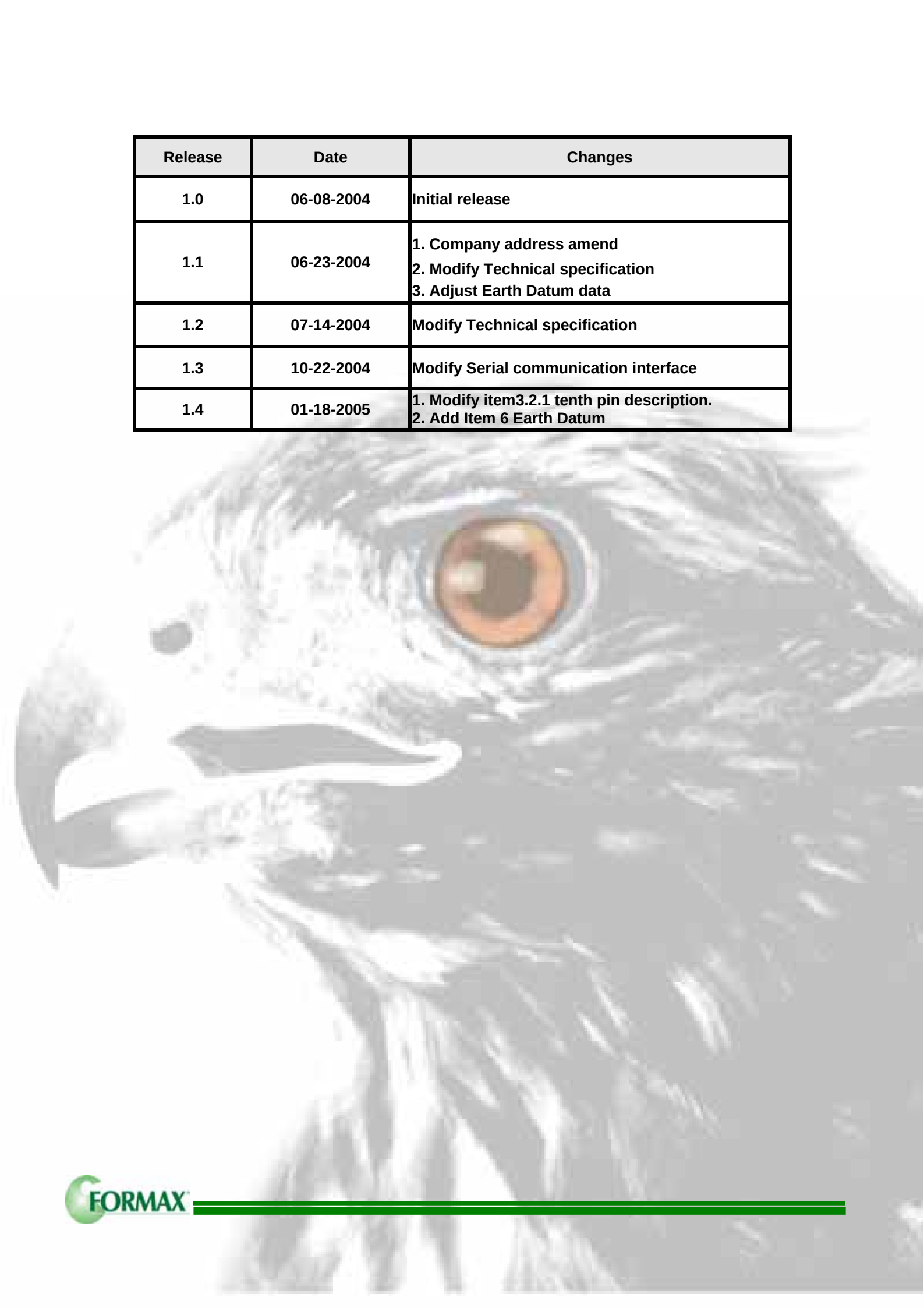
FORMAX GPS Engine Board

FXE Series Specification

Revision 1.4

FORMAX TECHNOLOGY CO.,LTD.
TEL: +886-2-87525130 FAX: +886-2-87525303
Email:formax@formax.com.tw Web site:www.formax.com.tw
5F-1, NO, 306, Sec.1, NEIHU RD.,NEIHU DISTRICT, TAIPEI CITY 114,TAIWAN

Release	Date	Changes
1.0	06-08-2004	Initial release
1.1	06-23-2004	1. Company address amend 2. Modify Technical specification 3. Adjust Earth Datum data
1.2	07-14-2004	Modify Technical specification
1.3	10-22-2004	Modify Serial communication interface
1.4	01-18-2005	1. Modify item3.2.1 tenth pin description. 2. Add Item 6 Earth Datum



CONTENTS

1 Introduction

1.1 Overview

The GPS signal receiving, data acquisitioning and positioning meet the needs such as car navigation, mapping, surveying, agriculture and so on. **FORMAX** communicates with other electronic utilities via compatible dual serial communication channels with TTL level and saves useful satellite data by on-chip memory backup to speed up the positioning. With low power consumption 32mA, the **FORMAX** tracks satellites using up to 12-channel correlators at a time. It re-acquires satellite signals in 100 ms and updates position data every second. Advanced power saving algorithm allows the unit operates a fraction of the time and intelligently saving satellite data and tracking history permits user to have a quick position fix even though the receiver usually stays off.

1.2 Features

The **FXE Series** provides the features that make the host easy for integration.

- ✓ Full navigation accuracy provided by Standard Positioning Service (SPS).
- ✓ Allows the receiver to track the satellites using up to 12-channel correlators.
- ✓ Dual serial communication channels and user selectable baud rates allow the design with maximum interface capability and flexibility.
- ✓ Optional to supports downloadable firmware code for upgrading the advanced programs.
- ✓ No any initialization setup is required while start to use.
- ✓ Support backup battery to sustain internal clock.

