

**...FROM THE PEOPLE WHO PUT CESIUM INTO THE  
GPS NAVSTAR SATELLITE...**

**OPERATING MANUAL**

**MODEL FTS 4060**

**CESIUM TIME AND FREQUENCY  
STANDARD**

Option Coverage:

- 010 Internal Battery
- 015 External Standby Battery Supply
- 061 1 MHz and 100 kHz Outputs
- 013 Rack Slides
- 116 Time of Day Display
- 117 1 PPS Advance/Delay
- 018 Time Code Generator (covered by Addendum)
- 062 Additional RF Outputs (covered by Addendum)
- 063 DS1 Frequency Synthesizer (covered by Addendum)
- 064 CEPT Frequency Synthesizer (covered by Addendum)
- 048 -48 Vdc Power Input (covered by Addendum)
- 075 Extended Tube Warranty

FTS Part Number: 07516-001-00000

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## TABLE OF CONTENTS

### SECTION 1. GENERAL INFORMATION

1.1 INTRODUCTION	1-1
1.2 SUMMARY DESCRIPTION	1-1
1.2.1 INSTRUMENT IDENTIFICATION	1-3
1.3 CESIUM BEAM TUBE OPERATING LIFETIME	1-3
1.4 STORAGE/SHELF LIFE, FTS 4060	1-12
1.4.1 Battery Storage	1-12
1.4.2 Cesium Beam Tube Vacuum	1-13
1.4.3 Cesium Beam Tube Shelf Life	1-13
1.5 PREPARATION FOR SHIPMENT	1-14
1.5.1 Hazardous Material (HAZMAT) Shipping Considerations	1-14
1.5.2 Packing Materials	1-14
1.5.3 Shipping Procedure	1-15
1.5.4 Placement of Labels on Shipping Case	1-15
1.5.5 Shipment	1-16
1.6 INSTALLATION	1-14
1.6.1 Environment	1-14
1.6.2 Mounting	1-14
1.6.3 Electrical Connections	1-18
1.6.4 Chassis Rack Slides (Option 013)	1-19
1.6.4.1 Mounting Procedure	1-19

### SECTION 2. OPERATION

2.1 INTRODUCTION	2-1
2.2 TURN-ON PROCEDURE	2-1
2.2.1 Turn-on Process	2-1
2.3 TURN-OFF AND RESTARTING	2-2
2.4 OPERATIONAL CHECK	2-8
2.5 PULSE SYNCHRONIZATION AND TIME SETTING	2-10
2.5.1 Time Setting Procedure (Option 116)	2-10
2.5.2 1 PPS Advance/Delay (Option 116 or 117)	2-11
2.5.2.1 1 PPS Advance/Delay Setting Procedure (Option 116 or 117)	2-12
2.5.2.2 1 PPS Advance/Delay Verification	2-12
2.6 OPERATIONAL CONTROLS	2-13
2.6.1 Fine Frequency Adjustment C-Field	2-13
2.6.2 Coarse Frequency Adjustment	2-14
2.6.3 Cesium Beam Current Gain Adjustment	2-14
2.6.4 Alignment, Microprocessor-controlled	2-18
2.6.5 Autolock Override	2-19
2.7 CONTROL VOLTAGE CENTERING ADJUSTMENT	2-20
2.8 OPERATION ON EXTERNAL DC POWER OR INTERNAL BATTERY	2-21
2.8.1 External DC Only (Internal Battery Off)	2-21
2.8.2 Internal Battery Only (Ext DC Off)	2-21
2.8.3 Battery Replacement	2-22

## TABLE OF CONTENTS

### SECTION 3. THEORY OF OPERATION

3.1 INTRODUCTION	3-1
3.2 CESIUM FREQUENCY STANDARD (CFS) MODULE, A1	3-4
3.2.1 Oscillator Assembly A1A6	3-4
3.2.2 Distribution Amplifier Assembly A1A5	3-4
3.2.3 Frequency Multiplier, A1A7	3-7
3.2.4 Cesium Beam Tube Assembly, A1A1	3-7
3.2.5 Microprocessor PCB Assembly, A1A3	3-11
3.2.5.1 Automatic Lock Routine	3-13
3.2.5.2 Monitoring	3-14
3.2.5.3 Microprocessor-controlled Alignment	3-15
3.2.6 12.6 MHz Synthesizer PCB Assembly, A1A4	3-15
3.2.7 Module Power Supply Assembly, A1A8 and Input Filter PCB Assembly, A1A9	3-16
3.3 FREQUENCY DISTRIBUTION AND TIME GENERATION	3-20
3.3.1 Buffered RF Outputs	3-20
3.3.2 1 PPS, TOD Display, and 1 PPS Advance/Delay	3-20
3.4 POWER SUPPLY OPERATION, FTS 4060	3-22
3.5 BATTERY AND AUTOMATIC CHARGER, Option 010	3-22

### LIST OF ADDENDUMS & APPENDICES

FTS 4060 CESIUM TIME AND FREQUENCY STANDARD Applicability: Option 062, Additional RF Outputs	4-1
FTS 4060 CESIUM TIME AND FREQUENCY STANDARD Applicability: Option 018, Time Code Generator	4-2
FTS 4060 CESIUM TIME AND FREQUENCY STANDARD Applicability: Option 063, DS1 Synthesizer	4-6
FTS 4060 CESIUM TIME AND FREQUENCY STANDARD Applicability: Option 064, CEPT Synthesizer	4-16
FTS 4060 CESIUM TIME AND FREQUENCY STANDARD Applicability: Option 048, -48 V Input	4-22
APPENDIX A     FTS 4060, Cesium Time and Frequency Standard Control Voltage Centering Adjustment	A-1

