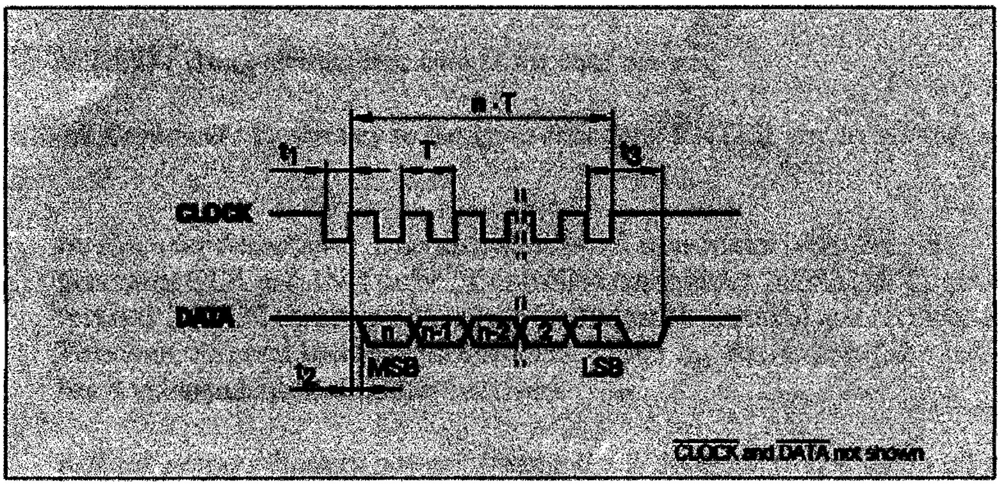
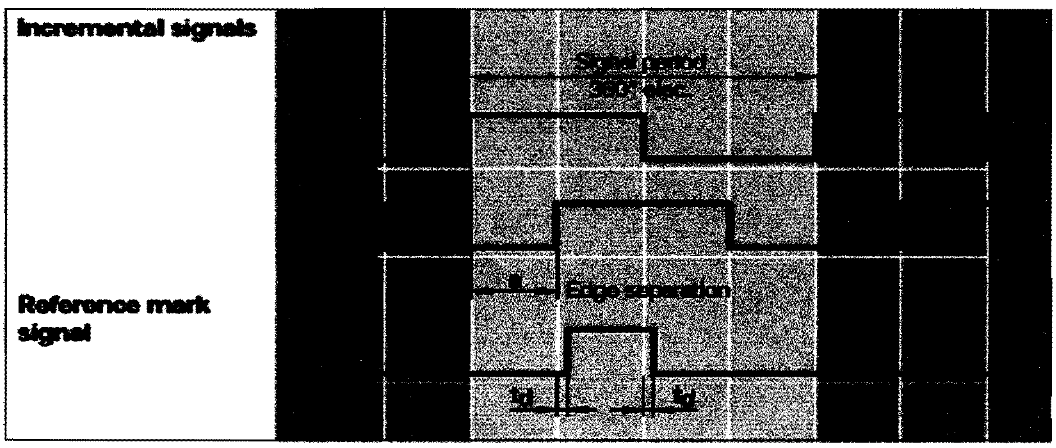


Fig. 6 : Heidenhain encoder with SSI protocol at antenna C04

4. **Incremental Encoder for FPS system** [Model ROD50]

This encoder genereates 2048 pulses per revolution and is used in Feed Position System . Like other encoder, it also communicates over differential line. After every rotation a UA0 pulse is generated .



Direction of rotation: U_{a1} lags U_{a2} with clockwise rotation (viewed from flange side)

Fig. 7 : Incremental Encoder Signals.

4 . HARDWARE: [refer to fig. 9,10]
The DRO's hardware has following blocks :

i. Microcontroller : Atmel AT89C51 with Flash RAM was selected for easy programmability and erasing of programs quickly during development.

ii. LCD : 16x2 characters , backlit for easy reading

iii.Keyboard : Down key to navigate encoders, ENTER key to see the reading

.

iv. Encoder Interface : Uncotrolled RS-422 transmitter chip 26LS31 generates CLK and INH pulse , Controlled transmitter 26LS31 & Controlled receiver 26LS32 forms transreceiver for EnDat01 protocol and receiver for Teledyne, SSI and Incremental encoders. [refer fig. 8]. IC 26LS32 / 26LS31 has 4 independent transmitter/receivers

v. Rack power / Battery power : Instrument is designed to use both rack power or alternatively power from AA size rechargeable batteries.