1.3 Technical specifications

Features	Specifications
Accuracy	SPS Position: 5~15m CEP w/o S/A Velocity: 0.1 m/sec w/o S/A Time: ±1μ sec
Acquisition	Cold start: < 60 sec Warm start: < 35 sec Hot start: < 10 sec
Dynamics	Altitude: max. 18,000m Velocity: max. 500m/sec Acceleration: max. ±4g
Navigation update rate	Once per second
PCB Dimension (mm)	FXE1 : 33(W) x 59(L), FX E2 : 40.1(W) x 71.5(L)
Serial I/O port	Series TTL x2
I/O port rate	4.8K, 9.6K, 19.2K and 38.4K (optional, up to 115.2K)
I/O protocols	NMEA 0183: GGA, GLL, GSV, GSA, RMC, VTG
Coordinate Datum	WGS 84
Power supply	+3.3 / +5.0 VDC
Power consumption	32mA (without active antenna)
Sensitivity	Acquisition: -131dBm Tracking: -140dbm
Support WASS Signal	Option
Sleep mode power saving	Yes
RTC support	Yes
Backup Battery	Super Cap for RTC
System Performance	12-channel correlators
F/W upgradeable	Optional
I/O connector	20-pin
RF connector	MCX
Antenna	Active
Antenna power supply	+3.3V
Timing output	1PPS x 1
GPIO pins	GPIO x 8
Reset Pin	Yes
Operating Temp.	-40°~ +85°C,
Storage Temp.	-55°~ +100°C
Humidity	5%~95%

1.4 20-pin I/O Interface

1. Dual communication channel with TTL level and user selectable baud rate (19,200-Default, 4,800, 9,600, 19,200, 38,400 and up to 115,200).
2. Support binary code mode for upgrading the firmware code and datum.
3. NMEA 0183 Version 3.0 ASCII output (GGA, GLL, GSV, GSA, RMC, VTG).

2 Operational characteristics

2.1 Initialization

As soon as the initial self-test is complete, the **FORMAX** engine board begins the process of satellite acquisition and tracking automatically. Under normal circumstances, it takes approximately 60 seconds to achieve a position fix, 35 seconds if ephemeris data is known. After a position fix has been calculated, information about valid position, velocity and time is transmitted over the output channel.

The **FORMAX** engine board utilizes initial data, such as last stored position, date, time and satellite orbital data, to achieve maximum acquisition performance. If significant inaccuracy exists in the initial data, or the orbital data is obsolete, it may take more time to achieve a navigation solution. The **FORMAX** engine board Auto-locate feature is capable of automatically determining a navigation solution without intervention from the host system.

However, acquisition performance can be improved as the host system initializes the **FORMAX** engine board in the following situation:

1. Moving further than 500 kilometers.
2. Failure of Data storage due to the inactive internal memory battery.

2.2 Navigation

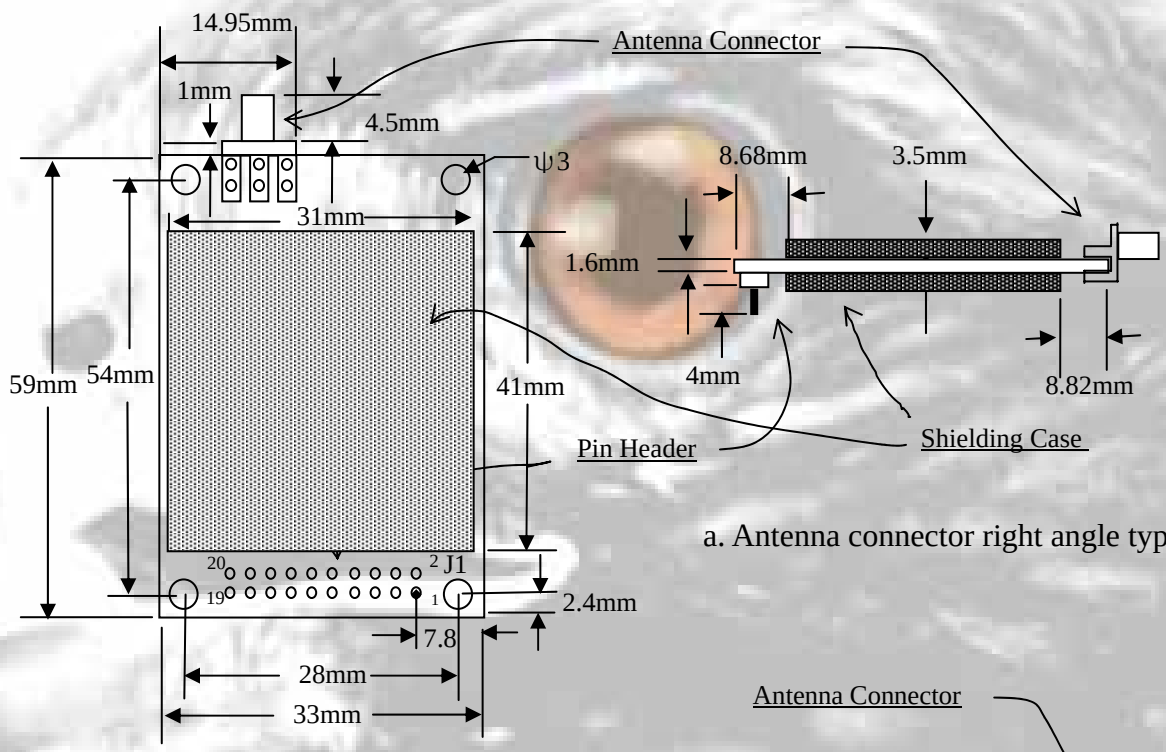
After the acquisition process is complete, the **FORMAX** engine board sends valid navigation information over output channels. These data include:

1. Latitude/longitude/altitude
2. Velocity
3. Date/time
4. Error estimates
5. Satellite and receiver status

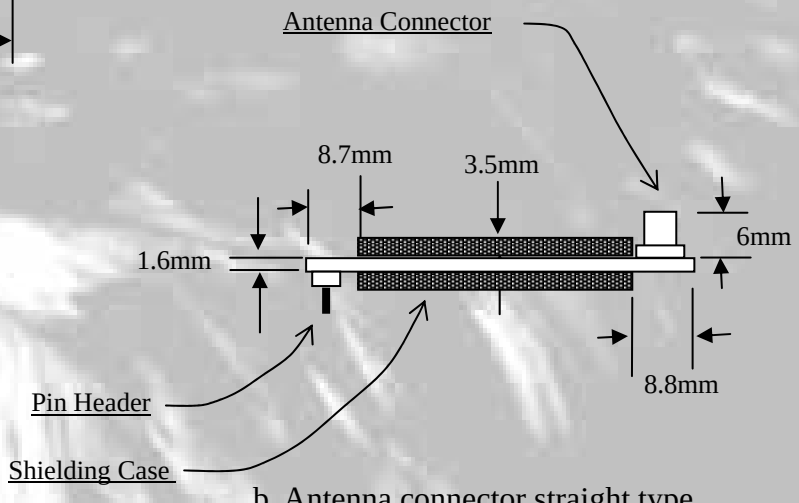
3 Hardware interface

3.1 PCB Dimension and layout descriptions

3.1.1 FXE1 PCB Dimension



a. Antenna connector right angle type

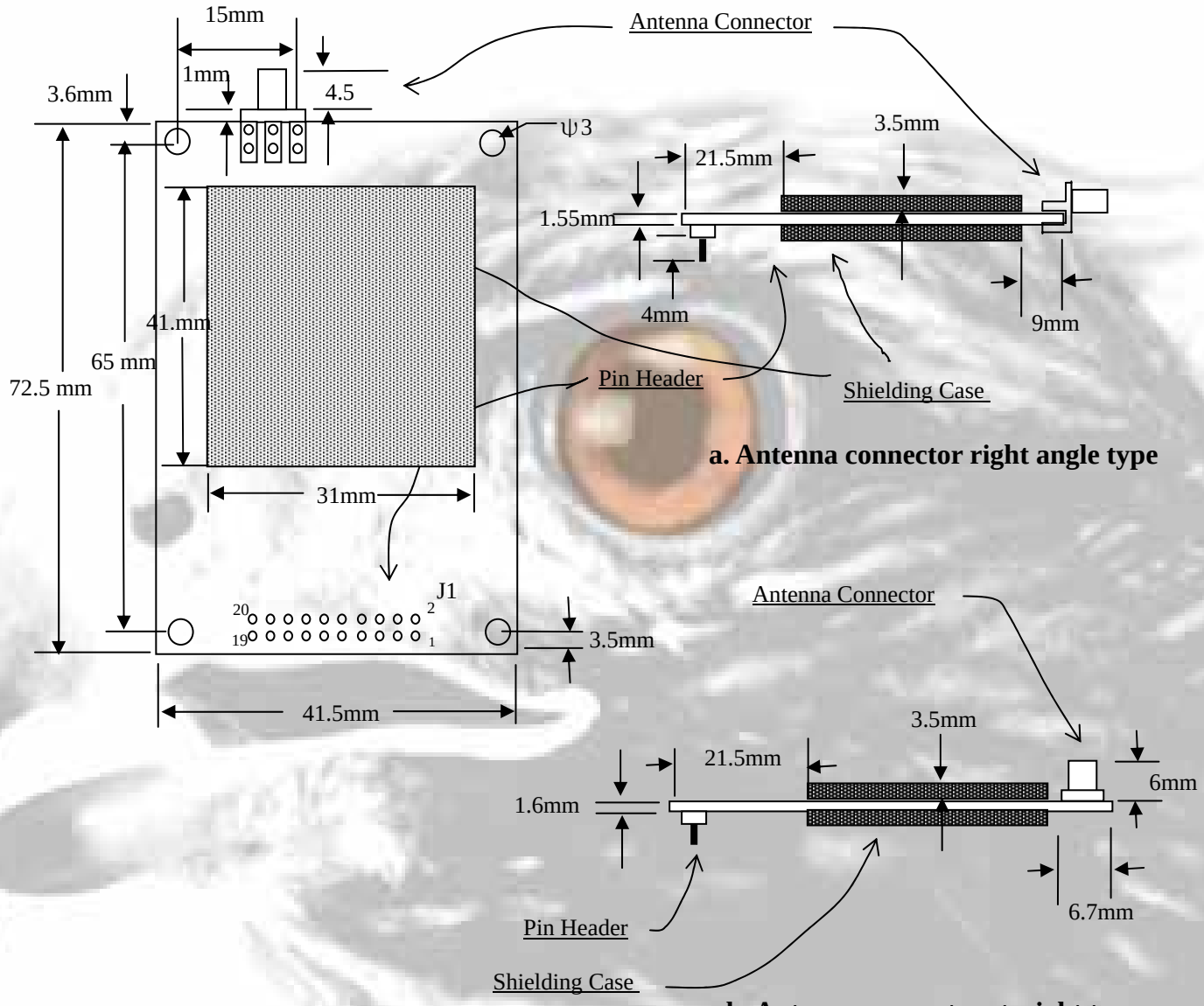


b. Antenna connector straight type

Notes:

1. J1: The serial communication interface I/O connector, is connected to GPS application system.

3.1.2 FXE2 PCB Dimension



a. Antenna connector right angle type

b. Antenna connector straight type

Notes:

1. J1: The serial communication interface I/O connector, is connected to GPS application system.

3.2 Serial communication interface

FORMAX engine board supports a 20-pin I/O connector to connect the host controller The pin definitions of 20-pin serial communication interface connector:

3.2.1 FXE1 Series pin definitions

Pin	Name	Function	Notes
1	Vcc_3.3V	3.3V DC power supply	+- 10%
2	GND	Ground	
3	TXDA	Serial data output A (transmit data)	4,800/9,600/19,200/38,400 and up to 115,200bps, no parity, 8-bit data, 1 stop-bit, for NMEA data
4	GPIO0	I/O control pin, connect to CPU PIO-1	
5	RXDA	Serial data input A (receive data)	
6	GPIO1	I/O control pin, connect to CPU PIO-2	
7	TXDB	Serial data output B (transmit data)	4,800/9,600/19,200/38,400 and up to 115,200bps, no parity, 8-bit data, 1 stop-bit, for binary data
8	GPIO2	I/O control pin, connect to CPU PIO-3	
9	RXDB	Serial data input B (receive data)	For binary data
10	GPIO3	I/O control pin, connect to CPU PIO-4	
11	Vbat_3.3V	+3.3V DC external backup battery	+3.6V ~ +3.0V DC
12	GPIO4	I/O control pin, connect to CPU PIO-5	
13	GND	Ground	
14	GPIO5	I/O control pin, connect to CPU PIO-6	
15	Reset	Active low, to reset the engine board	
16	GPIO6	I/O control pin, connect to CPU PIO-7	
17	1PPS	Time mark output for one pulse per second	
18	GPIO7	I/O control pin, connect to CPU PIO-8	
19	GND	Ground	
20	Vcc_5V	5V DC power supply	

3.2.2 FXE2 Series pin definitions

Pin	Name	Function	Notes
1	NC	No function	
2	Vcc	+ 5.0V DC power supply	
3	Vbat_3.3V	+3.3V DC external backup battery	+3.6V ~ +3.0V DC
4	Vcc	+ 5.0V DC power supply	
5	Reset	Active low, to reset the engine board	
6	GPIO0	I/O control pin, connect to CPU PIO-1	
7	GPIO1	I/O control pin, connect to CPU PIO-2	
8	GPIO2	I/O control pin, connect to CPU PIO-3	
9	GPIO3	I/O control pin, connect to CPU PIO-4	
10	GND	Ground	
11	TXDA	Serial data output A (transmit data)	4,800/9,600/19,200/38,400 and up to 115,200bps, no parity, 8-bit data, 1 stop-bit, for NMEA data
12	RXDA	Serial data input A (receive data)	
13	GND	Ground	
14	TXDB	Serial data output B (transmit data)	4,800/9,600/19,200/38,400 and up to 115,200bps, no parity, 8-bit data, 1 stop-bit, for binary data
15	RXDB	Serial data input B (receive data)	For binary data
16	GND	Ground	
17	GPIO4	I/O control pin, connect to CPU PIO-5	
18	GND	Ground	
19	1PPS	Time mark output for one pulse per second	
20	GPIO5	I/O control pin, connect to CPU PIO-6	

4 Software Interface

The **FORMAX** engine board interface protocol is based on the National Marine Electronics Association's NMEA-0183 interface specification, which is defined in NMEA 0183, Version 3.0. This engine board didn’t support the Radio Technical Commission for Maritime Services (RTCM) for Differential Navstar GPS Services.