## LIST OF FIGURES AND TABLES

TABLE 1-1 SPECIFICATIONS, FTS 4060	1-5
TABLE 1-2 RECOMMENDED TEST EQUIPMENT	1-11
TABLE 1-3 BATTERY RECHARGE INTERVALS	1-12
TABLE 1-4 NOT USED	
TABLE 1-5 CESIUM BEAM TUBE SHELF LIFE	1-13
TABLE 2-1 MONITORS AND INDICATORS	2-5
TABLE 2-2 MONITOR LOG	2-9
TABLE 3-1 ASSEMBLIES AND REFERENCE DESIGNATORS	3-3
TABLE 3-2 SPECIFICATIONS, CFS MODULE POWER SUPPLY, FTS 5030	3-19
FIGURE 1-1 FTS 4060	1-4
FIGURE 1-2 FREQUENCY STABILITY	1-10
FIGURE 1-3 SINGLE SIDE-BAND PHASE NOISE SPECTRAL DENSITY	1-10
FIGURE 1-4 ILLUSTRATION OF CESIUM SHIPPING CASE	1-17
FIGURE 1-5 LABEL INFORMATION	1-17
FIGURE 1-6 INTERFACE CONTROL DIAGRAM FTS 4060	1-20
FIGURE 1-7 RACK SLIDE ASSEMBLY DIAGRAM	1-24
FIGURE 2-1 FTS 4060 FRONT PANEL	2-3
FIGURE 2-2 FTS 4060 REAR PANEL	2-4
FIGURE 2-3 1 PPS ADVANCE/DELAY	2-11
FIGURE 2-4 1 PPS ADVANCE/DELAY TEST SET-UP	2-12
FIGURE 2-5 OPERATIONAL CONTROLS	2-13
FIGURE 2-5A MANUAL CESIUM BEAM SIGNAL GAIN ADJUSTMENT	2-16
FIGURE 2-5B CESIUM BEAM CURRENT GAIN ADJUSTMENT	2-17
FIGURE 2-6 SOFTWARE FLOWCHART	2-19
FIGURE 2-7 BATTERY REPLACEMENT	2-23
FIGURE 3-1 FTS 4060 BLOCK DIAGRAM	3-2
FIGURE 3-2 CFS MODULE BLOCK DIAGRAM	3-5
FIGURE 3-3 OSCILLATOR BLOCK DIAGRAM	3-6
FIGURE 3-4 DISTRIBUTION AMPLIFIER BLOCK DIAGRAM	3-6
FIGURE 3-5 FREQUENCY MULTIPLIER BLOCK DIAGRAM	3-8
FIGURE 3-6 BEAM CURRENT RESPONSE	3-9
FIGURE 3-7 CESIUM BEAM TUBE BLOCK DIAGRAM	3-10
FIGURE 3-8 SOFTWARE FLOWCHART	3-13
FIGURE 3-9 SYNTHESIZER BLOCK DIAGRAM	3-17
FIGURE 3-10 CFS MODULE POWER SUPPLY, BLOCK DIAGRAM	3-18
FIGURE 3-11 RF SIGNAL DISTRIBUTION AND TIME GENERATION	3-21
FIGURE 3-12 BATTERY CHARGE CYCLE	3-23
FIGURE A-1 FTS 4060, LEFT SIDE	A-5
FIGURE A-2 FTS 4060 TOP, CHASSIS VIEW	A-6
FIGURE A-3 FTS 4060 BOTTOM, CHASSIS VIEW	A-7
FIGURE A-4 OSCILLATOR TUNING POTENTIOMETER	A-8
FIGURE A-5 CONTROL VOLTAGE CENTERING ADJUSTMENT FLOWCHART	A-9



**SECTION 1. GENERAL INFORMATION****1.1 INTRODUCTION**

The FTS 4060 Cesium Beam Frequency and Time Standard (see Figure 1-1) is an accurate and stable frequency and time reference with microprocessor control. This manual contains detailed performance and installation specifications (Section 1), operating procedures (Section 2), and theory of operation (Section 3). A companion manual FTS 4060, SERVICE MANUAL (FTS P/N 06423-001-00000) contains service procedures, parts lists and assembly/schematic diagrams.

**1.2 SUMMARY DESCRIPTION**

The FTS 4060 Cesium Time and Frequency Standard is a primary frequency and time reference with microprocessor control. The major function of the FTS 4060 is to produce accurate, stable, and spectrally pure sinusoidal signals, and precise 1 pulse-per-second (1 PPS) timing signals. To accomplish this, a cesium beam tube resonator is used to stabilize the output of a quartz crystal oscillator. The oscillator drives output signals at both 10 and 5 MHz, and optionally at 1 MHz and 100 kHz. The 10 MHz signal is digitally divided to produce the 1 pps signal which can be advanced or delayed in 100 nanosecond steps. The FTS 4060 features both 5 MHz and 10 MHz outputs. The FTS 4060 is optimized for performance at 5 MHz with excellent close-in phase noise and short term stability.

A microprocessor is used to perform the following tasks:

- Digital demodulation and integration of the servo loop signals
- Monitoring of system parameters
- Control of adaptive servos including control of the loop time constant during the instrument warm-up
- Diagnostic functions to aid in troubleshooting
- Control of loop gain to constantly compensate for beam tube signal decay.

