SEL-2401 Satellite-Synchronized Clock Instruction Manual

Features, Benefits, and Applications

The role of satellite-synchronized clocks has grown from basic sequence-of-event and fault recorder time referencing to mission-critical roles such as synchrophasor measurement and detailed event analysis. These new applications require that satellite clocks meet the same environmental standards and be as reliable as the protective relays and other high-reliability devices with which these clocks are used.

The SEL-2401 Satellite-Synchronized Clock provides the following features:

- **Reliability**. Apply in harsh environments. Meets IEEE C37.90 and IEC 60255 protective relay surge and environmental standards.
- **Accuracy**. Apply for synchrophasor, relay event correlation, and other high-accuracy timing needs. Demodulated IRIG outputs with accuracy of ±100 ns average (±500 ns peak) meet requirements for existing and future timing applications.
- **Low Cost, High Function**. Provide demodulated IRIG-B timecode with time-quality values specified by IEEE C37.118-2005 (Standards for Synchrophasors for Power Systems). A custom **DST** command and preset daylight-saving time settings for the European Union and the United States of America provide automatic advance and return for daylight-saving time anywhere in the world.

Product Overview

Figure 1 and *Figure 2* provide a functional overview of the bottom and top of the SEL-2401.

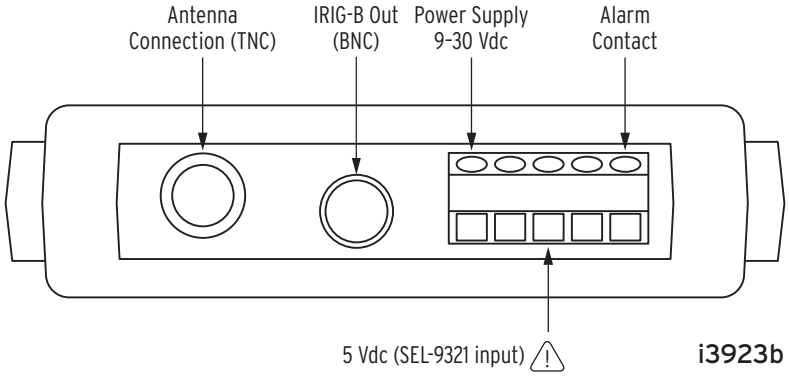


Figure 1 SEL-2401 Functional Overview

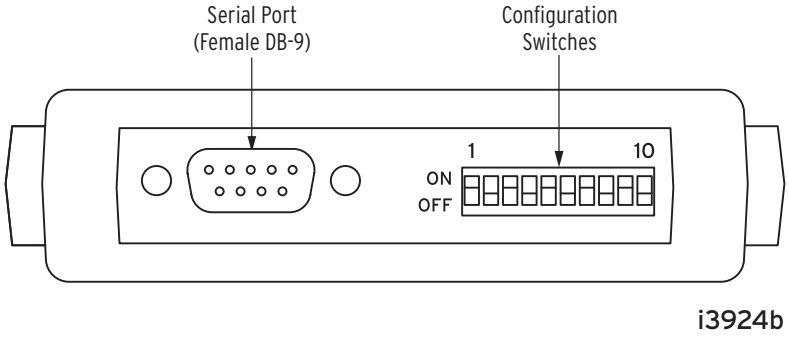


Figure 2 SEL-2401 Functional Overview Top

Accessories

Accessories enhance your SEL-2401 application. For a complete list of available accessories refer to the SEL Satellite-Synchronized Clocks Accessory Guide at selinc.com/SEL-2401/.

Installation and Maintenance

Antenna

The SEL-2401 GPS antenna must be installed in accordance with national electric codes. A clear view of the sky, 360 degrees, is preferred. The antenna is housed in waterproof packaging designed to withstand exposure to shock, excessive vibration, extreme temperatures, rain, snow, and sunlight. Position the antenna so that the radome points skyward.

The GPS antenna should be located low and close to the control house roof, above maximum snow accumulation and away from roof maintenance activities. If the SEL-2401 is in an outdoor cabinet, mount the antenna on the top of the cabinet or directly to a utility pole by using the optional antenna mounting hardware.

Lightning Protection

Mounting the antenna on an equipment building roof or cabinet is safest because the potential rise on the outside of either of these structures would be more or less equal to the potential on the inside. A lightning protector should be used to equalize the difference in potential that can occur between the center conductor and the shield of the coaxial cable between the antenna and the clock. The higher the GPS antenna is mounted on a support structure, the greater the probability of equipment damage resulting from a lightning strike.

In all surge-protector applications, you should mount the surge protector at the building or enclosure entrance and ground the surge-protector body at this entrance. Ground the clock to the same point as the surge-protector ground to avoid ground-rise-potential damage.

Antenna Cabling

The SEL-9524, the Gas Tube Coaxial Surge Protector, and the SEL-2401 are all equipped with TNC female connectors. The SEL-2401 supports a maximum cable length of 152 meters (500 ft) for LMR-400 (SEL-C961) antenna cable. Users can choose RG-8X (SEL-C965) cables if long distances are not required.

Power Connections

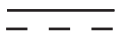
The SEL-2401 normal power input is 9–30 Vdc. The POWER terminals are not isolated from chassis to ground. Use 0.4 mm^2 (26 AWG) wire (or heavier) with a minimum temperature rating of 90°C to connect to the POWER terminals. Connection to external power must comply with IEC 60947-1 and IEC 60947-3.

The dc power source must be connected with the proper polarity, as indicated by the + and – symbols on the device. Use an external fuse holder in the + lead with a fuse rated for 0.5 A, medium blow. Upon connecting power, the **SATELLITE LOCK** and **OUTPUT** LEDs will illuminate for a short period followed by the **ENABLED** LED.

⚠CAUTION
This terminal is for use with a regulated +5 Vdc source only.

The terminal marked with the ⚠ symbol (as shown in *Figure 1*) is reserved for use with the +5 Vdc output of the SEL-9321 power supply module. The SEL-9321 +5 Vdc supply is internally protected for overcurrent conditions. When operating the SEL-2401 with the ⚠ supply input, the 9–30 Vdc input must not be used. When operating the SEL-2401 with the 9–30 Vdc input, the ⚠ terminal must not be used. Connecting both power inputs will result in equipment damage. The – connection is used in conjunction with either input to provide the return connection.

NOTE: The front-panel marking shown below indicates a direct-current connection.



When connecting the SEL-9321 power supply to the SEL-2401, keep this connection less than or equal to three meters. Use twisted-shielded pair cable with the shield grounded at the SEL-9321.

Disconnect Device

For installations, place an external circuit breaker no more than 3 m (9.8 ft) from the equipment. The circuit breaker must comply with IEC 60947-1 and IEC 60947-3 or an equivalent approved disconnect device appropriate for the country of installation and be identified as the disconnect device for this equipment. The overcurrent (OC) device must be sized to the conductors suppling the equipment. If the conductors can handle 20 A then the OC device can be 20 A or lower.

Compression Terminal Connectors

Terminate connections to the SEL-2401 compression terminal by stripping 8.0 mm (0.31 in) of the wire insulation. Wire size minimum is 26 AWG, and wire size maximum is 16 AWG. Tightening torque for the terminal connector screws is 0.50 Nm (4.4 in-lb).

Indicators

The SEL-2401 has three status indicator LEDs. *Table 1* describes these indicators which annunciate the status of the clock.

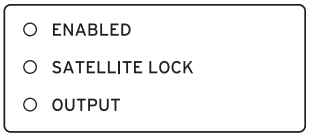


Table 1 Status Indicator LEDs

Label	Color	Description
ENABLED	Green	All self-tests passed
SATELLITE LOCK	Green	Clock has tracked four or more satellites and is currently tracking one or more satellites
OUTPUT	Green	Clock is outputting accurate time with a time quality (TQ) of 6 (100 microseconds) or better

Lock Sequence

The SEL-2401 front-panel LEDs show clock progress from start to satellite lock.