4.1 NMEA Transmitted Messages

The **FORMAX** engine board outputs data in NMEA-0183 format as defined by the National Marine Electronics Association (NMEA) standard.

The default communication parameters for NMEA output are 4800 baud, 8 data bits, 1 stop bit, and no parity.

The NMEA-0183 Output Messages are shown as below:

NMEA Record	Descriptions
GPGGA	Global positioning system fixed data
GPGLL	Geographic position- latitude/longitude
GPGSA	GNSS DOP and active satellites
GPGSV	GNSS satellites in view
GPRMC	Recommended minimum specific GNSS data
GPVTG	Course over ground and ground speed

4.1.1 Global Positioning System Fix Data (GGA)

The example of GPGGA:

$GPGGA,121212.456,3232.1234,N,12121.3322,W,1,07,1.0,9.0,M, , , ,0000*18

GGA data format:

Name	Example	Units	Descriptions
Message ID	$GPGGA		GGA protocol header
UTC Time	121212.456		hhmmss.sss
Latitude	3232.1234		ddmm.mmmm
N/S Indicator	N		N = North or S = South
Longitude	12121.3322		dddmm.mmmm
E/W Indicator	W		E = East or W = West
Position Fix Indicator	1		0: Fix invalid or not available 1: Fix valid, GPS SPS mode 2: Fix valid, Differential GPS 3; Fix valid, GPS PPS mode
Satellites Used	07		Range 0 to 12
HDOP	1.0		Horizontal Dilution of Precision
MSL Altitude	9.0	Meters	The unit is referring to the next field.
Units	M		Meters
Geoid Separation		Meters	The unit is referring to the next field.
Units	M		Meters
Age of Diff. Corr.		Seconds	Null fields when DGPS is not used
Diff. Ref. Station ID	0000		
Checksum	*18		
<CR> <LF>			End of message termination

4.1.2 Geographic Position with Latitude/ Longitude(GLL)

The example of GPGLL:

$GPGLL,3232.1234,N,12121.3322,W,121212.456,A*2C

GLL data format:

Name	Example	Units	Descriptions
Message ID	$GPGLL		GLL protocol header
Latitude	3232.1234		ddmm.mmmm
N/S Indicator	N		N = North or S = South
Longitude	12121.3322		dddmm.mmmm
E/W Indicator	W		E = East or W = West
UTC Time	121212.456		hhmmss.sss
Status	A		A = data valid or V = data not valid
Checksum	*2C		
<CR> <LF>			End of message termination

4.1.3 GNSS DOP and Active Satellites (GSA)

The example of GPGSA:

$GPGSA,A,3,07,09,15,27,02,04,26, , , , , ,1.8,1.0,1.5*25

GSA data format:

Name	Example	Units	Descriptions
Message ID	$GPGSA		GSA protocol header
Mode 1	A		M: Manual -- forced to operate in 2D or 3D mode A: 2D automatic -- allowed to automatically switch 2D/3D
Mode 2	3		1: Fix Not Available 2: 2D 3: 3D
Satellite Used	07		Sv on Channel 1
Satellite Used	09		Sv on Channel 2
Satellite Used	15		Sv on Channel 3
Satellite Used	27		Sv on Channel 4
Satellite Used	02		Sv on Channel 5
Satellite Used	04		Sv on Channel 6

Satellite Used	26		Sv on Channel 7
……..			…….
Satellite Used			Sv on Channel 12
PDOP	1.8		Position Dilution of Precision
HDOP	1.0		Horizontal Dilution of Precision
VDOP	1.5		Vertical Dilution of Precision
Checksum	*25		
<CR> <LF>			End of message termination

4.1.4 GNSS Satellites in View (GSV)

The example of GPGSV:

$GPGSV,2,1,07,09,25,305,42,07,68,058,42,27,38,235,41,05,33,105,41*68
$GPGSV,2,2,07,02,48,067,41,15,21,048,42,04,15,168,42*40

First GSV frame data format:

Name	Example	Units	Descriptions
Message ID	$GPGSV		GSV protocol header
Number of Messages	2		Range 1 to 3
Message Number	1		Range 1 to 3
Satellite in view	07		Total 7 satellites
Satellite ID	09		SV on Channel 1, (Range 1 to 32)
Elevation	25	Degrees	Channel 1, (Maximum 90)
Azimuth	305	Degrees	Channel 1, (True, range 0 to 359)
SNR (C/No)	42	DB/Hz	Channel 1, (Range 0 to 99), Null when not tracking
……..			……..
Satellite ID	04		SV on Channel 4, (Range 1 to 32)
Elevation	15	Degrees	Channel 4, (Maximum 90)
Azimuth	168	Degrees	Channel 4, (True, range 0 to 359)
SNR (C/No)	42	DB/Hz	Channel 4, (Range 0 to 99), Null when not tracking
Checksum	*40		
<CR> <LF>			End of message termination

Second GSV frame data format:

Name	Example	Units	Descriptions
Message ID	$GPGSV		GSV protocol header
Number of Messages	2		Range 1 to 3
Message Number	2		Range 1 to 3
Satellite in view	07		Total 7 satellites
Satellite ID	02		SV on Channel 5, (Range 1 to 32)
Elevation	48	Degrees	Channel 5, (Maximum 90)
Azimuth	67	Degrees	Channel 5, (True, range 0 to 359)
SNR (C/No)	41	DB/Hz	Channel 5, (Range 0 to 99), Null when not tracking
…….			…..
Satellite ID	05		SV on Channel 7, (Range 1 to 32)
Elevation	33	Degrees	Channel 7, (Maximum 90)
Azimuth	105	Degrees	Channel 7, (True, range 0 to 359)
SNR (C/No)	40	DB/Hz	Channel 7, (Range 0 to 99), Null when not tracking
Checksum	*68		
<CR> <LF>			End of message termination

NOTE: Items, Satellite ID, Elevation, Azimuth and SNR are repeated for each satellite in view. And up to a maximum of four satellites per frame. Other residual satellites in view must be sent in subsequent frame. These fields will be null if unused.