When turned on or at user request, an autolock routine assures lock to the correct cesium resonance by checking and correcting:

- Oscillator control voltage
- Oscillator drift rate
- Operation of modulation circuits
- Cesium beam current level

## 1.2 SUMMARY DESCRIPTION (cont'd)

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Operating controls on the front panel include:

- Switches for manual adjustment of the cesium control loop (modulation and feed-back loop)
- Automatic alignment pushbutton switch; assures lock to the correct cesium resonance and calibrates beam current level if necessary.
- Switches for scanning of either the frequency control voltage or the loop gain
- Fine frequency C-field adjustment
- Control switches for synchronizing and advancing or delaying the 1 pps signal
- Switches for setting the Time-of-Day display

LED indicators on the monitor panel are provided for frequency lock/alarm, monitor alarm, ac power/alarm, and battery charge conditions. Monitor functions available on the front panel meter are:

- Oscillator oven power
- Cesium oven temperature
- Cesium beam current
- Oscillator control voltage
- Internal power supply voltage
- Battery charge current

A 25 pin type "D" connector on the rear panel provides analog outputs for the monitors listed above, as well as the ion pump current monitor. Deguassing inputs are also provided on this connector.

For module maintainability, the FTS 4060 has designed-in serviceability:

- Monitoring diagnostics and automatic or manual adjustments described above
- Functional isolation at the board level
- Slide out assemblies and quick connect cables

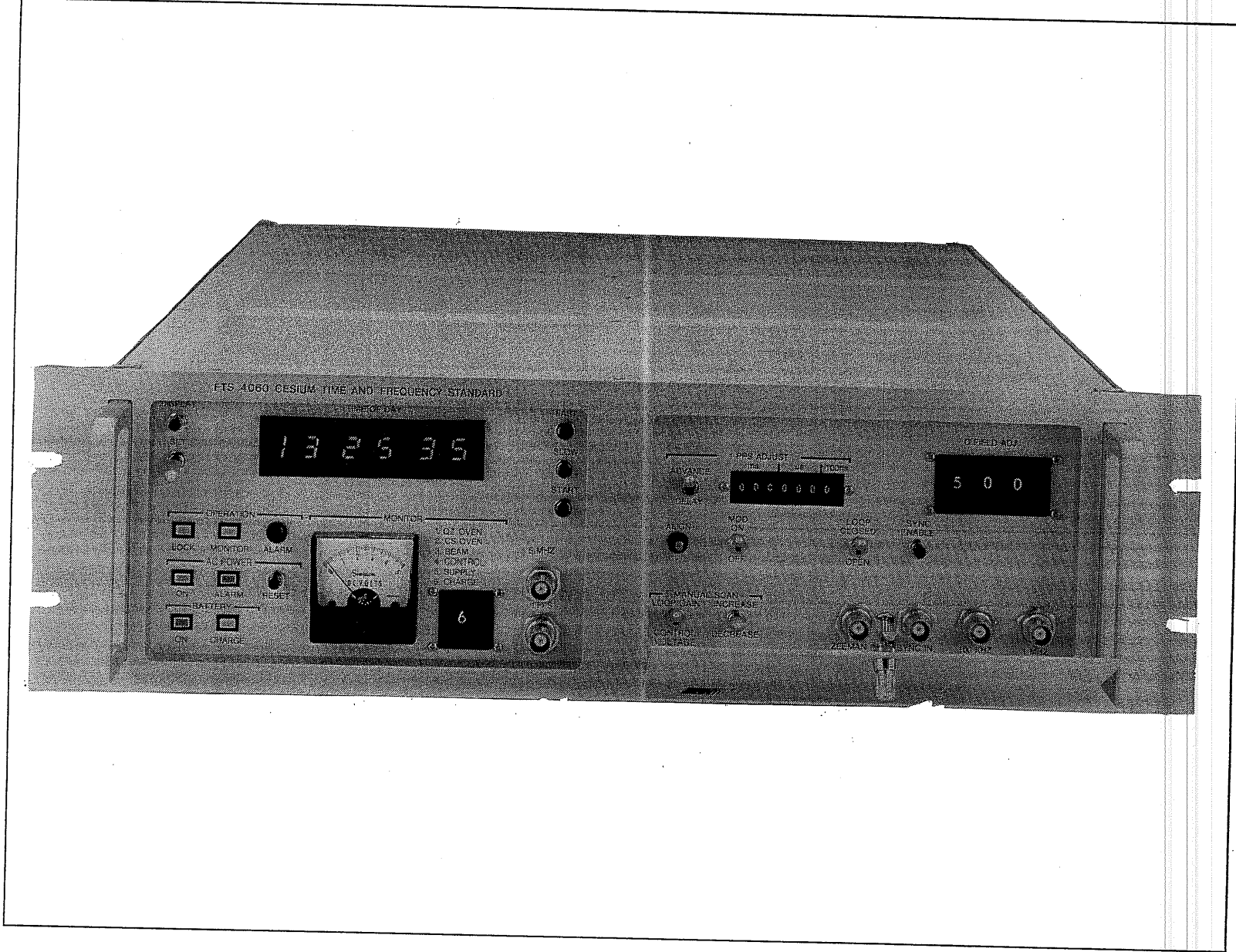
## 1.2 SUMMARY DESCRIPTION (cont'd)

The FTS 4060 operates from 115/230 V ac or 22 to 30 V dc. An optional internal battery/charger provides for a nominal 1 h standby protection from power failure.

A complete list of performance characteristics is provided in Table 1-1. Figures 1-2 and 1-3 are characteristic curves of the rf output signals in the frequency and time domains. Table 1-2 lists recommended test equipment for operating and performance checks, troubleshooting, and alignment.

## 1.3 INSTRUMENT IDENTIFICATION

A slash (/) and a three-digit number, following the four-digit model number (4060) specifies an option that is supplied within the instrument. See Table 1-1 for a list of available options.