Cold-Start Sequence

NOTE: Carrier-to-noise density (C/N_0) is a measurement of the signal quality comparing the signals the clock needs to perform its functions to the general noise that the receiver receives. This density is expressed in dB-Hz, and the larger the number, the better the signal. 30 dB-Hz is a minimum accepted signal level.

The SEL-2401 does not have battery backup to retain time or almanac information. When initially powered and prior to acquiring satellite lock, the SEL-2401 reports the time as `99:99:99`. Satellite lock occurs when the SEL-2401 detects and tracks at least four satellites each with a carrier-to-noise density (C/N_0) of 30 dB-Hz or better. After satellite lock, the clock must continue to track at least one satellite to remain locked. The correct time, per the offsets programmed with Switches **4** through **9**, is reported when the **OUTPUT** LED is illuminated.

IRIG-B

IRIG-B is a serial data time format consisting of a 1-second frame that contains 100 pulses divided into fields. The time-synchronized device decodes the second, minute, hour, and day fields and sets the device internal time clock upon detecting valid time data in the IRIG time mode.

The SEL-2401 provides only an unmodulated IRIG-B output (according to the Range Commanders Council IRIG Standard 200-04). Unmodulated IRIG-B time-code is IRIG-B00*x*. The last digit, either 2 or 0, indicates the coded expression(s).

The time-code format IRIG-B002 is binary-coded decimal (BCD) timecode (HH,MM,SS,DDD). This format represents traditional or legacy IRIG-B.

The time-code format IRIG-B000 consists of BCD timecode (HH,MM,SS,DDD), plus straight binary seconds (SBS) of the day (0–86400 s), and also contains control function extensions that include data for: year, leap second, daylight-saving time, UTC time offset, time quality, and parity (odd).

These control function extensions are described in IEEE C37.118-2005 Annex F.

Cleaning

Use care when cleaning the SEL-2401. Use only a mild soap or detergent solution and a damp cloth to clean the chassis. Be careful cleaning the front and rear panels because a permanent plastic sheet covers each panel.

Do not use abrasive materials, polishing compounds, or harsh chemical solvents (such as xylene or acetone) on any surface.

Settings and Commands

Settings

Most settings for the SEL-2401 are performed through configuration switches located on the top end of the device (shown in *Figure 2*).

The switches are labeled **SW1**–**SW10** starting from the left side. The switch settings are listed in *Table 2*.

Table 2 Control (DIP) Switches and Functions

Switch	Function		
1	ON = Password protection disabled (only use to reset password when lost) OFF = Password protection enabled		
2	ON = **ALARM** output does not include loss of satellite lock OFF = Adds loss of satellite lock to **ALARM** output		
3	IRIG-B output format ON = extended IRIG-B000 format (odd parity) OFF = standard IRIG-B002 format		
4–9	Local Time Offset:		
	4	ON	= add to UTC
		OFF	= subtract from UTC
	5	ON	= 8 hour increment
	6	ON	= 4 hour increment
	7	ON	= 2 hour increment
	8	ON	= 1 hour increment
	9	ON	= 1/2 hour increment
10	Daylight-Saving Time (DST) ON = daylight-saving time enabled OFF = daylight-saving time disabled		

Setting Local Time

Control the time format with Switches **SW4**–**SW9**. The clock output is UTC time when these switches are all in the **OFF** position. To set for local time, you need to set the appropriate offset from UTC time.

NOTE: All time configuration switches have a delayed activation time (five seconds), which prevents false time outputs during setting changes while the clock is powered. The clock does not implement a new setting until five seconds after the last switch change.

Always set the clock to the local region standard time (for daylight-saving time, see *Daylight-Saving Time (DST)*). Set Switches **SW4**–**SW9** incrementally. For example, to set the local time to EST (Eastern Standard Time) use the following settings:

SW4 = **OFF** (subtract from UTC time)
SW5 = **OFF**
SW6 = **ON** (4 hour)
SW7 = **OFF**
SW8 = **ON** (1 hour)
SW9 = **OFF**

These settings will set local time to five hours less than UTC time.

Daylight-Saving Time (DST)

The clock supports five modes of DST: Off, Manual, Custom, and two preset modes (EU, USA). Switch **SW10** determines whether the clock adjusts for DST, and it must be switched to **ON** for any of the modes other than Off to operate. The status page **SW10** setting reflects the current DST mode.

Preset DST

The clock has two preset DST configurations: European Union (EU) and North America (USA). When **SW10** is **ON** and a custom DST is not set, the clock determines from its GPS location whether one of these modes should be selected.

If the GPS location is within the area boundary defined by the latitude and longitude, then that preset DST rule is enabled. The status page under **SW10** will reflect either Auto (EU) or Auto (USA). *Table 3* defines the preset DST conditions and when the offsets will be active.

Table 3 Preset DST Conditions

DST Rule	Latitude	Longitude[a]	Start Month	Start Week	Start Day	Start Hour	End Month	End Week	End Day	End Hour
North America (USA)	15° N → 89°N	–170° → –60°	Mar	2nd	Sunday	2:00 a.m. Local	Nov	1st	Sunday	2:00 a.m. Local
European Union (EU)	35° N → 89°N	–15° → 40°	Mar	Last	Sunday	1:00 a.m. UTC	Oct	Last	Sunday	1:00 a.m. UTC

[a] All longitude ranges West to East.

Custom DST

In all areas you can use the **DST ASCII** command to set the date and time when daylight-saving time begins and ends (see *DST Command (Access Level 1 and Access Level 2) on page 11*). This custom DST setting method must be used in areas outside the European Union and North America for implementing automatic daylight-saving time changes. For areas in the preset regions, the **DST** command changes the preprogrammed daylight-saving time, which is useful where local rules differ from regional practice. **SW10** must be set to ON for the Custom DST to operate, and the status page under **SW10** will reflect Auto (CUSTOM).

Manual DST

When the clock is operating without a custom daylight-saving time and outside of the defined preset DST areas, the clock is operating in manual DST mode. This will be reflected on the status page under **SW10** as MANUAL. **SW10** advances the time manually by one hour when ON. When you set Manual DST, the time

changes when the seconds output reaches 00 after crossing 25 seconds. For example, if the present time is 08:09:10 when the DST setting is turned to ON, the time will change at the end of the immediate minute from 08:09:59 to 09:10:00. However, if the current time is 03:45:28 when the DST setting is turned to ON, the time will change at the end of the following minute from 03:46:59 to 04:47:00. The clock uses this delay to transmit the correct IRIG-B time-change notification sequence to downstream relays and other equipment.

Serial Port Communications

The SEL-2401 has one EIA-232 serial port. The fixed serial port settings are shown in *Table 4*.

Table 4 Serial Port Configuration

Data Rate:	9600 bps
Data Bits:	8
Stop Bits:	1
Parity:	None
Port Time-Out:	15 minutes

Serial Port Connections

Pinout functions on the rear EIA-232 port are shown in *Table 5*. The SEL-2401 does not support hardware or software flow control.

Table 5 Pinout Functions

Pin	Function
Pin 1	N/C
Pin 2	RXD
Pin 3	TXD
Pin 4	N/C
Pin 5	GND
Pin 6	N/C
Pin 7	RTS
Pin 8	CTS
Pin 9	N/C

Communications Port Access Levels

Table 6 shows communications port commands available at each access level. There are two access levels (1 and 2); all commands available at Access Level 1 are also available at Access Level 2.

NOTE: Unlike most SEL products, the SEL-2401 Clock does not have an Access Level 0.

Table 6 Communications Port Command Summary

Serial Command	Access Level	Description
ACC	1	Enter access level
2AC	1	Enter second access level
BX	1	Set broadcast command on serial port
CON	1	Display time controlled pulses for **ALARM**
DST	1	Display custom daylight-saving time settings
LOC	1	Request current location of clock
STA	1	Request status of clock
TIM	1	Request local time
UTC[a]	1	Request UTC
BX	2	Set broadcast command on serial port
CLO	2	Close **ALARM** contact
CON	2	Time controlled pulses for **ALARM**
DST	2	Modify custom daylight-saving time setting
FTQ	2	Force time quality (expires after 18 hours)
L_D	2	Begin firmware upgrade process
OPE	2	Open **ALARM** contact
PAS	2	Change password
STA	2	Request clock status and satellite signal quality
TIM	2	Manually set clock time

[a] UTC = Universal Coordinated Time, also known as GMT, or Greenwich Mean Time.