4.1.5 Recommended Minimum Specific GNSS Data (RMC)

The example of GPRMC:

$GPRMC,121212.456,A,3232.1234,N,12121.3322,W,0.15,305.12,121299, ,*22

RMC data format:

Name	Example	Units	Descriptions
Message ID	$GPRMC		RMC protocol header
UTC Time	121212.456		hhmmss.sss
Status	A		A = data valid or V = data not valid
Latitude	3232.1234		ddmm.mmmm
N/S Indicator	N		N = North or S = South
Longitude	12121.3322		dddmm.mmmm
E/W Indicator	W		E = East or W = West
Speed Over Ground	0.15	knots	
Course Over Ground	305.12	Degrees	True
Date	121299		ddmmyy
Magnetic Variation (Note1)		Degrees	E=east or W=west
Checksum	*22		
<CR> <LF>			End of message termination

Note1: FORMAX Technology Inc. does not support magnetic declination. All “ course over ground ” data are geodetic WGS84 directions.

4.1.6 Course over Ground and Ground Speed (VTG)

The example of GPVTG:

$GPVTG,305.12,T, ,M,0.15,N,0.3,K*6C

RMC data format:

Name	Example	Units	Descriptions
Message ID	$GPVTG		VTG protocol header
Course	305.12	Degrees	Measured heading
Reference	T		True
Course		Degrees	Measured heading
Reference	M		Magnetic (Note1)
Speed	0.15	knots	The unit is in knots referring to next field
Unit	N		Unit in Knots
Speed	0.3	km/hr	Measured horizontal speed, The unit is in km/hr referring to next field
Unit	K		Unit in kilo-meters per hour
Checksum	*5C		
<CR> <LF>			End of message termination

Note1: FORMAX Technology Inc. does not support magnetic declination. All " course over ground " data are geodetic WGS84 directions.

4.2 Binary Message

This **FORMAX** engine board also supports the messages in binary format. The usage of binary messages is different from that of standard NMEA messages. The standard NMEA messages are used to report the position, time, and satellites status information. The binary messages are also used to report the position, time and satellites status information, and more to control the GPS system through the serial communication interface. The detail specification is by request.

4.3 Earth Datum Support

In addition to WGS84, there are total 218 kinds of earth datum supported by **FORMAX** engine board other different datum support is by request.

4.4 Manufacturing Default

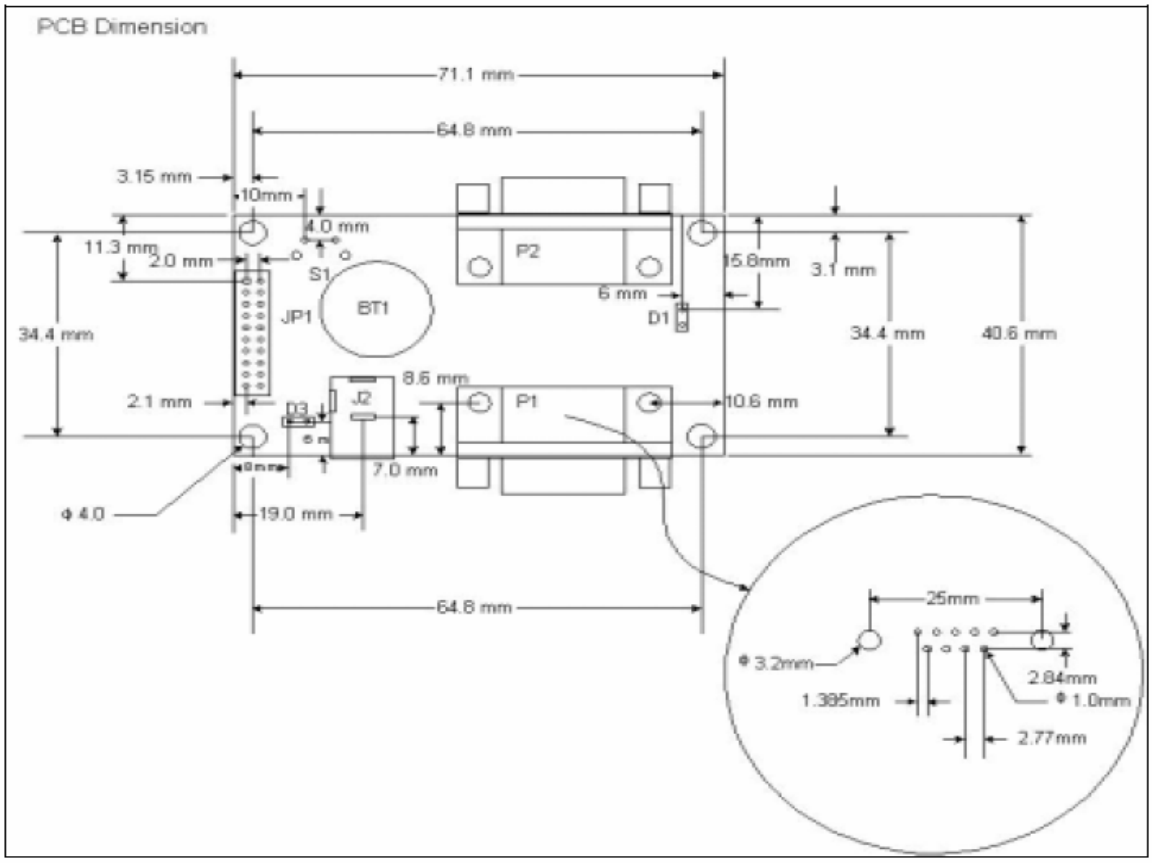
The setting and selection of the configuration could be executed by the utility GPSinfo provided by **FORMAX**. The manufacturing default is as following:

Datum: WGS84.
Baud Rate: 4800.
Output: GGA, GSA, GSV, RMC or by demand.

5 Engine Board Evaluation Kit

5.1 Overview

The Evaluation Kit is defined specially for testing the **FORMAX** engine board. It connects to the **FORMAX** engine board through JP1, 20-pin connector and converts the serial communication signals from TTL level to the RS-232 signal level. And it connects the RS-232 signals to PC's COM port through P1 or P2. One can run the test program on PC to get the NMEA 0183 data and issue commands from PC for binary mode operations.
The Evaluation Kit outline is shown as below:



Notes:

1. J2: The DC power connector, is connect to DC +5V power supply.
2. JP1: Serial communication interface connector, is defined in section 3.2.
3. P1: RS-232 port-1, is used to output the NMEA-0183 data and also used to input and output binary messages.
4. P2: RS-232 port-2, is used for transmitting and receiving data from PC for engineering.
5. The dimension of engine board evaluation kit only for referring

5.2 Serial Communication interface

Refer the section 3.2 to see the pin definitions of 20-pin serial communication interface connector.