1-4

FIGURE 1-1 FTS 4060  
(shown with Options 061, 116, and 117)

TABLE 1-1 SPECIFICATIONS, FTS 4060 (at 25 °C unless otherwise specified)

PERFORMANCE

ACCURACY	$\pm 7 \times 10^{-12}$	
RETRACE (Reproducibility)	$\pm 3 \times 10^{-12}$	
SETTABILITY (Frequency)	$\pm 2 \times 10^{-13}$	
FREQUENCY CHANGE Over operating temperature Under dc magnetic field (2 gauss dc; ac, 50, 60, 400 Hz)	$< 5 \times 10^{-12}$ $< 2 \times 10^{-12}$	
OPERATING TEMPERATURE RANGE	0 to 50 °C	
STABILITY $\sigma_y(\tau)$ <u>Averaging Time (<math>\tau</math>)</u> 1 s 10 s 100 s 1,000 s 10,000 s	$7 \times 10^{-12}$ $7 \times 10^{-12}$ $5 \times 10^{-12}$ $2 \times 10^{-12}$ $5 \times 10^{-13}$	
SSB PHASE NOISE $\epsilon(f)$ (1 Hz Bandwidth) <u>Offset from Carrier (f)</u> 1 Hz 10 Hz 100 Hz 1000 Hz	<u>@ 10 MHz</u> -99 dBc -130 dBc -140 dBc -150 dBc	<u>@ 5 MHz</u> -108 dBc -140 dBc -150 dBc -157 dBc

TABLE 1-1 SPECIFICATIONS, FTS 4060 (cont'd)

PERFORMANCE (cont'd)

SPECTRAL PURITY	Harmonics	@ 10 MHz	@ 5 MHz
	Spurious Signals	< -40 dBc	< -40 dBc
	Signal-to-phase noise ratio in 30 kHz noise BW	< -80 dBc	< -80 dBc
		> 81 dB	> 87 dB
WARM-UP TIME *		30 minutes	

\*Note: If the FTS 4060 has been in storage for an extended period, the warm-up time may be greater than specified

OUTPUTS

<p>SINUSOIDAL OUTPUTS</p> <p>Rear Panel (standard 1 ea) (w/Option 061)</p> <p>Front Panel (w/Option 061) Amplitude</p>	<p>10 MHz, 5 MHz</p> <p>Add 1 MHz, 100 kHz</p> <p>Add 5 MHz, 1 MHz, 100 kHz</p> <p>0.9 to 1.5 Vrms into 50 ohm load</p>
<p>PULSE OUTPUTS (w/Opt 116 or 117)</p> <p>Front Panel</p> <p>Rear Panel</p> <p>Amplitude</p> <p>Width</p> <p>Rise Time</p> <p>Fall Time</p>	<p>1 pps advance/delay</p> <p>1 pps advance/delay, 1 pps master</p> <p>10 V ± 1 V peak into 50 ohm load</p> <p>20 us ± 10%</p> <p>&lt; 50 ns</p> <p>&lt; 2 μs</p>
<p>MONITOR OUTPUTS</p> <ul style="list-style-type: none"> <li>-cesium beam current</li> <li>-oscillator control voltage</li> <li>-oscillator oven power</li> <li>-battery charge current</li> <li>-cesium oven temperature</li> <li>-internal power supply voltage</li> <li>-monitor alarm</li> <li>-fault alarm</li> </ul>	<p>(25 contact "D" connector on rear panel; also on front panel meter)</p> <p>(see Table 2-1)</p>

TABLE 1-1 SPECIFICATIONS, FTS 4060 (cont'd)

INPUTS

<p><b>PULSE SYNCHRONIZATION INPUT</b> (front panel)(w/Opt 116 or 117) Amplitude Width Rise Time Synchronization Accuracy</p>	<p>4 to 10 V peak into 50 ohm load &gt; 500 ns &lt; 50 ns &lt; ± 150 ns</p>
<p><b>C-FIELD DEGAUSS INPUT</b></p>	<p>2 contacts on rear panel "D" connector</p>
<p><b>ZEEMAN INPUT</b></p>	<p>Front panel BNC connector 42.82 kHz @ 1 V rms</p>
<p><b>CONTROLS</b> Lock Alarm Indicator Reset AC Power Alarm Reset Modulation On/Off Loop Open/Close Loop Gain Adjustment Oscillator Control Voltage Adjust Alignment Control C-field Adjust Sync Enable TOD Display: Set, Fast, Slow, Start</p>	

GENERAL

	<u>AC</u>	<u>DC</u>
<p><b>POWER REQUIREMENTS</b> Operating Voltage With Option 010 Frequency Range Power (operating) (warm-up) Option 061 Additional RF Outputs Option 010 Internal Batt/Charger (Fast Charge) (Trickle Charge) Option 116 Time of Day Display Option 117 TOD Display with 1 PPS Delay</p>	<p>115/230 V ac ± 10%  47 to 400 Hz 68 W 128 W Add 4 W  Add 16 W Add 2 W Add 12 W Add 6 W</p>	<p>22 to 30 V dc 26 to 30 V dc N/A 28 W 60 W Add 4 W  N/A N/A Add 6 W Add 3 W</p>

TABLE 1-1 SPECIFICATIONS, FTS 4060 (cont'd)

GENERAL (cont'd)

<p><b>MATING CONNECTORS</b>                  Rear Panel                  AC Line Input                  External DC Input                  RF and 1 pps Outputs                  Monitor Output                  Front panel                  1 PPS Output                  RF Outputs                  SYNC Input                  Zeeman Input</p>	<p>Belden #17250 Power Cord                  MS3106A-14S-5S                  BNC                  25 Contact, male, Cannon #DB-25P                    BNC                  BNC                  BNC                  BNC</p>
<p><b>FUSES</b>                  AC Line Input @ 115 V                  Ext DC Input @ 230 V                  Battery</p>	<p>2 A SB, 0.25" x 1.25"                  1 A SB, 0.25" x 1.25"                  4 A, 0.25" x 1.25"                  2 A, 0.25" x 1.25"</p>
<p><b>DIMENSIONS</b>                  Height                  Width                  Depth    <b>WEIGHT</b> FTS 4060                  Option 010 Internal Battery/Charger</p>	<p>133 mm (5.2")                  483 mm (19")                  533 mm (21")                    27.2 kg (60 lbs)                  Add 4.5 kg (10 lbs)</p>