ACC (Access Level 1)

The default access level is Access Level 1. The => prompt indicates Level 1 access. There is no password protection at this level. Use the **ACC** command from Access Level 2 to return to Access Level 1.

2AC (Access Level 2)

Use the **2AC** command to enter Access Level 2. At this level, the clock issues a password prompt. When you enter the correct password, the **ALARM** contact pulses for one second to indicate that the settings level was accessed. Level 2 access is indicated with the =>> prompt. Note that all commands are available at this level.

SEL ASCII Commands

For all commands, use a terminal emulation program to enter the selected command string followed by a carriage return to issue the command to the clock. (A carriage return is not required for **BX** commands.)

BX Commands (Access Level 1 and Access Level 2)

BX commands give the ability to control and format time broadcasts from the serial port from Access Level 1 and Access Level 2. These broadcast commands allow a way to synchronize a remote PC or RTU through a serial connection.

The broadcast commands have the format BX with one parameter X.

X can have one of the following values:

0 = Deactivates broadcast mode

1 = Activates broadcast of ddd:hh:mm:ss

5 = Activates broadcast of l YY ddd:hh:mm:ss.000

6 = Activates broadcast of ddd:hh:mm:ss q

8 = Activates broadcast of YYYY:ddd:hh:mm:ss q

L = Configures B1, B5, B6 and B8 broadcasts to send local time

U = Configure B1, B5, B6 and B8 broadcasts to send UTC time

The following are definitions of the formats used above:

YY = The last 2 digits of the year (00–99)

YYYY = Date year (2000–9999)

ddd = Day of the year (1–366)

hh = Time hours (00–23)

mm = Time minutes (00–59)

ss = Time seconds (00–59)

l = The satellite lock status, with the values:

<SP> = Locked

? = Unlocked

q = The time quality, with the values:

<SP> = Locked

. = <1 microsecond

* = <10 microsecond

= <100 microsecond

? = >100 microsecond

If the **B1** command is issued, then the clock will enter time broadcast mode and respond with `ddd:hh:mm:ss` once per second. Note that any time the broadcast commands are issued they are not echoed to the screen.

```
=>B1 <Enter>
313:11:17:14
313:11:17:15
313:11:17:16
313:11:17:17
313:11:17:18
313:11:17:19
313:11:17:20
313:11:17:21
313:11:17:22
313:11:17:23
313:11:17:24
313:11:17:25
```

This broadcast will continue indefinitely until the cancel command **B0** is issued.

CLO Command (Access Level 2)

The **CLO** command forces the **ALARM** contact to the closed state and is reset when any key is pressed.

CON (Access Level 1 and Access Level 2)

The **CON** command forces the **ALARM** contact closed one or more times, beginning at a specified time, and with a specified duration. This command implements a precise alarm clock function with an accuracy of ±0.5 ms, and a pulse length that you set.

NOTE: Alarm contacts must be set to the open condition before the alarm clock function can be used. Enter the **CON ALARM** command without any other parameters to open the alarm contact. When the alarm clock function is no longer needed, enter **CON ALARM C** to restore normal contact operation.

The **CON** command is the following format:

CON ALARM [C] [xxxxx.xx] [[yyyy-mm-dd] [Thh:mm:ss.ff]] [P[dd] [Thh:mm:ss.ff]]

where:

- **C** cancels the command. When this parameter is present, the clock ignores all other parameters.
- **xxxxx.xx** is the pulse width in the range 0.01 to 64800.00 seconds. When this parameter is not present, the default pulse width is 1.00 seconds.
- **yyyy-mm-dd** is the pulse local start date. When this parameter is not present, the default start date is today.
- **Thh:mm:ss.ff** is the pulse local start time. When this parameter is not present, the default start time is the local time now.
- **PddThh:mm:ss.ff** is the pulse "period time" or repetition period in the range 0T00:00:00.05 to 99T23:59:59.99. When this parameter is not present, the clock outputs a single pulse (single shot). If the dd parameter is not present, then the clock assumes 0 days. If the Thh:mm:ss.ff parameter is not present, the clock assumes 00:00:00.00.

Once you have entered the **CON** command parameters to output a pulse, the clock displays a confirmation message similar to the following.

```
Alarm Clock Settings are:

Start Date    Start Time     Pulse Width    Repetition Period

yyyy-mm-dd    hh:mm:ss.ff    xxxxx.xx       hh:mm:ss.ff

or            or                            or

Today       Immediately                   Single Shot
Begin Precision Alarm Clock Operation on Alarm (Y,N)?
```

Answer **Y <Enter>** to begin Precision Alarm Clock operation. To return to Normal Alarm operation you must issue the **CON ALARM C <Enter>** command.

Table 7 CON Command Examples (Sheet 1 of 2)

Command	Description
CON ALARM	Begin precision alarm clock operation
CON ALARM 5	Single shot 5-second pulse, starting immediately
CON ALARM T17:00:00	Single shot 1-second pulse, starting at 5:00 p.m. local time
CON ALARM 5.5 T8:29:24.5	Single shot 5.5-second pulse, starting at 8:29:24.50 a.m. local time
CON ALARM PT00:00:10	1-second pulse, repeating every 10 seconds, starting immediately
CON ALARM 0.05 PT00:00:00.25	0.05-second pulse, repeating every 0.25 seconds, starting immediately

Table 7 CON Command Examples (Sheet 2 of 2)

Command	Description
CON ALARM T6:30:00 P1	1-second pulse, repeating daily, starting at 6:30:00 a.m. local time
CON ALARM 5 2006-9-25 T12:00:00 P7	5-second pulse, repeating weekly, starting at noon local time on September 25, 2006
CON ALARM 30 T8:00:00 PT1:00:00	30-second pulse, repeating hourly, starting at 8:00:00 a.m. local time
CON ALARM C	Cancel precision alarm clock operation

DST Command (Access Level 1 and Access Level 2)

At Access Level 1, the **DST** command shows the custom daylight-saving time setting that the clock uses to automatically advance and return local time by one hour.

```
=>DST <Enter>
Custom Daylight Saving Settings
Begin DST at 2:00 hours on the second Sunday of March
End DST at 2:00 hours on the third Sunday of October
=>
```

The SEL-2401 reports "`Custom DST not set`" and uses the values 99,9,9,99 when there is no valid custom daylight-saving time setting.

To change the custom DST setting, you must enter Access Level 2 (see *2AC (Access Level 2) on page 8*). At Access Level 2, the **DST** command customizes the time when daylight-saving time begins and ends. This custom method must be used in areas outside the European Union and North America for implementing automatic daylight-saving time changes; for areas in the preset regions, the **DST** command changes the preprogrammed daylight-saving time, which is useful where local rules differ from regional practice.

NOTE: The minimum separation for Begin DST and End DST settings is three hours.

For testing the beginning of daylight-saving time, set the Begin DST time at the next hour change and the End DST time at least three hours in the future. For testing the end of daylight-saving time, set the Begin DST time at least three hours in the past, and set the End DST time at the next hour change.

With these methods, you can examine whether time-consuming devices correctly apply the daylight-saving time changeover bits in the extended IRIG-B timecode (IRIG-B000).