EnDat interface: Recommended input circuitry of subsequent electronics

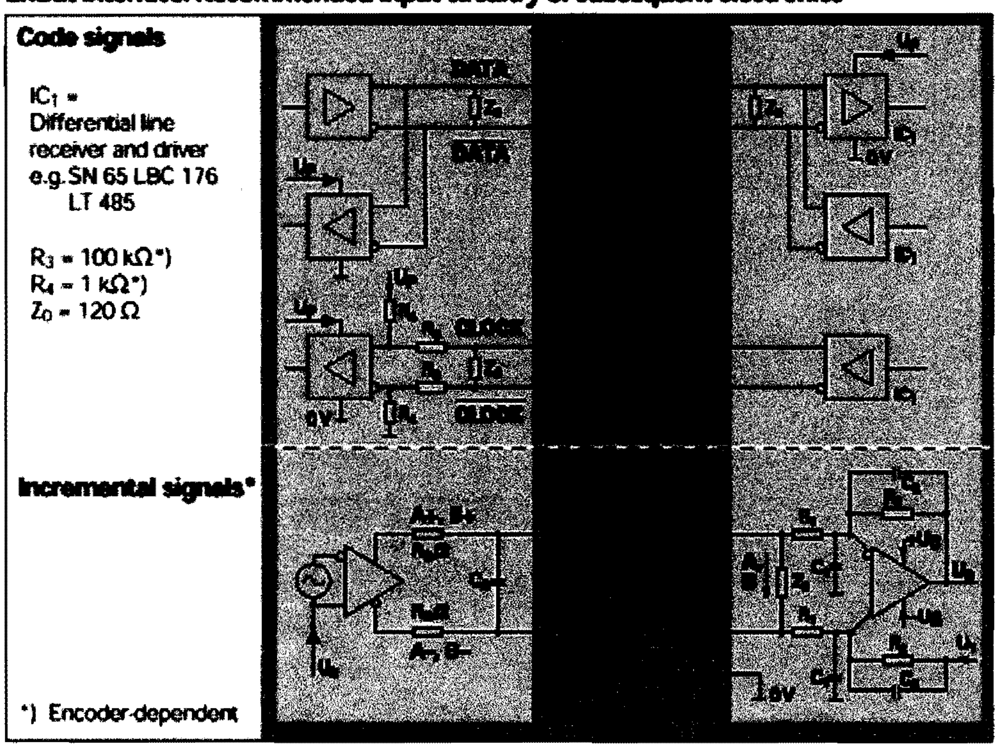
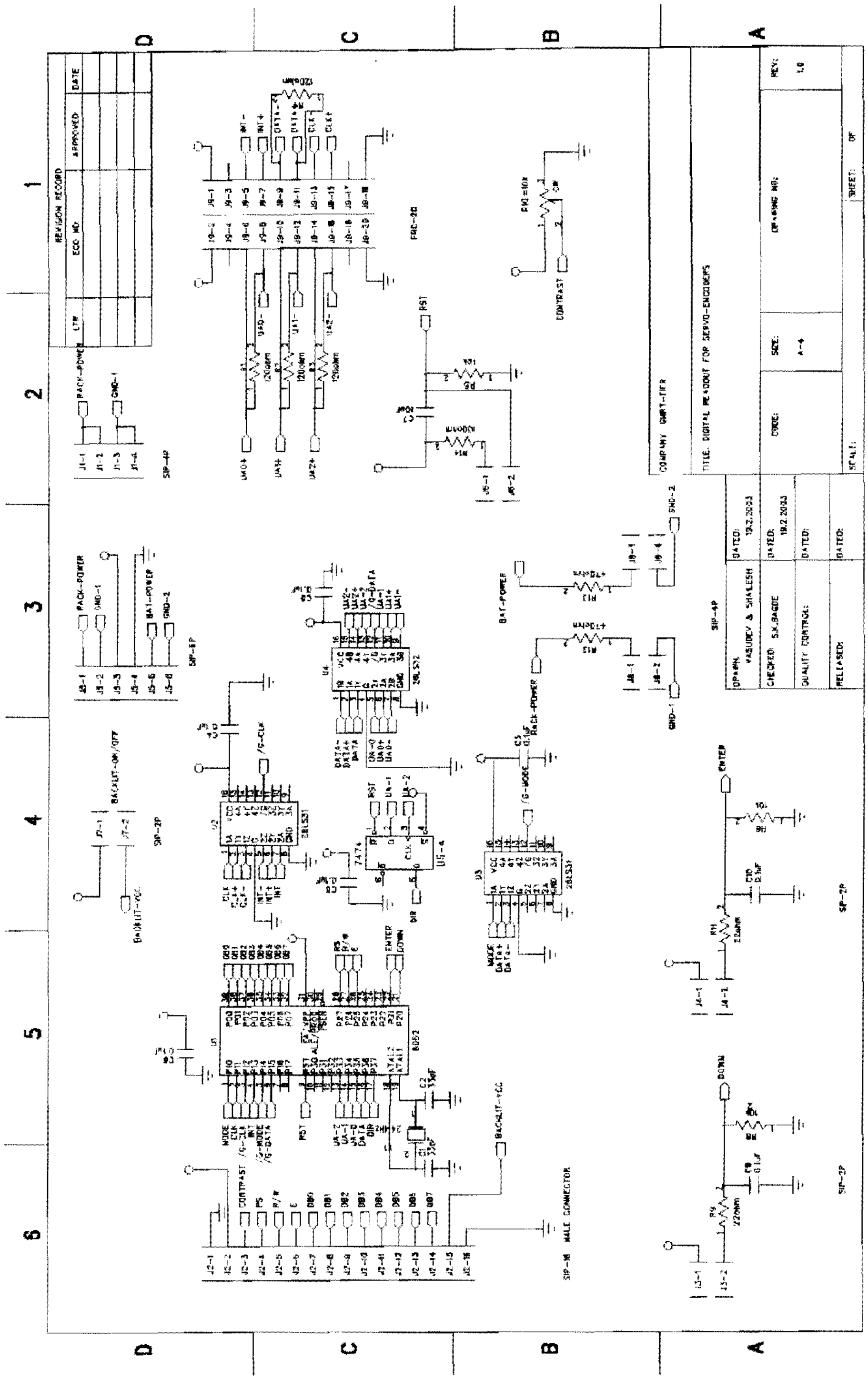