ENVIRONMENT

<p>TEMPERATURE, OPERATING                  TEMPERATURE, NON-OPERATING                  Storage                  Short-term                  HUMIDITY, OPERATING                  MAGNETIC FIELD</p>	<p>0 to 50 °C                    -40 to +50 °C                  -40 to +75 °C                  95% up to 50 °C                  0 to 2 gauss</p>
---	--



TABLE 1-1 SPECIFICATIONS, FTS 4060 (cont'd)

**OPTIONS**

010	Internal Battery
015	External Standby Battery Supply
061	1 MHz and 100 kHz Outputs
013	Rack Slides
116	Time of Day Display
117	1 PPS Advance/Delay
018	Time Code Generator (covered by Addendum)
062	Additional RF Outputs (covered by Addendum)
063	DS1 Frequency Synthesizer (covered by Addendum)
064	CEPT Frequency Synthesizer (covered by Addendum)
048	-48 Vdc Power Input (covered by Addendum)
075	Extended Tube Warranty

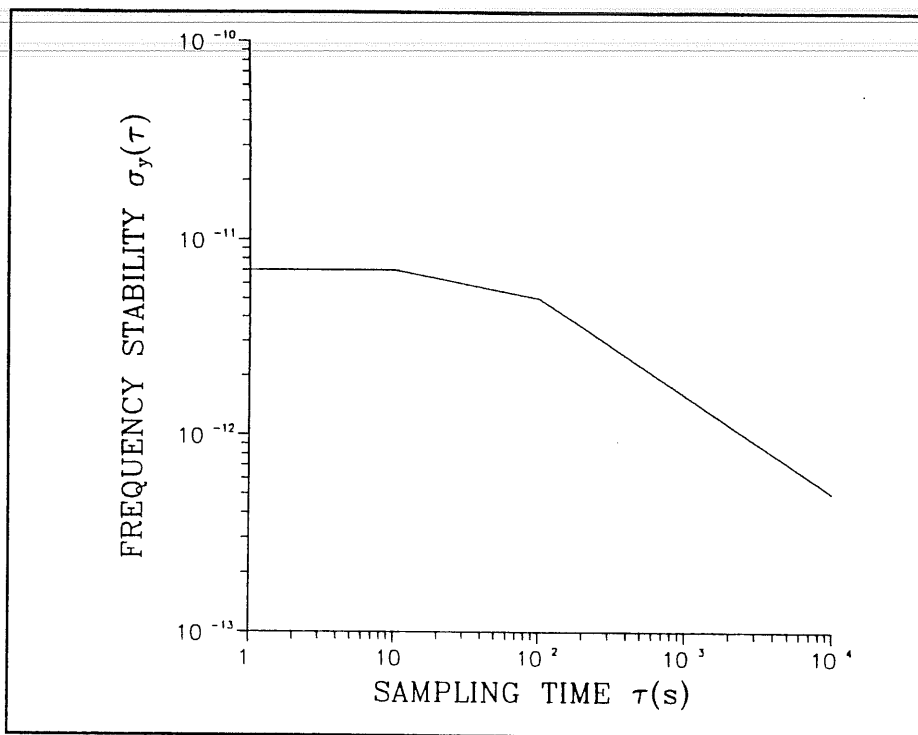


FIGURE 1-2 FREQUENCY STABILITY

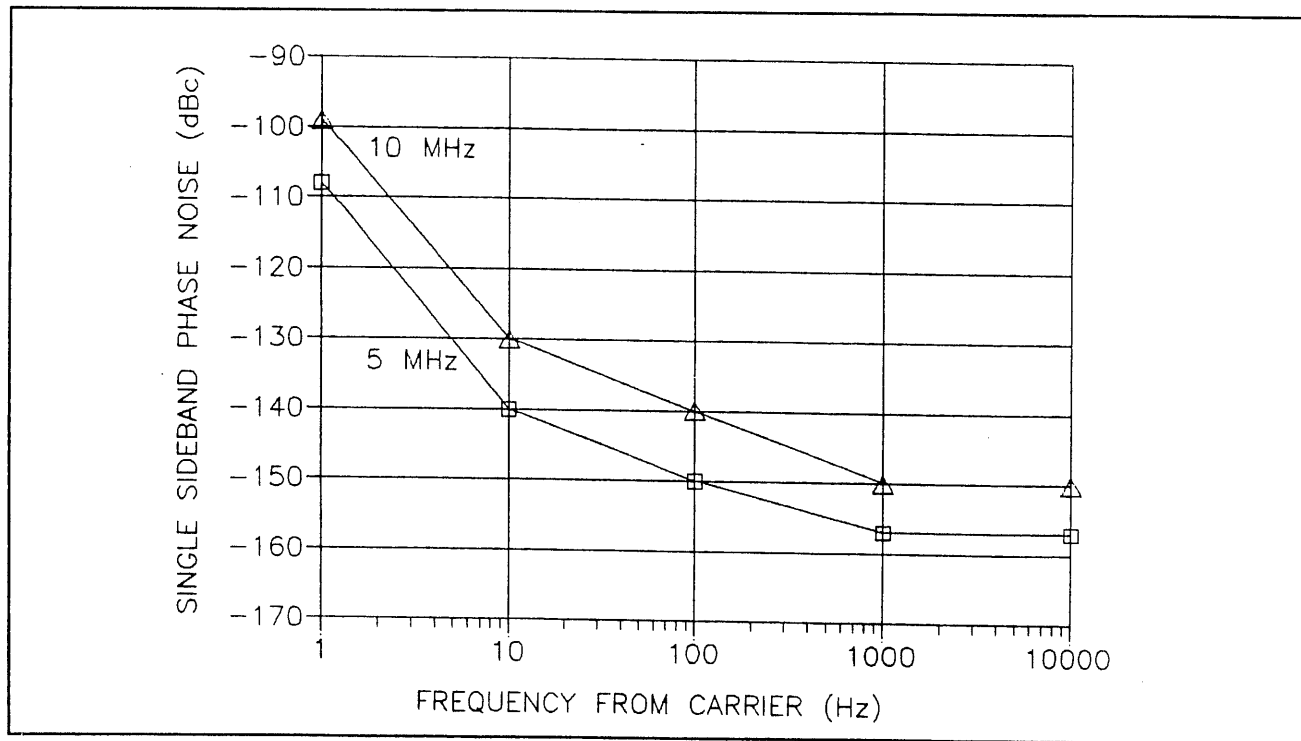


FIGURE 1-3 SINGLE SIDE-BAND PHASE NOISE SPECTRAL DENSITY

TABLE 1-2 RECOMMENDED TEST EQUIPMENT

ITEM NO. AND DESCRIPTION	REQUIRED CHARACTERISTICS	PURPOSE/USE	EXAMPLES OF APPROPRIATE EQUIPMENT
1. Primary Frequency Standard	Accuracy, stability, and phase noise commensurate with FTS 4060.	Performance Check	FTS 4000, 4010, 4050, 4100, 4150, 5030
2. Spectrum Analyzer	Freq. range: 100 kHz to 10 MHz Scan Width: 2 kHz to 100 MHz	Performance Check Input Level: 13 dBm/50 $\Omega$	HP 8858B
3. Oscilloscope	Frequency Response: 60 MHz Sensitivity: 10 mV/div Calibrated Sweeps: 2 s to 0.1 $\mu$ s/div	Performance Check Troubleshooting	TEK 2213
4. Digital Multimeter	4 1/2 Digit Display	Troubleshooting Adjustments	Data Precision 2480R
5. Signal Generator	Frequency: 5 Hz to 5 MHz Output: up to 13 dBm/50 ohms	Performance Check Troubleshooting Adjustments	HP 3301A
6. Phase Comparator	Frequency: 10 MHz Linear Output: 0 - 1 V	Performance Check	FTS 6101
7. Strip Chart	Speed: 3cm/h Span: 1, 10 V fs	Performance Check	SOLTEC S4201
8. Power Supply	Power Range: 0 to 40 V 0 to 3 A	Troubleshooting	LAMBDA LA-532
9. Termination Feedthrough	BNC, Male to Female, 50 ohm	Performance Check	TEK 011-0049-01
10. Control and Monitor Module	Compatible with FTS 5030	Troubleshooting	FTS 6006
11. Frequency and Time-Interval Counter	Frequency: 0 to 10 MHz Sensitivity: 100 mV Accuracy: 10 ns, 10 digit display	Performance Check Troubleshooting	HP 5328A