The clock **DST** command uses the following format:

DST [C] [HH,N,D,MM] [hh,n,d,mm]

- **C** clears any previously set custom DST setting. When this parameter is present, the clock ignores all other parameters.
- **HH,N,D,MM** sets the DST begin rule
  - HH = local time hour to begin DST (range is 0–23)
  - N = week of the month to begin DST (range is 1–4, L [first, second, third, fourth, last])
  - D = day of week to begin DST (range: 1–7 [Sunday–Saturday])
  - MM = month to begin DST (range: 1–12 [January–December])
- **hh,n,d,mm** sets the DST end rule
  - hh = Local time hour to end DST (range: 0–23)
  - n = Week of the month to end DST (range: 1–4, L [first, second, third, fourth, last])
  - d = Day of week to end DST (range: 1–7 [Sunday–Saturday])
  - mm = Month to end DST (range: 1–12 [January–December])

```
=>>DST <Enter>
Custom Daylight Saving Settings
Custom DST not set.
Setting ranges are:
hh = Hour, range 0-23 (local time hour)
n = Occurrence in month, range 1-3, L (first, second, third, last)
d = Day-of-week, range 1-7 (Sunday - Saturday)
mm = Month, range 1-12 (January - December)
Begin DST (hh,n,d,mm) 99,9,9,99 ? 02,2,1,03 <Enter>
End DST (hh,n,d,mm) 99,9,9,99 ? 02,1,1,11 <Enter>
Begin DST at 2:00 hours on the second Sunday of March
End DST at 2:00 hours on the first Sunday of November
Save changes (Y,N)? Y <Enter>
Settings Saved
=>>
```

Upon issuing the **DST** command, the clock reports the present setting and help information on how to correctly use the **DST** command. If you enter an incorrect range parameter, the clock replies with an invalid setting prompt. Once valid DST arguments are entered, the clock reports the new custom daylight-saving time changes and prompts you to save these new times. Answer **Y** to change to (new) custom daylight-saving time settings, or **N** to retain the previous settings.

Use the **DST C** command to clear both the Begin DST and End DST settings. This command returns the settings to the default value, which enables manual DST operation outside of the European Union and North America regions.

Use the custom DST setting for areas where time changes occurring at midnight must be set differently. For example, if DST is observed the second Saturday in October to the second Saturday in March, with the transitions at 24:00 local time, the DST setting would be set to the following:

DST 0,3,1,10 0,3,1,3

The local time hour change for daylight-saving time is at 24 but the setting only allows 0–23. In this case, the setting must be set one day ahead with an hour setting of 0. This change causes the day of the week to occur on Sunday which now is the third week of the month. The week of the month needs to be set to three instead of two because daylight-saving time occurs on Sunday at 0:00:00 local time.

FTQ Command (Access Level 2)

The **FTQ** command forces a selected value for the IEEE C37.118-2005 extensions time-quality output (useful for testing whether IEDs connected to the clock outputs are properly receiving and decoding these extended control function bits). To force a time-quality output, issue the command **FTQ *n***, where *n* represents a time-quality value shown in *Table 8*. To return to normal operation, issue the **FTQ C** (clear) command. The SEL-2401 forces and reports the time-quality values listed in *Table 8* during this testing mode. Only use the **FTQ** command when the clock is in Satellite Lock or manual time mode. The **FTQ** command will expire after 18 hours, and the SEL-2401 will then return to normal operation.

Table 8 Test Operation Forced Values for Time Quality (Sheet 1 of 2)

n	Time Quality	n	Time Quality
0	Locked	8	10 milliseconds
1	1 nanosecond	9	100 milliseconds
2	10 nanoseconds	10	1 second
3	100 nanoseconds	11	10 seconds
4	1 microsecond	12	100 seconds
5	10 microseconds	13	1000 seconds

Table 8 Test Operation Forced Values for Time Quality (Sheet 2 of 2)

n	Time Quality	n	Time Quality
6	100 microseconds	14	10000 seconds
7	1 millisecond	15	Fault

L_D Command (Access Level 2)

Use this command for upgrading firmware in the SEL-2401. See *Firmware Upgrade Instructions* for instructions on issuing this and other commands in the correct order to upgrade firmware.

LOC Command (Access Level 1 and Access Level 2)

At Access Level 1, the **LOC** command shows the current location of the GPS clock. If the clock is not satellite locked or does not have the previous location the latitude, longitude, and altitude will display all 0. The **LOC** command has two arguments to show two different formats of the GPS location. If the **LOC** command is entered either without any arguments or with the argument "D" the clock will display GPS coordinates as shown in *Figure 3*.

```
=>LOC <Enter>
46°44'33.069"N 117°11'25.794"W 00752.724m
=>
```

Figure 3 LOC Command Example Without Any Arguments

The **LOC** command is also set to send in a digital format that is easier for computers to read and parse. Issuing the **LOC** command with the argument "H" will display the clock's location in a digital format, as shown in *Figure 4*.

```
=>LOC H <Enter>
+464433.08–1171125.73+00755.623CRSWGS_84/
=>
```

Figure 4 LOC H Command Example For Digital Format

OPE Command (Access Level 2)

The **OPE** command forces the **ALARM** contact to the open state and is reset when any key is pressed.

PAS Command (Access Level 2)

The **PAS** command allows changing serial port access passwords.

The default password for Access Level 2 is TAIL. (Firmware versions earlier than R109 had a default password of ACCESS+2401.)

Passwords can include as many as 12 characters. The printable characters from the 7-bit ASCII set (i.e., values between 0x21 and 0x7e) are the only allowed password characters.

There is also a calibration access level used at the factory as a part of testing and validation procedures. There are no commands valuable to the user at this level. Some security processes require that there be a means for security officers to change any password in the device. To change the CAL Level password, you must first move to the CAL Level. At Access Level 2, type **CAL** and, when prompted, the CAL Level password. The default Access Level CAL password is **CLARKE** (firmware versions before R109 had a default CAL Level password of

HAWKING+2401). CAL Level access is indicated with the ==>> prompt. At the Access Level CAL, use the **PAS** command to change the Access Level CAL password.

R_S Command (Access Level 2)

Use the **R_S** command to restore factory-default settings and passwords and reboot the system.

STA Command (Access Level 1 and Access Level 2)

The **STA** command displays the clock status, firmware versions, and control (DIP) switch setting information.

The SEL-2401 provides additional firmware information in the Access Level 2 **STA** command.

```
=>>STA <Enter>
SEL-2401 Satellite Synchronized Clock     Local Date/Time = 2013-06-19  23:25:02
FID=SEL-2401-R200-V0-Z003002-D20130627    CID=60FF
RFID=SEL-2401-R103-V1-D20130531
RXFID=NAV-V00.00-D00000101 DSP-V00.00-D00000101 HW-0000-SN      0

SELF TEST RESULTS
RTL         FLASH       SDRAM       DISPLAY     ANTENNA     GPS_RX
OK          OK          OK          OK          OK          OK
SETTINGS
SW 1        SW 2        SW 3        SW 4-9        SW 10
PASSWORD    ALARM       IRIG FORMAT OFFSET        DST
Enabled    Enable      Extended    +0.0          Off

SATELLITES
   # Signal   # Signal   # Signal   # Signal   # Signal   # Signal   # Signal
  17  55.0   28  49.0   24  48.0    9  46.0    1  51.0    4  46.0   15  48.0
   # Signal   # Signal   # Signal   # Signal   # Signal   # Signal   # Signal
  26  50.0    8  42.0   12  46.0    3  20.0   11   0.0   20   0.0    -   -.-
STATUS
CLOCK       SIGNAL      ALMANAC
Enabled     Locked      Complete

=>>
```

Table 9 Status Report Elements (Sheet 1 of 2)

Report Element	Response
FID	FID is the firmware identifier string. It identifies the firmware revision.
CID	CID is the firmware checksum identifier.
RTL	Processor, OK or FAIL.
RFID	FPGA firmware identifier string.
RXFID	GPS receiver firmware ID.
FLASH, SDRAM	Memory status, OK or FAIL.
DISPLAY	Display panel status, OK or FAIL.
ANTENNA	Antenna status, OK or FAIL.
GPS_RX	GPS receiver module status, OK or FAIL.
SW 1 PASSWORD	Required or Disabled.
SW 2 ALARM	Enable: ALARM output follows self-test result; Lock: adds satellite lock in ALARM output.
SW 3 IRIG FORMAT	Extended or Standard. (Extended = IEEE C37.118-2005 [1344] IRIG-B000 format; Standard = IRIG-B002 format.)
SW 4-9 OFFSET	Local Time Offset ±hh.h.