5.3 Installation

First, it needs to connect the **FORMAX** engine board to the evaluation kit. The evaluation kit provides the physical link conversion for the serial communication. It can connect the P1 or P2 RS-232 port of the evaluation kit to COM port of the PC for testing.

Second, it needs to setup the testing software on PC. **FORMAX** supports a testing utility, GPSinfo on PC for customer test. It can also run other GPS testing tool from third party supplier.

5.4 LED indications

There are two LEDs on the evaluation kit. One is for power on indicator and another is the GPS status indicator.

6 Earth Datum

6.1 Support Earth Datum

The following is a list of the earth datum index and the corresponding earth datum name. The Datum ID is referred to issue the binary message for selecting the datum.

Region	Ellipsoid	Datum	dX	dY	dZ
Global	WGS84	WGS84	0	0	0
Afghanistan	International 1924	Herat North	-333	-222	114
(Africa, Center) MEAN FOR Burkina Faso & Niger	Clarke 1880	Point 58	-106	-129	165
(Africa, East) MEAN FOR Kenya;Tanzania	Clarke 1880	Arc 1960	-160	-6	-302
(Africa) MEAN FOR Ethiopia;Sudan	Clarke 1880	Adindan	-166	-15	204
(Africa, Southeast) MEAN FOR Botswana; Lesotho; Malawi; Swaziland; Zaire; Zambia; Zimbabwe	Clarke 1880	Arc 1950	-143	-90	-294
Alaska (Aleutian Ids East of 180øW)	Clarke 1866	North American 1927	-2	152	149
Alaska (Aleutian Ids West of 180øW)	Clarke 1866	North American 1927	2	204	105
Alaska (Excluding Aleutian Ids)	Clarke 1866	North American 1927	-5	135	172
Alaska (Excluding Aleutian Ids)	GRS 80	North American 1983	0	0	0
Albania	Krassovsky 1940	S-42 (Pulkovo 1942)	24	-130	-92
Aleutian Ids	GRS 80	North American 1983	-2	0	4
Algeria	Clarke 1880	North Sahara 1959	-186	-93	310
Algeria	Clarke 1880	Voirol 1960	-123	-206	219
(America, Center) Mexico; Central America	GRS 80	North American 1983	0	0	0
(America, Center) Bahamas; Florida	Clarke 1866	Cape Canaveral	-2	151	181

(America, Center) MEAN FOR Antigua; Barbados; Barbuda; Caicos Islands; Cuba; Dominican Republic; Grand Cayman; Jamaica; Turks Islands	Clarke 1866	North American 1927	-3	142	183
(America, Center) MEAN FOR Bolivia; Chile; Colombia; Ecuador; Guyana; Peru; Venezuela	International 1924	Provisional South American 1956	-288	175	-376
(America, South) MEAN FOR Belize; Costa Rica; El Salvador; Guatemala; Honduras; Nicaragua	Clarke 1866	North American 1927	0	125	194
(America, South) MEAN FOR Argentina; Bolivia; Brazil; Chile; Colombia; Ecuador; Guyana; Paraguay; Peru; Trinidad & Tobago; Venezuela	South American 1969	South American 1969	-57	1	-41
American Samoa Islands	Clarke 1866	American Samoa 1962	-115	118	426
Antarctica (McMurdo Camp Area)	International 1924	Camp Area Astro	-104	-129	239
Antigua (Leeward Islands)	Clarke 1880	Antigua Island Astro 1943	-270	13	62
Argentina	International 1924	Campo Inchauspe	-148	136	90
Argentina	South American 1969	South American 1969	-62	-1	-37
Ascension Island	International 1924	Ascension Island 1958	-205	107	53
(Asia, East) MEAN FOR Iraq; Israel; Jordan; Lebanon; Kuwait; Saudi Arabia; Syria	International 1924	European 1950	-103	-106	-141
(Asia, East) MEAN FOR Japan; South Korea;	Bessel 1841	Tokyo	-148	507	685

Okinawa					
(Asia, Center) India; Nepal	Everest (India 1956)	Indian	295	736	257
(Asia, South) Brunei; E. Malaysia (Sabah Sarawak)	Everest (Sabah Sarawak)	Timbalai 1948	-679	669	-48
(Atlantic Ocean) Porto Santo; Madeira Islands	International 1924	Porto Santo 1936	-499	-249	314
Australia; Tasmania	Australian National	Australian Geodetic 1966	-133	-48	148
Australia; Tasmania	Australian National	Australian Geodetic 1984	-134	-48	149
Azores (Corvo & Flores Islands)	International 1924	Observatorio Meteorologico 1939	-425	-169	81
Azores (Faial; Graciosa; Pico; Sao Jorge; Terceira)	International 1924	Graciosa Base SW 1948	-104	167	-38
Azores (Sao Miguel; Santa Maria Ids)	International 1924	Sao Braz	-203	141	53
Bahamas (Except San Salvador Id)	Clarke 1866	North American 1927	-4	154	178
Bahamas (San Salvador Island)	Clarke 1866	North American 1927	1	140	165
Bahrain	International 1924	Ain el Abd 1970	-150	-250	-1
Bangladesh	Everest (India 1830)	Indian	282	726	254
Bermuda	Clarke 1866	Bermuda 1957	-73	213	296
Bolivia	International 1924	Provisional South American 1956	-270	188	-388
Bolivia	South American 1969	South American 1969	-61	2	-48
Botswana	Clarke 1880	Arc 1950	-138	-105	-289
Brazil	International 1924	Corrego Alegre	-206	172	-6
Brazil	South American 1969	South American 1969	-60	-2	-41
Burkina Faso	Clarke 1880	Adindan	-118	-14	218
Burundi	Clarke 1880	Arc 1950	-153	-5	-292
Cameroon	Clarke 1880	Adindan	-134	-2	210
Cameroon	Clarke 1880	Minna	-81	-84	115
Canada	GRS 80	North American	0	0	0