<p>NOTE: If desired, additional test equipment, equipment combinations, and test procedures for frequency-time performance analysis may be obtained in Characterization of Clocks and Oscillators, NIST (formerly NBS) Technical Note 1337, U.S. Government Printing Office, March 1990.</p>			

1.4 STORAGE/SHELF LIFE, FTS 4060

During storage of the FTS 4060, there are three factors to consider; battery shelf life, cesium beam tube vacuum and shelf life.

1.4.1 Battery Storage

Prior to placing the unit in storage, the internal battery should be brought to a fully charged condition by operating the instrument from ac power for a suitable length of time (48 hours maximum for discharged batteries). After removing ac power, be sure to turn off the FTS 4060 by removing the BATTERY FUSE on the rear panel.

At storage temperatures of 35 °C and above, the battery should be recharged periodically on a schedule determined by the storage temperature (see Table 1-3). To insure the most efficient recharge cycle, recharge the instrument in an ambient temperature of 25 ± 10 °C.

**Table 1-3 BATTERY RECHARGE INTERVALS**

Temperature ( °C)	Recharge Interval (mo)	
	Battery Disconnected	Battery Connected
<35	24	12
45	12	6
55	6	3
65	3	1.5

Alternatively, the battery may be removed during extended high temperature storage and stored in a cooler location to preclude this maintenance procedure.

1.4.2 Cesium Beam Tube Vacuum

If extended high temperature storage is anticipated, the ion pump in the cesium beam tube must be operated periodically to maintain the tube vacuum. The ion pump functions whenever the FTS 4060 is connected to an external power source (ac or dc). The FTS 4060 must be operated for at least 30 minutes for every six months of storage time. Refer to Section 2 for the turn-on procedure.

1.4.3 Cesium Beam Tube Shelf Life

Extended high temperature storage reduces the expected operating life of the cesium beam tube. The reduction in tube life expectancy for each year at a given temperature may be approximated by Table 1-5.

**Table 1-5 CESIUM BEAM TUBE SHELF LIFE**

Storage Reduced Life Temperature ( °C)	Reduction in Life Expectancy per Year at Storage Temperature
40	20 d
50	1 mo
60	2 mo
70	4 mo

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**1.5 PREPARATION FOR SHIPMENT**

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**CAUTION**

**After ac power is removed, the BATTERY FUSE must be removed; if not, the battery will continue to operate the instrument until the battery is discharged.**

To turn off FTS 4060 prior to shipment, remove ac and ext dc power. Remove the battery fuse for a period of 10 seconds then reinstall.