Table 9 Status Report Elements (Sheet 2 of 2)

Report Element	Response
SW 10 DST	Daylight-Saving Time, OFF, AUTO (USA), AUTO (EU), AUTO (CUSTOM), or MANUAL.
# Signal	nn pp.p, where nn = GPS satellite number (0–32); pp.p = GPS signal power received in linear AMU.
CLOCK	Enabled or Disabled.
SIGNAL	GPS signal, Locked, Locking, Lock+UTC, Holdover, or None.
ALMANAC	Satellite tracking, Complete or Acquiring.

TIM Command (Access Level 1 and Access Level 2)

Use the **TIM** command to either view the current local time or to manually set the time if no satellite lock is available. This command is useful for either testing roll-over date and time values for downstream devices or for areas where a satellite lock is not available. At Access Level 1, the **TIM** command will respond with the local time in hours, minutes, seconds (hh:mm:ss). At Access Level 2, the **TIM** command allows you to manually set the date and time. Manually setting the date and time will set the clock display, enable IRIG-B outputs, and set the time quality to 4. The date can only be set between the years 2006 and 2100. Once the date and time are manually set, the clock will not synchronize to the current date and time even if the clock picks up satellite lock. To clear the manual date and time, either cycle power or issue the **TIM C** command. The **TIM** command has a time-out period of 18 hours. When the time-out expires, the clock returns to normal operation. The **TIM** command has the following parameters:

TIM [C] [YYYY-MM-DDThh:mm:ss]

where:

- **C** cancels the user time setting.
- **YYYY-MM-DDThh:mm:ss** is the local date and time setting.
  - **YYYY** = 4 digit year
  - **MM** = Month
  - **DD** = Day of Month
  - **T** = Required separator between date and time
  - **hh** = Hour of day in 24-hour format
  - **mm** = Minutes
  - **ss** = Seconds

UTC Command (Access Level 1 and Access Level 2)

Upon receipt of the **UTC** command, the SEL-2401 responds with the UTC date, time, and local time offset in the following format (ISO 8601:2000):

YYYY-MM-DDThh:mm:ss±HH:NN

Table 10 UTC Format

YYYY =	UTC Date Year (2000–9999)
MM =	UTC Date Month (01–12)
DD =	UTC Day of the Month (01–31)
T =	Literal Time Separator
hh =	UTC Time Hours (00–23)
mm =	UTC Time Minutes (00–59)
ss =	UTC Time Seconds (00–60)
±HH =	Local Time Hours Offset including Daylight-Saving Time (–15 to +16)
NN =	Local Time Minutes Offset (00 or 30)

The **UTC *n*** command repeats the UTC time output for *n* times at the beginning of each second. A special case of this command is **UTC 0**, which outputs UTC time continually until the communications port receives any valid ASCII character (including **<Ctrl+X>**).

Applications

Timecode Distribution

The SEL-2401 has sufficient driving capacity to provide demodulated timecode signals to many products simultaneously.

Demodulated Timecode

Table 11 shows typical drive capabilities per demodulated BNC output for the SEL-2401 to other SEL equipment. The demodulated BNC outputs provide a standard IRIG-B00X DC level-shift (TTL) signal. The accuracy of this signal is ±100 ns, average. A series/parallel connection of SEL-100 and SEL-200 series products consists of two relays in series, with as many as 10 of these series pairs connected in parallel.

Table 11 Output Drive Capacity (Sheet 1 of 2)

Product	Connection	Input Impedance (Ohms)	Units Per SEL-2401
SEL-100 Series	AUX INPUT (Conxall®)	56/82	2 parallel, 20 series/parallel[a]
SEL-200 Series	AUX INPUT2	56/82	2 parallel, 20 series/parallel[a]
Legacy SEL-300 Series	(DEMODULATED) IRIG-B	333	10[b]
New SEL-300 Series	IRIG-B	1 K	10[b]
SEL-351R and SEL-351R Falcon	(DEMODULATED) IRIG-B	333	10[b]
SEL-400 Series	IRIG-B, serial port	2.5 K	20[c]
New SEL-400 Series	IRIG-B, BNC	>1 K	20[d]

Table 11 Output Drive Capacity (Sheet 2 of 2)

Product	Connection	Input Impedance (Ohms)	Units Per SEL-2401
SEL-500 Series	(DEMODULATED) IRIG-B	333	10[b]
SEL-651R	IRIG-B	1.33 K	20[c]
SEL-700 Series	IRIG-B	4.5 K or 2.5 K[e]	20[c]
SEL-734	IRIG-B	2.5 K	20[c]
SEL-2032, SEL-2030, SEL-2020	IRIG-B (In) (BNC)	333	10[b]
SEL-2240	IRIG-B	2.5 K	20[c]
SEL-2411	IRIG-B	4.5 K or 2.5 K[e]	20[c]
SEL-2414	IRIG-B	4.5 K or 2.5 K[e]	20[c]
SEL-2431	IRIG-B	750	10[b]
SEL-2440	IRIG-B	2.5 K	20[c]
SEL-2523, SEL-2533	IRIG-B	2.5 K	20[c]
SEL-2810MT	IRIG-B	25 K	20[c]
SEL-2812MT	IRIG-B	2 K	20[c]
SEL-3031	IRIG-B	333	10[b]
SEL-3350 Series, SEL-3530, SEL-3610, SEL-3620, SEL-3622	IRIG-B	2.5 K	20[c]
SEL-3401 manufactured before Sept. 2011	IRIG-B (In)	332	10[b]
SEL-3401 manufactured Sept. 2011 or later	IRIG-B (In)	1.33 K	15[b]

[a] Do not add external terminating resistor.
[b] Install 50-ohm termination resistor on farthest device for 4 or fewer devices.
[c] Install 50-ohm termination resistor on farthest device.
[d] Set internal 50-ohm termination resistor on farthest device.
[e] 2.5 kilohm if no Ethernet or single copper Ethernet port; 4.5 kilohm if fiber-optic or dual Ethernet port(s).

The maximum cable length is 40 m (131.2 feet). Connect multiple devices as illustrated in *Figure 5*.

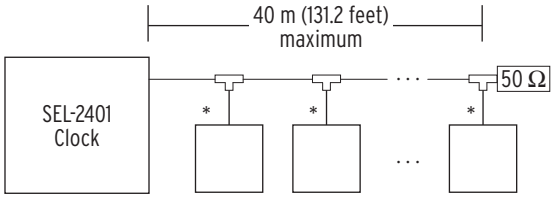


Figure 5 Multiple Device Connections

Testing and Troubleshooting

The Clock Will Not Lock

When the clock is unable to achieve a lock, the cause of such failure typically is poor receive signal quality. For the clock to lock, the receiver must track at least four satellites (not all in the same region). To remain locked, the clock must be tracking at least one satellite.

To verify the signal, use the serial port **STA** command from Access Level 2.

Step 1. After connecting the antenna verify that the status window displays `OK`.

If `OK` is not displayed, check the connections and the cable for short or open circuits.

Step 2. Verify the signal quality of the tracked satellites.

There are 14 satellite-status fields listed near the bottom of the status screen. The first two-digit number is the GPS satellite designator for each tracked satellite. The next number is the carrier-to-noise density in dB-Hz.

To achieve lock, the clock must have a minimum reading of 30 dB-Hz on four satellites. If carrier-to-noise density does not meet these requirements, the signals are too weak. After lock is achieved, the clock must have the minimum reading on at least one satellite to remain locked.

If signals are too weak to achieve lock, perform the following steps:

Step 1. Reposition the antenna for an unobstructed view of the sky.

Step 2. Verify that the antenna cable or external lightning protection is not damaged.