Fig. 8 : Hardware interface for Endat01 encoders

Along with above hardware, magnetic lock and a belt were used so that DRO can be easily placed / carried anywhere in the antenna.

Fig 9 : Circuit Diagram of DRO



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5. Product Specifications :

With all above considerations DRO comes into existence with following specifications :

a) *Power* : DC 5V ±10% , 600mA from regulated power supply/ battery (selectable).

b) *Output*: LCD- 16x2 characters,5x7 dot matrix.

c) *Resolution:* 9.88 arcsec for 17 bit encoders, 1.25 arcsec for 20 bit encoder.

d) *Input Encoders*:

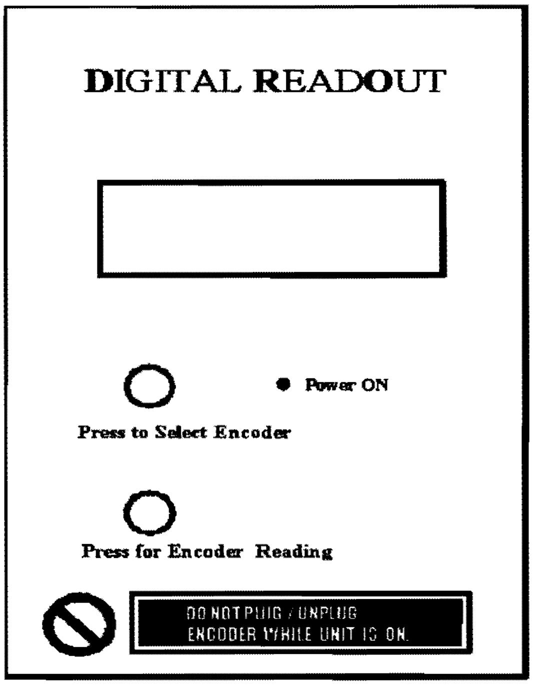
i.) Teledyne.[Model A25S]
ii.) Heidenhain17-bit (SSI) [Model ROC417].
iii.) Heidenhain17-bit (Endat).[Model ROC417]
iv.) Heidenhain 20-bit (Endat). [Model RCN220]
v } Incremental encoder [Model ROD 50, Heidenhain]

e)*Weight of DRO* : 500 gms (without batteries)

f) *Dimensions* : 96mm x 48 mm x 100 mm

g)*Operating temperature*: 0-55°C.