		1983			
(Canada) MEAN FOR Canada	Clarke 1866	North American 1927	-10	158	187
Canada (Alberta; British Columbia)	Clarke 1866	North American 1927	-7	162	188
Canada (Manitoba; Ontario)	Clarke 1866	North American 1927	-9	157	184
Canada (New Brunswick; Newfoundland; Nova Scotia; Quebec)	Clarke 1866	North American 1927	-22	160	190
Canada (Northwest Territories; Saskatchewan)	Clarke 1866	North American 1927	4	159	188
Canada (Yukon)	Clarke 1866	North American 1927	-7	139	181
Canal Zone	Clarke 1866	North American 1927	0	125	201
Canary Islands	International 1924	Pico de las Nieves	-307	-92	127
Caroline Islands	International 1924	Kusaie Astro 1951	647	1777	-1124
Cayman Brac Island	Clarke 1866	L. C. 5 Astro 1961	42	124	147
Chile	South American 1969	South American 1969	-75	-1	-44
Chile (Near 53øS) (Hito XVIII)	International 1924	Provisional South Chilean 1963	16	196	93
Chile (Northern; Near 19øS)	International 1924	Provisional South American 1956	-270	183	-390
Chile (Southern; Near 43øS)	International 1924	Provisional South American 1956	-305	243	-442
Cocos Islands	Australian National	Anna 1 Astro 1965	-491	-22	435
Colombia	International 1924	Bogota Observatory	307	304	-318
Colombia	International 1924	Provisional South American 1956	-282	169	-371
Colombia	South American 1969	South American 1969	-44	6	-36
Congo	Clarke 1880	Pointe Noire 1948	-148	51	-291
CONUS	GRS 80	North American 1983	0	0	0
(CONUS)	Clarke 1866	North American	-8	160	176

MEAN FOR CONUS		1927			
(CONUS) MEAN FOR CONUS (East of Mississippi; River Including Louisiana; Missouri; Minnesota)	Clarke 1866	North American 1927	-9	161	179
(CONUS) MEAN FOR CONUS (West of Mississippi; River Excluding Louisiana; Minnesota; Missouri)	Clarke 1866	North American 1927	-8	159	175
Croatia -Serbia, Bosnia-Herzegovina	Bessel 1841 (Namibia)	Hermannskogel Datum	653	-212	449
Cuba	Clarke 1866	North American 1927	-9	152	178
Cyprus	International 1924	European 1950	-104	-101	-140
Czechoslavakia	Krassovsky 1940	S-42 (Pulkovo 1942)	26	-121	-78
Czechoslavakia (Prior 1 JAN 1993)	Bessel 1841	S-JTSK	589	76	480
Deception Island; Antarctia	Clarke 1880	Deception Island	260	12	-147
Diego Garcia	International 1924	ISTS 073 Astro 1969	208	-435	-229
Djibouti	Clarke 1880	Ayabelle Lighthouse	-79	-129	145
East Falkland Island	International 1924	Sapper Hill 1943	-355	21	72
Easter Island	International 1924	Easter Island 1967	211	147	111
Ecuador	International 1924	Provisional South American 1956	-278	171	-367
Ecuador	South American 1969	South American 1969	-48	3	-44
Ecuador (Baltra; Galapagos)	South American 1969	South American 1969	-47	26	-42
Efate & Erromango Islands	International 1924	Bellevue (IGN)	-127	-769	472
Egypt	International 1924	European 1950	-130	-117	-151
Egypt	Helmert 1906	Old Egyptian	-130	110	-13

		1907			
England	Airy 1830	Ordnance Survey Great Britain 1936	371	-112	434
England; Channel Islands; Scotland; Shetland Islands	International 1924	European 1950	-86	-96	-120
England; Ireland; Scotland; Shetland Islands	International 1924	European 1950	-86	-96	-120
(England) MEAN FOR England; Isle of Man; Scotland; Shetland Islands; Wales	Airy 1830	Ordnance Survey Great Britain 1936	375	-111	431
England; Isle of Man; Wales	Airy 1830	Ordnance Survey Great Britain 1936	371	-111	434
(England) Scotland; Shetland Islands	Airy 1830	Ordnance Survey Great Britain 1936	384	-111	425
Espirito Santo Island	International 1924	Santo (DOS) 1965	170	42	84
Estonia	Bessel 1841	Estonia; Coordinate System 1937	374	150	588
Ethiopia	Clarke 1880	Adindan	-165	-11	206
Ethiopia (Eritrea)	Bessel 1841	Massawa	639	405	60
(European) MEAN FOR Austria; Finland; Netherlands; Norway; Spain; Sweden; Switzerland	International 1924	European 1979	-86	-98	-119
(European) MEAN FOR Austria; Belgium; Denmark; Finland; France; W Germany; Gibraltar; Greece; Italy; Luxembourg; Netherlands; Norway; Portugal; Spain; Sweden; Switzerland	International 1924	European 1950	-87	-98	-121
(European) MEAN FOR Austria; Denmark; France; W	International 1924	European 1950	-87	-96	-120

Germany; Netherlands; Switzerland					
(European) Finland; Norway	International 1924	European 1950	-87	-95	-120
(European) Portugal; Spain	International 1924	European 1950	-84	-107	-120
Fiji (Viti Levu Island)	Clarke 1880	Viti Levu 1916	51	391	-36
Gabon	Clarke 1880	M'Poraloko	-74	-130	42
Ghana	Clarke 1880	Leigon	-130	29	364
Global Definition	WGS 72	WGS 1972	0	0	0
Greece	International 1924	European 1950	-84	-95	-130
Greenland (Hayes Peninsula)	Clarke 1866	North American 1927	11	114	195
Greenland (South)	International 1924	Qornoq	164	138	-189
Guadalcanal Island	International 1924	GUX 1 Astro	252	-209	-751
Guam	Clarke 1866	Guam 1963	-100	-248	259
Guinea	Clarke 1880	Dabola	-83	37	124
Guinea-Bissau	International 1924	Bissau	-173	253	27
Guyana	International 1924	Provisional South American 1956	-298	159	-369
Guyana	South American 1969	South American 196	-53	3	-47
Hawaii	GRS 80	North American 1983	1	1	-1
Hawaii	Clarke 1866	Old Hawaiian	89	-279	-183
Hong Kong	International 1924	Hong Kong 1963	-156	-271	-189
Hungary	Krassovsky 1940	S-42 (Pulkovo 1942)	28	-121	-77
Iceland	International 1924	Hjorsey 1955	-73	46	-86
Indonesia	Indonesian 1974	Indonesian 1974	-24	-15	5
Indonesia (Bangka & Belitung Ids)	Bessel 1841	Bukit Rimpah	-384	664	-48
Indonesia (Kalimantan)	Bessel 1841	Gunung Segara	-403	684	41
Indonesia (Sumatra)	Bessel 1841	Djakarta (Batavia)	-377	681	-50
Iran	International 1924	European 1950	-117	-132	-164
Ireland	Modified Airy	Ireland 1965	506	-122	611
Italy (Sardinia)	International 1924	European 1950	-97	-103	-120
Italy (Sardinia)	International	Rome 1940	-225	-65	9