Mechanical Diagrams

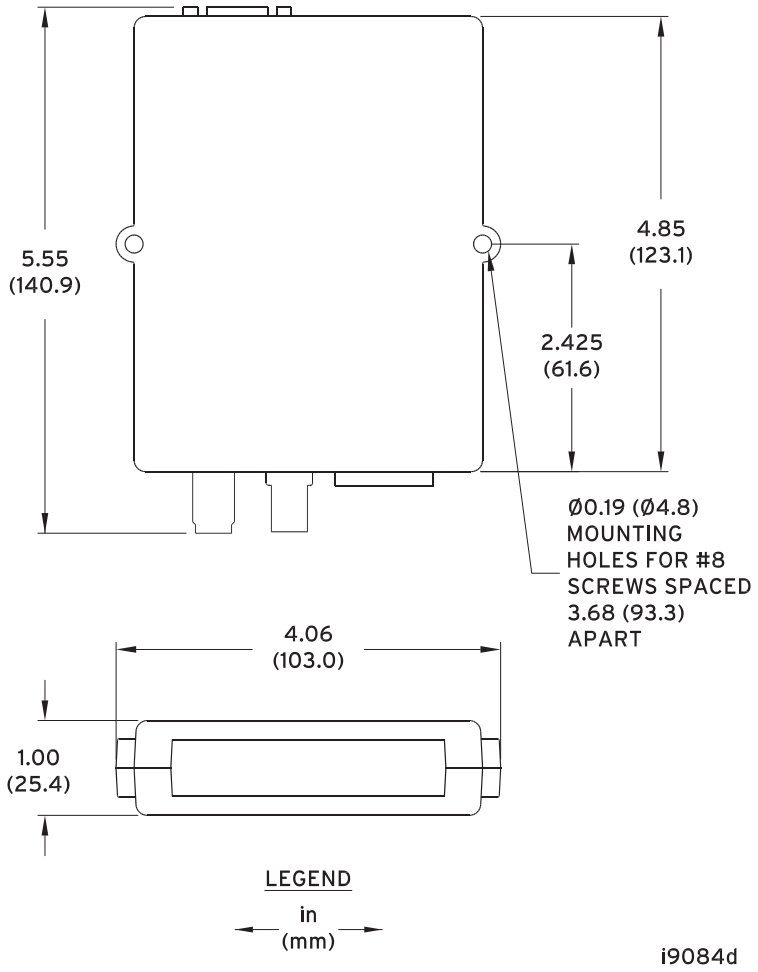


Figure 6 SEL-2401 Dimension Drawing

Specifications

Compliance

Designed and manufactured under an ISO 9001 certified quality management system

CE Mark

UKCA Mark

47 CFR 15B, Class A

Note: This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to Part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area may be likely to cause harmful interference in which case the user will be required to correct the interference at his own expense. Any changes or modifications not expressly approved by the manufacturer can void the user's authority to operate the equipment.

RoHS compliant

Receiver

Satellite Tracking:	GPS L1, C/A Code (1575.42 MHz) 14-channel continuous tracking

Acquisition Times

Hot Start:	135 s
Cold Start:	135 s + UTC compensation time
Typical Cold Start:	330 s

Clock Accuracy (to UTC Time)

Demodulated IRIG-B:	±100 ns average, ±500 ns peak

Holdover Stability

±0.08 ppm for 20 minutes (from –40° to +80°C)

Antenna Requirements

5 V, <80 mA

25 dB preamp, min. LNA gain

IRIG-B Output Drive Level

Demodulated IRIG-B000 and IRIG-B002,
TTL: 5 V nominal, 4 V (min) into 50 Ω

ALARM Contact

Form A Carry:	100 mA
Rated Voltage:	48 Vdc

Note: The alarm contact is open during an alarm condition.

Power Supply

Rating:	12 Vdc
Range:	9–30 Vdc
Burden:	<2 W

Serial Port

EIA-232 DB-9 Female

Fixed 9600 bps

8 data bits

No parity

1 stop bit

15-minute timeout, fixed

Operating Temperature Range

–40° to +80°C (–40° to +176°F)

Humidity

0% to 95% without condensation

Altitude

2000 m (6600 ft)

Atmospheric Pressure

80–110 kPa (23.6–32.5 in. Hg)

Pollution Degree

2

Overvoltage Category

II

Insulation Class

III

Unit Weight

0.27 kg (0.6 lb)

Dimensions

Height:	25.4 mm (1.00 inches)
Depth:	103.0 mm (4.06 inches)
Width:	123.1 mm (4.85 inches)

Type Tests

Product Family Standards

Electromagnetic Compatibility:	IEC 60255-26:2013
Product Safety:	IEC 60255-27:2013

Electromagnetic Compatibility Emissions

IEC 60255-26:2013
CISPR 11:2009 + A1:2010
CISPR 22:2008
Canada ICES-001 (A) / NMB-001 (A)
47 CFR Part 15.107 and 109
Severity Level: Class A

Electromagnetic Compatibility Immunity

Note: All tests were conducted using a 10-meter serial port cable.

Conducted RF Immunity:	IEC 60255-22-6:2001 IEC 61000-4-6:2008 Severity Level: 10 Vrms
Radiated RF Immunity:	IEC 60255-22-3:2007 IEC 61000-4-3:2008 Severity Level: 10 Vrms IEEE C37.90.2:2004 Severity Level: 20 V/m (unmodulated); 35 V/m (modulated)
Electrostatic Discharge Immunity:	IEC 60255-22-2:2008 IEC 61000-4-2:2008 Severity Level: 2, 4, 6, 8 kV contact; 2, 4, 8, 15 kV air IEEE C37.90.3-2001 Severity Level: 2, 4, 8 kV contact; 4, 8, 15 kV air

Fast Transient/Burst Immunity:	IEC 60255-22-4:2008 IEC 61000-4-4:2012 Severity Level: 4 kV @ 5 kHz on EIA-232 Port, Antenna Input, and IRIG Output
Surge Withstand Capability:	IEC 60255-22-1:2007 Severity Level: ±2.5 kV peak common mode, ±1.0 kV peak differential mode IEEE C37.90.1:2002 Severity Level: ±2.5 kV, 1 MHz oscillatory; ±4 kV, 2.5 kHz fast transient
Surge Immunity:	IEC 60255-22-5:2008 IEC 61000-4-5:2005 Severity Level: ±0.5 kV, 1 kV line-to-line; ±0.5 kV, 1 kV, 2 kV line-to-earth; ±0.5 kV, 1 kV, 2 kV on communications ports
Power Frequency Magnetic Field Immunity:	IEC 60255-26:2013 IEC 61000-4-8:2009 Severity Level: 1000 A/m 1 s to 3 ; 100 A/m continuous
Power Supply Immunity:	IEC 61000-4-11:2004 Severity Level: 5 cycles at 0% residual voltage (when used with an SEL-9321 power supply) IEC 6100-4-29:2000 Severity Level: 50 ms at 0% residual voltage (when used with an SEL-9321 power supply)
Voltage Ripple:	IEC 60255-26:2013 IEC 61000-4-17:1999+A1:2001+A2:2008 Severity Level: 15% Un 100/120

Environmental Tests

Cold:	IEC 60068-2-1:2007 Severity Level: 16 hours @ –40°C
Dry Heat:	IEC 60068-2-2:2007 Severity Level: 16 hours @ +80°C
Damp Heat Cyclic:	IEC 60068-2-30:2005 Severity Level: 25° to 55°C, 6 cycles, Relative Humidity: 95%
Vibration:	IEC 60255-21-1:1988 Severity Level: Class 1 (Endurance), Class 2 (Response)
Shock and Bump:	IEC 60255-21-2:1988 Severity Level: Class 1 (Shock Withstand, Bump); Class 2 (Shock Response)
Seismic:	IEC 60255-21-3:1993 Severity Level: Class 2 (Quake Response)

Safety

Insulation Coordination:	IEC 60255-5:2000 IEEE C37.90-2005 Dielectric (HiPot) Severity Level: I/O, CT, PT: 2500 Vac Power Supply: 3100 Vdc Impulse Severity Level: 0.5 J; 5 kV, 1.2/50 µs
Protection IP Code:	IEC 60529:2001 + CRGD:2003 IP Code: IP3X for category 2 equipment

Firmware and Manual Versions

Determining the Firmware Version in Your Clock

To determine the firmware version, view the status report by using the serial port **STATUS** command. The status report displays the Firmware Identification (FID) number. The firmware version number is after the R, and the release date is after the D. For example, the following is firmware version number R100, release date December 03, 2014.

FID=SEL-2401-R100-V0-Z001001-D20141203

The firmware version will be either a standard release or a point release. A standard release adds new functionality to the firmware beyond the specifications of the existing version. A point release is reserved for modifying firmware functionality to conform to the specifications of the existing version.