h) *Magnetic Lock and belt for easy fixing /carrying of DRO*



6. Bill of Materials and PCB for DRO

Bill Of Materials for Dro.sch on Tue Mar 30 17:30:48 2004

Item	Qty	Reference	Part Name	Manufacturer	Description
1	1	U5	7474		
2	1	U1	AT89C51		
3	1	U2	26LS31		
4	1	U3	26LS31		
5	1	U4	26LS32		
6	1	C1	CAP-CK05		33pF ,unless specified all ceramic capacitors
7	1	C2	CAP-CK05		33pF
8	1	C3	CAP-CK05		0.1uf
9	1	C4	CAP-CK05		0.1uf
10	1	C5	CAP-CK05		0.1uf
11	1	C6	CAP-CK05		0.1uf
12	1	C7	CAP-CK05		10uf , tantalum
13	1	C8	CAP-CK05		0.1uf
14	1	C9	CAP-CK05		0.1uf
15	1	C10	CAP-CK05		0.1uf
16	1	J2	CON-SIP-16P		
17	1	J3	CON-SIP-2P		
18	1	J4	CON-SIP-2P		
19	1	J6	CON-SIP-2P		
20	1	J7	CON-SIP-2P		
21	1	J1	CON-SIP-4P		
22	1	J8	CON-SIP-4P		
23	1	J5	CON-SIP-6P		
24	1	J9	HEADER20		
25	1	R1	RES-1 4W		120•
26	1	R2	RES-1 4W		120•
27	1	R3	RES-1 4W		120•
28	1	R4	RES-1 4W		120•
29	1	R5	RES-1 4W		10K•
30	1	R6	RES-1 4W		10K•
31	1	R8	RES-1 4W		10K•
32	1	R9	RES-1 4W		22•
33	1	R11	RES-1 4W		22•
34	1	R12	RES-1 4W		470•
35	1	R13	RES-1 4W		470•
36	1	R14	RES-1 4W		100•
37	1	R10	VRES		10k• -Trimpot
38	1	Y1	XTAL1		24MHz

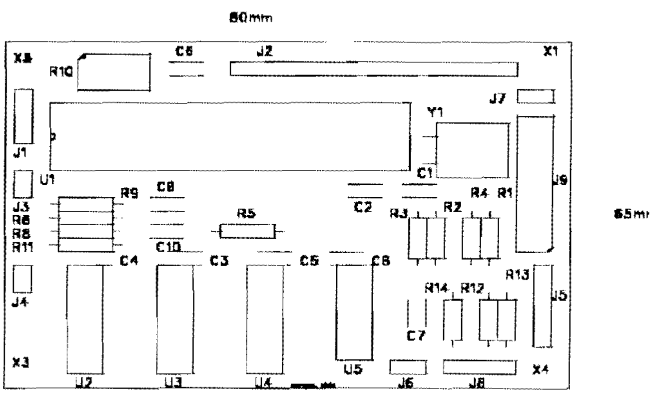
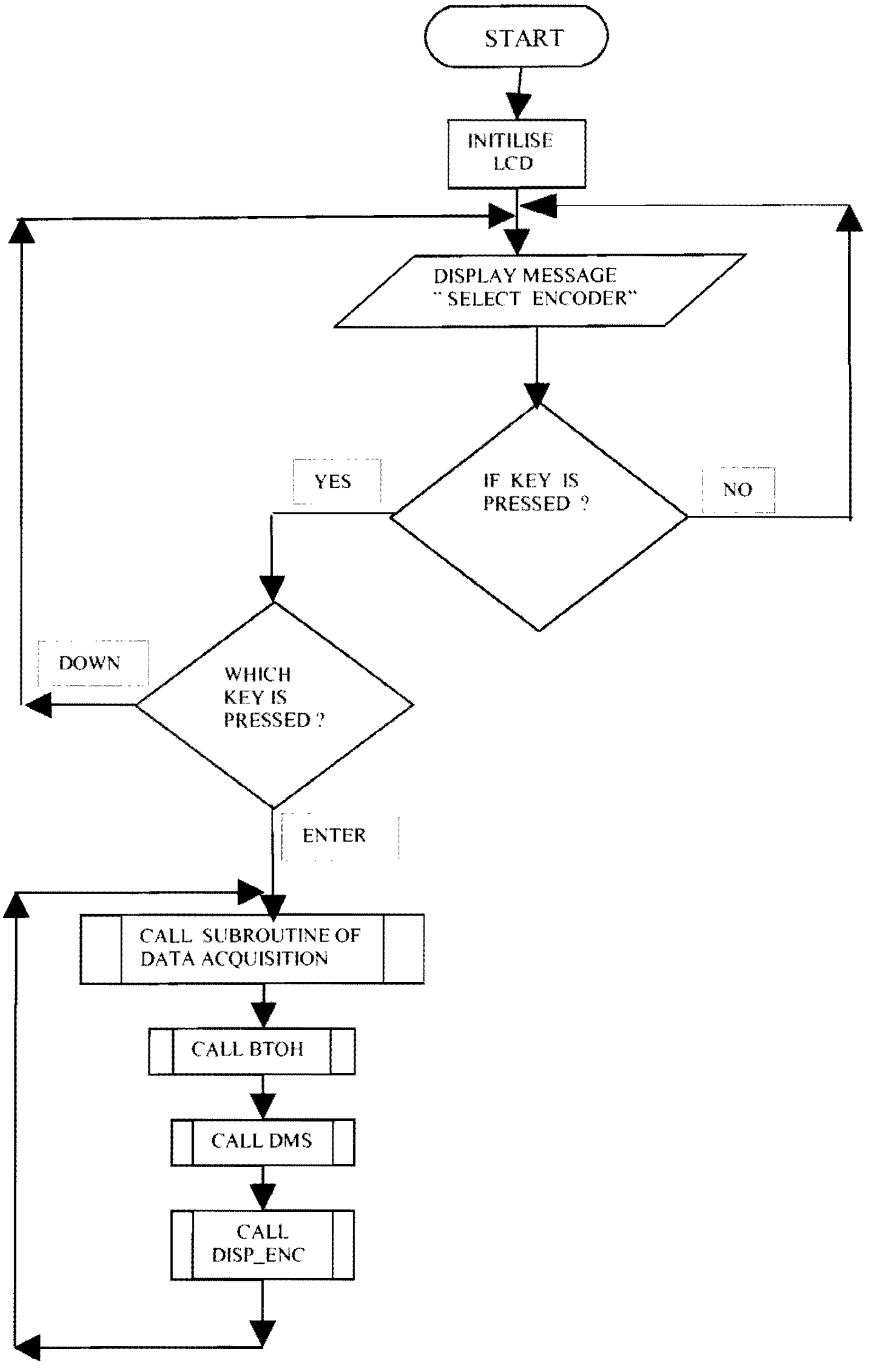