**1.5.1 Hazardous Material (HAZMAT) Shipping Considerations**

FTS Cesium standards contain a small amount of cesium metal. The cesium isotope used (cesium 133) is non-radioactive. However, because of its reactive chemical properties, cesium is technically classified as a hazardous material by the U.S. Department of Transportation (USDOT) and the International Air Transport Association (IATA). During normal handling the FTS 4060 presents no danger since the cesium is encased within a vacuum sealed metal enclosure. However, hazardous materials, depending upon their specific nature, are subject to certain shipping regulations of the USDOT and the IATA. These regulations govern the shipping case as well as its labeling.

The initial shipment of every FTS cesium standard complies with HAZMAT regulations: the shipping case used has been tested and certified.

FTS has designed this case to meet current hazardous shipping regulations. The case design has been engineered to prevent damage to the unit during shipment. This case has an expiration date and will require update of certification numbers after its expiration. Updated certification numbers can be obtained from FTS Customer Service.

In order to facilitate customer shipment of its cesium products, Frequency and Time Systems (FTS) provides certified shipping case which comply with USDOT and IATA regulations. This case provides the necessary physical protection for the instrument during shipping. Contact FTS Technical Service for information about this service.

The cesium standard shipping case is FTS Part Number 08748-701.

### 1.5.2 Packing Materials

The Packing Materials are composed of:

- a) an ATA case with protective antistatic foam,
- b) labels to identify the case:

Labels: FRAGILE LABEL  
UN LABEL  
DANGEROUS WHEN WET  
DANGER NO PASSENGER AIRCRAFT  
CESIUM UN1407I

### 1.5.3 Shipping Procedure

The authorized shipper is responsible for the overall condition of the case; i.e. latches locked, no visible damage to the case and to properly place all labels on the case, etc.

### 1.5.4 Placement Of Labels On Shipping Case

See Figure 1-5 for proper placement of labels.

Make sure an address label, proper HAZMAT labels, and packing slip (if necessary) are affixed to the shipping case and are clearly visible.

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**1.5.5 Shipment**

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Several United States and international shipping companies can accommodate properly packaged hazardous materials. United Parcel Service and Federal Express are examples for the United States. Intercontinental (617-569-4400) provides international shipping services.

Contact one of these shipping companies for assistance. If you need additional help, call FTS Technical Service.

The following information is typically requested:

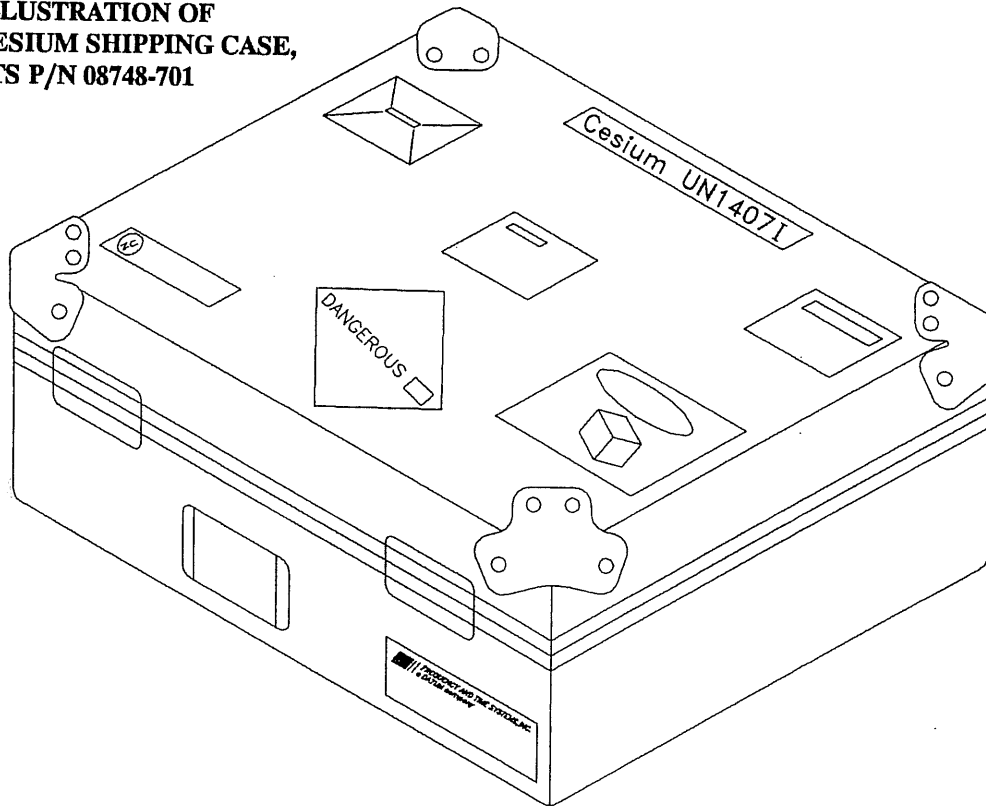
Proper Shipping Name:	Caesium (Cesium) Dangerous When Wet
Class Or Division:	4.3
UN or ID No.:	UN1407I
Quantity & Type Of Packing:	One Fiberboard Box X 5 Grams * Carton(s)
Packing Inst.	412

\* Insert number of cartons covered by the shipping paperwork.