A standard release is identified by a change in the R-number of the device FID number.

Existing firmware:

FID=SEL-2401-**R100**-V0-Z001001-Dxxxxxxxx

Standard release firmware:

FID=SEL-2401-**R101**-V0-Z001001-Dxxxxxxxx

A point release is identified by a change in the V-number of the device FID number.

Existing firmware:

FID=SEL-2401-R100-**V0**-Z001001-Dxxxxxxxx

Point release firmware:

FID=SEL-2401-R100-**V1**-Z001001-Dxxxxxxxx

Table 12, Table 13, and *Table 14* list the firmware versions, a description of modifications, and the product manual date code that corresponds to firmware versions. The most recent firmware version is listed first.

Table 12 300-Series Firmware Revision History

Firmware Identification (FID) Number	Summary of Revisions	Manual Date Code
SEL-2401-R300-V0-Z003002-D20190725 **Note:** R300-series firmware uses new hardware and is not compatible with R200-series or R100-series firmware.	➤ Introduced new clock hardware on R300 firmware. Not backwards compatible.	20191119

Table 13 200-Series Firmware Revision History

Firmware Identification (FID) Number	Summary of Revisions	Manual Date Code
SEL-2401-R200-V0-Z003002-D20130627 **Note:** R200-series firmware uses new hardware and is not compatible with R100-series firmware.	➤ Introduced new clock hardware on R200 firmware. Not backwards compatible with R100-series firmware. ➤ Increased antenna receiver sensitivity. ➤ Updated satellite locking mechanism so that the clock can remain locked with only one satellite in view after initial satellite lock.	20130627

Table 14 100-Series Firmware Revision History (Sheet 1 of 2)

Firmware Identification (FID) Number	Summary of Revisions	Manual Date Code
SEL-2401-R112-V1-Z003002-D20190604	➤ Updated firmware to correctly set the date if installed following the recent GPS rollover event experienced on April 6, 2019.	20190604
SEL-2401-R112-V0-Z003002-D20130828	➤ Corrected leap second time adjustment where time jumped by one minute and one second for a duration of one second, then returned to the correct time. ➤ Corrected leap second time adjustment where SBS had incorrect seconds during the leap second change. ➤ Modified leap second time adjustment so that the Leap Second Pending bit in IRIG-B now triggers one minute before the time change at zero seconds. ➤ Corrected issue where, if a leap second occurred on a Saturday, the clock would increment/decrement the time by one second one week early. ➤ Corrected the status command signal indication when the clock loses lock. ➤ Corrected error that would have occurred on September 15, 2024 where the clock would have rolled back to January 30, 2005 because of an internal week rollover. ➤ Corrected certain custom **DST** command rules that would not increment or decrement the hour properly. ➤ Revised the **TIM** command to require complete date and time as arguments when setting manual time. ➤ Revised the **STA** command to show satellite signals in dB-Hz. ➤ Revised custom DST settings to be a command interface and no longer a settings prompt. ➤ Corrected signal-level mask change incorrectly introduced in R111.	20130828
SEL-2401-R111-V0-Z002002-D20130315	➤ Corrected condition where clock can lock exactly one second off. ➤ Added **LOC** command for obtaining clock's GPS coordinates.	20130315
SEL-2401-R110-V0-Z002002-D20120309	➤ Corrected issue where the clock could send out the incorrect seconds for as long as 5 seconds before correcting itself. ➤ Corrected issue where the clock may not obtain satellite lock on cold start. Cycling power would previously fix this problem. ➤ Corrected issue where the clock may not send out time for a few seconds.	20120309
SEL-2401-R109-V0-Z002002-D20110408	➤ Added ability to update GPS chip firmware via SEL firmware upgrade to correct rare failure to reacquire satellite lock condition. ➤ Changed 2AC and CAL default passwords.	20110408
SEL-2401-R108-V0-Z002002-D20100504	➤ Corrected very rare condition of the clock getting exactly one second slow for a brief time before automatically correcting itself. ➤ Corrected condition where new leap second would update one day late.	20100504
SEL-2401-R107-V0-Z002002-D20080515	➤ Corrected UTC hour display for GPS clocks located in the positive local time zones.	20080515
SEL-2401-R106-V0-Z002002-D20070411	➤ Made the alarm contact initialize correctly when Control (DIP) Switch 2 is on.	20070411
SEL-2401-R105-V0-Z002002-D20070209	➤ Made the alarm contact work properly when set to change state from loss of satellite lock. ➤ Corrected upgrading firmware where the status Flash would show a FAIL until the satellite obtained initial satellite lock.	20070209
SEL-2401-R104-V0-Z002002-D20061220	➤ Added the following ASCII commands: **BX** broadcast, **CON** time controlled pulses, and **TIM** manually set date and time.	20061220
SEL-2401-R103-V0-Z002001-D20061002	➤ Added the **CON** command.	20061002

Table 14 100-Series Firmware Revision History (Sheet 2 of 2)

Firmware Identification (FID) Number	Summary of Revisions	Manual Date Code
SEL-2401-R102-V0-Z001001-D20060608	➤ Added the custom **DST** command. ➤ Added the **UTC *n*** command. ➤ Added CE compliance.	20060608
SEL-2401-R101-V0-Z000000-D20060206	➤ Initial version.	20060206

Determining the Manual Version

The date code at the bottom of each page of this manual reflects the creation or revision date.

Table 15 lists the product manual release dates and a description of modifications. The most recent product manual revisions are listed at the top.

Table 15 Manual Revision History (Sheet 1 of 2)

Revision Date	Summary of Revisions
20221027	➤ Updated *Specifications* to include UKCA Mark.
20210630	➤ Updated *Specifications*.
20191119	➤ Added *Antenna Cabling*. ➤ Added return connection clarification under *Power Connections*. ➤ Updated torque for terminal connector screws under *Compression Terminal Connectors*. ➤ Updated *Table 1: Status Indicator LEDs*. ➤ Updated *Cold-Start Sequence*. ➤ Updated *IRIG-B Output Drive Level* in *Specifications*. ➤ Updated for firmware version R300-V0.
20190604	➤ Updated for firmware version R112-V1.
20180215	➤ Updated *Table 2: Control (DIP) Switches and Functions.* ➤ Added FTQ command to *Table 6: Communications Port Command Summary*. ➤ Updated *Daylight-Saving Time (DST)*. ➤ Added *FTQ Command (Access Level 2)*. ➤ Updated *Specifications*.
20150715	➤ Renamed *Certifications* to *Compliance*, and moved it to the top of *Specifications*. ➤ Added CE Mark to *Compliance* in *Specifications*. ➤ Updated *Type Tests* in *Specifications*.
20140924	➤ Removed *Figure 3: Serial-Number/Compliance Label and FCC Label*. ➤ Removed CE Mark certification from *Specifications*.
20130828	➤ Updated for firmware version R112.
20130627	➤ Updated *Accessories*. ➤ Updated *Table 1: Status Indicator LEDs*, *Cold Start Sequence*, and *Testing and Troubleshooting*, changing the number of satellites needed to stay locked from three to one. ➤ Updated *DST Command (Access Level 1 and Access Level 2)*. ➤ Updated the example screen capture in *STA Command (Access Level 1 and Access Level 2)*. ➤ Updated *Table 10: Output Drive Capacity*. ➤ Updated *Specifications*. ➤ Updated for firmware version R200.
20130315	➤ Added **LOC** serial command in *Table 9: Communications Port Command Summary*. ➤ Added *LOC Command (Access Level 1 and Access Level 2)*. ➤ Updated for firmware version R111.
20120309	➤ Updated for firmware version R110.