Fig. 11 DRO PCB | 80 mm x 65 mm | component mounting Details

Fig 12. Flowchart for DRO software :



7 . SOFTWARE embedded in DRO

1.Algorithm : The main program has various subroutines such as

i)LCD initialisation.
ii)Keyboard Reading
ii)Data acquisition.
iii)Raw Encoder Data to Floating Point conversion.
iv)Floating Point Data to Deg:Min:Sec Conversion
v)Display of Encoder Reading

Refer to Flowchart in Fig 12

2. Calculations for Encoder Reading :

i . Resolution of the Encoders

1.)For 17-bit encoder

1bit = 360deg (1 rotation) / 2^17 (131072 states)
= 0.00274°
= 0.16479'
= 9.88"
= .00B4 H [17 bit Encoder Resolution]

2.)For 20-bit encoder

1bit = 360/2^20
= 0.00034°
= 0.02059'
= 1.2359"
= .0168 H

ii . Sample Calculations for 8 bit Microcontroller :

1. Encoder Raw Data to Floating point Conversion

For 17-bit, assuming acquired data =1FFFF H

```
   1FFFF H
 x 0.00B4 H
 ----------
 167.FF4C H
```

2.Floating Point to Deg.: Min.: Sec. Conversion

For 1FFFF H raw encoder data, floating point data= 167. FF4C H

Conversion is done by multiplying above FP data by 60 (3C H)

1. **Degree** = 167 H = 359°

2. **Minutes** = 0.FF4C H x 3C H =3D.D5D0 H
   3D H =59'

3. **Seconds** = 0.D5D0 H x 3C H = 32.1CC0 H
   32 H = 50"

. **100th of Seconds** = 0.1CC0 H x 64 H = 0.7360"

Actual Seconds = 50.7360"

so 167.FF4C H = 359 : 59 : 50.7360

8 . Operating Instructions for DRO :

1. Connect Encoder to intrument.
2. Switch ON the instrument.
3. Select BATTERY / RACK POWER mode by using switch.
4. Select Encoder type by pressing DOWN key.
5. Press ENTER key.
6. Set Encoder shaft at desired position.
7. Switch OFF the instrument and remove Encoder connector.

References :

1. www.heidenhain.com
2. www.gurley.com
3. 8051 : Kenneth Ayala.
4. Interfacing Heidenhain-SSI encoder with SSC
   [internal tech. Report] : S K Bagde