	1924				
Italy (Sicily)	International 1924	European 1950	-97	-88	-135
Iwo Jima	International 1924	Astro Beacon E 1945	145	75	-272
Japan	Bessel 1841	Tokyo	-148	507	685
Johnston Island	International 1924	Johnston Island 1961	189	-79	-202
Kauai	Clarke 1866	Old Hawaiian	45	-290	-172
Kazakhstan	Krassovsky 1940	S-42 (Pulkovo 1942)	15	-130	-84
Kenya	Clarke 1880	Arc 1960	-157	-2	-299
Kerguelen Island	International 1924	Kerguelen Island 1949	145	-187	103
Latvia	Krassovsky 1940	S-42 (Pulkovo 1942)	24	-124	-82
Lesotho	Clarke 1880	Arc 1950	-125	-108	-295
Liberia	Clarke 1880	Liberia 1964	-90	40	88
Madagascar	International 1924	Tananarive Observatory 1925	-189	-242	-91
Mahe Island	Clarke 1880	Mahe 1971	41	-220	-134
Malawi	Clarke 1880	Arc 1950	-161	-73	-317
Mali	Clarke 1880	Adindan	-123	-20	220
Malta	International 1924	European 1950	-107	-88	-149
Marcus Island	International 1924	Astronomical Station 1952	124	-234	-25
Marshall Islands	Hough 1960	Wake-Eniwetok 1960	102	52	-38
Mascarene Islands	International 1924	Reunion	94	-948	-1262
Maui	Clarke 1866	Old Hawaiian	65	-290	-190
Mexico	Clarke 1866	North American 1927	-12	130	190
Midway Islands	International 1924	Midway Astro 1961	912	-58	1227
Montserrat (Leeward Islands)	Clarke 1880	Montserrat Island Astro 1958	174	359	365
Morocco	Clarke 1880	Merchich	31	146	47
Namibia	Bessel 1841 (Namibia)	Schwarzeck	616	97	-251
Nevis; St. Kitts (Leeward Islands)	Clarke 1880	Fort Thomas 1955	-7	215	225
New Georgia Islands (Gizo Island)	International 1924	DOS 1968	230	-199	-752
New Zealand	International 1924	Geodetic Datum 1949	84	-22	209

New Zealand (Chatham Island)	International 1924	Chatham Island Astro 1971	175	-38	113
Nigeria	Clarke 1880	Minna	-92	-93	122
Oahu	Clarke 1866	Old Hawaiian	58	-283	-182
Okinawa	Bessel 1841	Tokyo	-158	507	676
Oman	Clarke 1880	Oman	-346	-1	224
Oman (Masirah Island)	Clarke 1880	Nahrwan	-247	-148	369
(Pacific) MEAN FOR Hawaii; Kauai; Maui; Oahu	Clarke 1866	Old Hawaiian	61	-285	-181
Pakistan	Everest (Pakistan)	Indian	283	682	231
Paraguay	International 1924	Chua Astro	-134	229	-29
Paraguay	South American 1969	South American 1969	-61	2	-33
Peru	International 1924	Provisional South American 1956	-279	175	-379
Peru	South American 1969	South American 1969	-58	0	-44
Philippines (Excluding Mindanao)	Clarke 1866	Luzon	-133	-77	-51
Philippines (Mindanao)	Clarke 1866	Luzon	-133	-79	-72
Phoenix Islands	International 1924	Canton Astro 1966	298	-304	-375
Pitcairn Island	International 1924	Pitcairn Astro 1967	185	165	42
Poland	Krassovsky 1940	S-42 (Pulkovo 1942)	23	-124	-82
Puerto Rico; Virgin Islands	Clarke 1866	Puerto Rico	11	72	-101
Qatar	International 1924	Qatar National	-128	-283	22
Republic of Maldives	International 1924	Gan 1970	-133	-321	50
Romania	Krassovsky 1940	S-42 (Pulkovo 1942)	28	-121	-77
Russia	Krassovsky 1940	Pulkovo 1942	28	-130	-95
Salvage Islands	International 1924	Selvagem Grande 1938	-289	-124	60
Saudi Arabia	International 1924	Ain el Abd 1970	-143	-236	7
Saudi Arabia	Clarke 1880	Nahrwan	-243	-192	477
Senegal	Clarke 1880	Adindan	-128	-18	224
Sierra Leone	Clarke 1880	Sierra Leone	-88	4	101

		1960			
Singapore	Modified Fischer 1960	South Asia	7	-10	-26
Somalia	Krassovsky 1940	Afgooye	-43	-163	45
South Africa	Clarke 1880	Cape	-136	-108	-292
St Helena Island	International 1924	Astro DOS 71/4	-320	550	-494
Sudan	Clarke 1880	Adindan	-161	-14	205
South Georgia Islands	International 1924	ISTS 061 Astro 1968	-794	119	-298
South Korea	GRS 80	Korean Geodetic System	0	0	0
South Korea	Bessel 1841	Tokyo	-147	506	687
Sri Lanka	Everest (India 1830)	Kandawala	-97	787	86
Suriname	International 1924	Zanderij	-265	120	-358
Swaziland	Clarke 1880	Arc 1950	-134	-105	-295
Taiwan	International 1924	Hu-Tzu-Shan	-637	-549	-203
Tanzania	Clarke 1880	Arc 1960	-175	-23	-303
Tern Island	International 1924	Astro Tern Island (FRIG) 1961	114	-116	-333
Thailand	Everest (India 1830)	Indian 1954	217	823	299
Thailand	Everest (India 1830)	Indian 1975	210	814	289
Trinidad & Tobago	South American 1969	South American 1969	-45	12	-33
Tristan da Cunha	International 1924	Tristan Astro 1968	-632	438	-609
Tunisia	Clarke 1880	Carthage	-263	6	431
Tunisia	International 1924	European 1950	-112	-77	-145
Trinidad & Tobago	International 1924	Naparima BWI	-10	375	165
United Arab Emirates Uruguay	Clarke 1880 International 1924	Nahrwan Yacare	-249 -155	-156 171	381 37
Venezuela	International 1924	Provisional South American 1956	-295	173	-371
Venezuela	South American 1969	South American 1969	-45	8	-33
Vietnam (Con Son Island)	Everest (India 1830)	Indian 1960	182	915	344
Vietnam (Near	Everest (India	Indian 1960	198	881	317

16øN)	1830)				
Wake Atoll	International 1924	Wake Island Astro 1952	276	-57	149
Wales	Airy 1830	Ordnance Survey Great Britain 1936	370	-108	434
West Malaysia & Singapore	Everest (Malay. & Sing)	Kertau 1948	-11	851	5
Zaire	Clarke 1880	Arc 1950	-169	-19	-278
Zambia	Clarke 1880	Arc 1950	-147	-74	-283
Zimbabwe	Clarke 1880	Arc 1950	-142	-96	-293