Table 15 Manual Revision History (Sheet 2 of 2)

Revision Date	Summary of Revisions
20110805	➤ Updated description for **STA** serial command in *Table 9: Communications Port Command Summary*. ➤ Added detail about **STA** command display in *STA Command (Access Level 1 and Access Level 2)*. ➤ Updated *Table 13: Output Drive Capacity* with additional information about SEL-3401 manufacture dates.
20110408	➤ Corrected antenna bracket number in *Table 1: GPS Signal-Acquisition Accessories*. ➤ Clarified that plug adapter is for 230-0604 supply in *Table 3: Power Accessories*. ➤ Changed default **2AC** password and added instruction to change the **CAL** password in *PAS Command*. ➤ In *Table 4: Status Indicator LEDs*, *Cold Start Sequence*, and *Testing and Troubleshooting*, clarified that four satellites are needed to achieve lock, and three are needed to stay locked. ➤ Deleted obsolete safety standard reference in *Specifications*. ➤ Updated for firmware version R109. ➤ Add GPS firmware upgrade description in *Firmware Upgrade Instructions*.
20100504	➤ Updated for firmware version R108.
20091120	➤ Updated *Figure 3: Serial-Number/Compliance Label and FCC Label*. ➤ Updated *Table 13: Output Drive Capacity*. ➤ Updated *Specifications*.
20090508	➤ Updated/added time accessory products.
20080515	➤ Updated for firmware version R107.
20070411	➤ Updated for firmware version R106.
20070209	➤ Updated for firmware version R105.
20061220	➤ Removed *Table 6: Universal Time Conversion Local Time Offset*. ➤ Updated *Table 9: Communications Port Command Summary* with the ASCII commands: BX and TIM.
20061002	➤ Updated *Table 1: GPS Signal-Acquisition Accessories*. ➤ Updated for firmware version R103.
20060608	➤ Added material to support custom **DST** command, **UTC *n*** command, and CE marking.
20060206	➤ Initial version.

Firmware Upgrade Instructions

Overview

SEL may occasionally offer firmware upgrades to improve the performance of your clock. The clock stores firmware in Flash memory; therefore, changing physical components is not necessary. A firmware loader program called SELBOOT resides in the clock. These instructions give a step-by-step procedure to upgrade the clock firmware by uploading a file from a personal computer to the clock via direct connection to the serial port.

Required Equipment

You will need the following to perform a firmware upgrade.

- Personal computer
- Terminal emulation software that supports the Xmodem/CRC protocol (these instructions use HyperTerminal® from a Microsoft Windows operating system)
- Serial communications cable (SEL-C234 or equivalent)
- The firmware upgrade file (Rxxx24*nn*.hex), where *nn* indicates the last two digits in the product number

Firmware Upgrade Procedure

Step 1. Connect the PC to the serial port of the clock, and enter Access Level 2.

a. Type **2AC <Enter>**.

b. Enter the Access Level 2 password.

Step 2. Record DST settings.

a. If the clock has custom daylight-saving time settings, issue the **DST** command.

b. Record the beginning and ending daylight-saving time settings.

Step 3. Start the upgrade process.

a. Issue the **L_D** command to the clock.

b. Type **Y <Enter>** at the following prompt:

```
Disable device to receive firmware (Y,N) ?
```

c. Type **Y <Enter>** at the following prompt:

```
Are you sure (Y, N)?
```

The clock will respond with the following message and send the `!>` prompt.

```
Device disabled
```

Step 4. Issue the **BAU 115200** command. On your terminal or computer terminal program, change the terminal data rate to 115200 bps.

Step 5. Begin the transfer of the new firmware to the clock by issuing the **REC** command.

Step 6. Type **Y** to erase the existing firmware, or press **<Enter>** to abort.

Step 7. Start the file transfer.

a. Select the send file option in your communications software.

b. Use the Xmodem or 1K Xmodem protocol and send the file that contains the new firmware.

After the file transfer, the clock reboots.

Step 8. If the GPS firmware in the SEL firmware is newer than the firmware in the GPS chip, the clock will upgrade the GPS firmware. While the firmware upgrade is progressing, several progress messages will be sent to the serial port.

On completion of the GPS firmware upgrade, or if there is no GPS firmware upgrade, the **ENABLED** LED will illuminate and the clock will return to Access Level 1. Change the terminal data rate back to 9600 bps to access the clock serial port.

Step 9. Press any key (e.g., **<Enter>**) when the clock sends a prompt.

```
=>>L_D <Enter>
Disable device to receive firmware (Y,N) ? <Enter>
Are you sure (Y/N) ? Y <Enter>
Device disabled

!>REC <Enter>
Caution! This command erases the firmware.
If you erase the firmware then new firmware
must be loaded before returning the IED to service.

Are you sure, you want to erase the existing firmware (Y/N)?
Y <Enter>
Erasing firmware.
Erase successful.
Press any key to begin transfer and then start transfer at the terminal.
```

Step 10. Issue the **STA** command, and examine the status report for FAIL messages.

If the status report shows a FAIL message, perform the following steps.

a. Type **2AC <Enter>**.

b. Enter the Access Level 2 password.

c. Type **R_S <Enter>**.

At this time you must reenter passwords and any custom daylight-saving time settings.

d. Type **2AC <Enter>**.

e. Enter the default Access Level 2 password **TAIL**.

f. Use the **PAS** command to change the default password to your secure password (see *PAS Command (Access Level 2)* in the *SEL-2401 Instruction Manual*).

g. If necessary, use the **DST** command to set the beginning and ending times for daylight-saving (summer) time (see *DST Command (Access Level 1 and Access Level 2)* in the *SEL-2401 Instruction Manual*).

NOTE: The Access Level 2 password for an SEL-2401 Clock is **TAIL**.

This completes the firmware upgrade instructions. If you have a field-programmable gate array (FPGA) configuration upgrade, continue with the following procedure.

FPGA Configuration Upgrade Procedure

Step 1. Connect the PC to the serial port of the clock, and enter Access Level 2.

Step 2. Start upgrading of firmware.

a. Issue the **L_D** command to the clock.

b. Type **Y <Enter>** at the following prompt:

```
Disable device to receive firmware (Y,N) ?
```

c. Type **Y <Enter>** at the following prompt:

```
Are you sure (Y, N)?
```

The clock will respond with the following message and send the !> prompt.

```
Device disabled
```

Step 3. Issue the **BAU 115200** command, and change the terminal baud rate to 115200 bps.

Step 4. Begin the transfer of the new FPGA configuration file (rtl_Rxxx) to the clock by issuing the **CFG** command.

Step 5. Type **Y** to erase the existing FPGA configuration or press **<Enter>** to abort.

Step 6. Press any key (e.g., **<Enter>**) when the clock sends a prompt.

Step 7. Start the file transfer.

a. Select the send file option in your communications software.

b. Use the Xmodem protocol and send the file that contains the new firmware.

After the file transfer, the clock will reboot and return to Access Level 1. Change the terminal data rate back to 9600 bps to access the clock serial port.

```
=>>L_D <Enter>
Disable device to receive firmware (Y,N) ? Y <Enter>
Are you sure (Y/N) ? Y <Enter>
Device disabled

!>CFG <Enter>
Caution! This command overwrites the FPGA configuration and SELboot.

Are you sure, you want to overwrite
the existing FGPA configuration and SELboot (Y/N)? Y <Enter>

Press any key to begin transfer and then start transfer at the terminal.
```

The satellite-synchronized clock is now ready for commissioning.

Technical Support

We appreciate your interest in SEL products and services. If you have questions or comments, please contact us at:

Schweitzer Engineering Laboratories, Inc.
2350 NE Hopkins Court
Pullman, WA 99163-5603 U.S.A.
Tel: +1.509.338.3838
Fax: +1.509.332.7990
Internet: selinc.com/support
Email: info@selinc.com

⚠CAUTION This terminal is for use with a regulated +5 Vdc source only.	**⚠ATTENTION** Cette borne doit être raccordé uniquement une source de tension régulée de +5 VCC.
⚠WARNING Operator safety may be impaired if the device is used in a manner not specified by SEL.	**⚠AVERTISSEMENT** La sécurité de l'opérateur peut être compromise si l'appareil est utilisé d'une façon non indiquée par SEL.

SCHWEITZER ENGINEERING LABORATORIES, INC.
2350 NE Hopkins Court • Pullman, WA 99163-5603 U.S.A.
Tel: +1.509.332.1890 • Fax: +1.509.332.7990
selinc.com • info@selinc.com

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