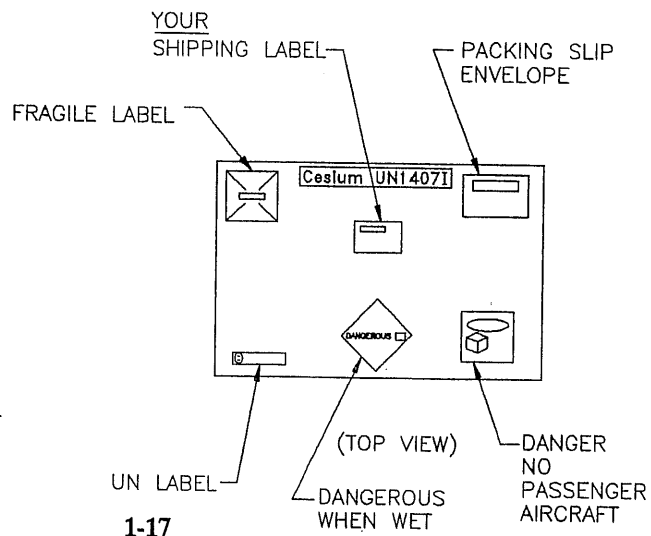


**FIGURE 1-4**

**ILLUSTRATION OF  
CESIUM SHIPPING CASE,  
FTS P/N 08748-701**



**FIGURE 1-5  
LABEL INFORMATION**



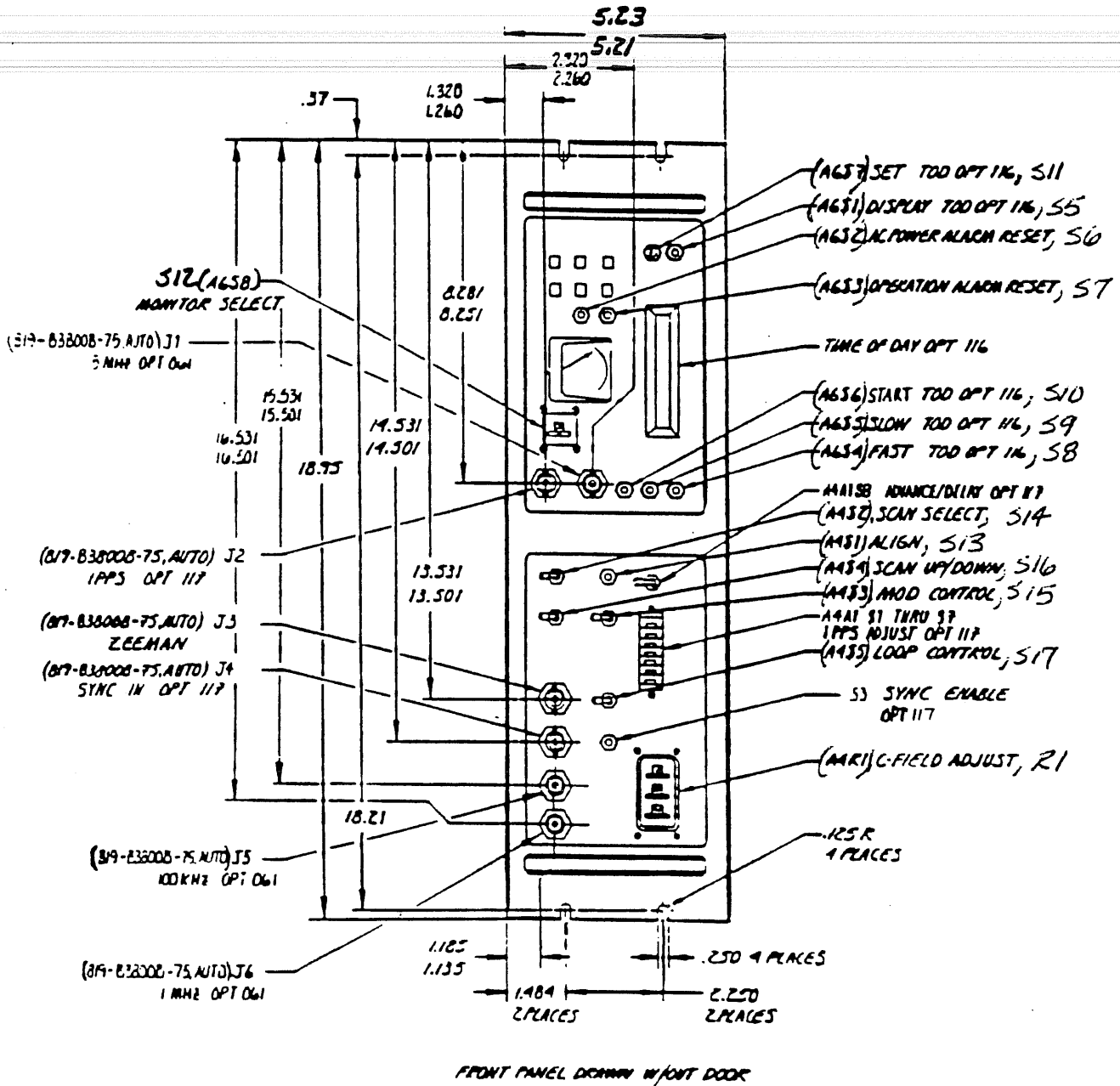
## 1.6 INSTALLATION

### 1.6.1 Environment

When installing the instrument, consideration should be given to standard environmental factors (temperature, humidity, vibration, etc.) and also to the presence of magnetic fields that might affect the accuracy of the reference. Avoid installing or using the instrument near large motors, generators, transformers, or other equipment which radiate strong fields of 2 gauss or more. Also avoid placing the instrument near a strong permanent magnetic field.

### 1.6.2 Mounting

The FTS 4060 is designed to be mounted in a standard 19-inch equipment rack. Figure 1-6 INTERFACE CONTROL DRAWING shows all applicable dimensions and mounting details. The front panel occupies a height of 5.2 inches. The FTS 4060 is 21 inches deep with a few additional inches required for attaching cables to the rear panel connectors. The FTS 4060 side plates are drilled and tapped to accept chassis rack slides. The use of chassis rack slide or other means of support is recommended because of the weight and weight distribution of the instrument.



TOLERANCES:  
XX ± .01  
XXX ± .005

FIGURE 1-6 INTERFACE CONTROL DRAWING, FTS 4060

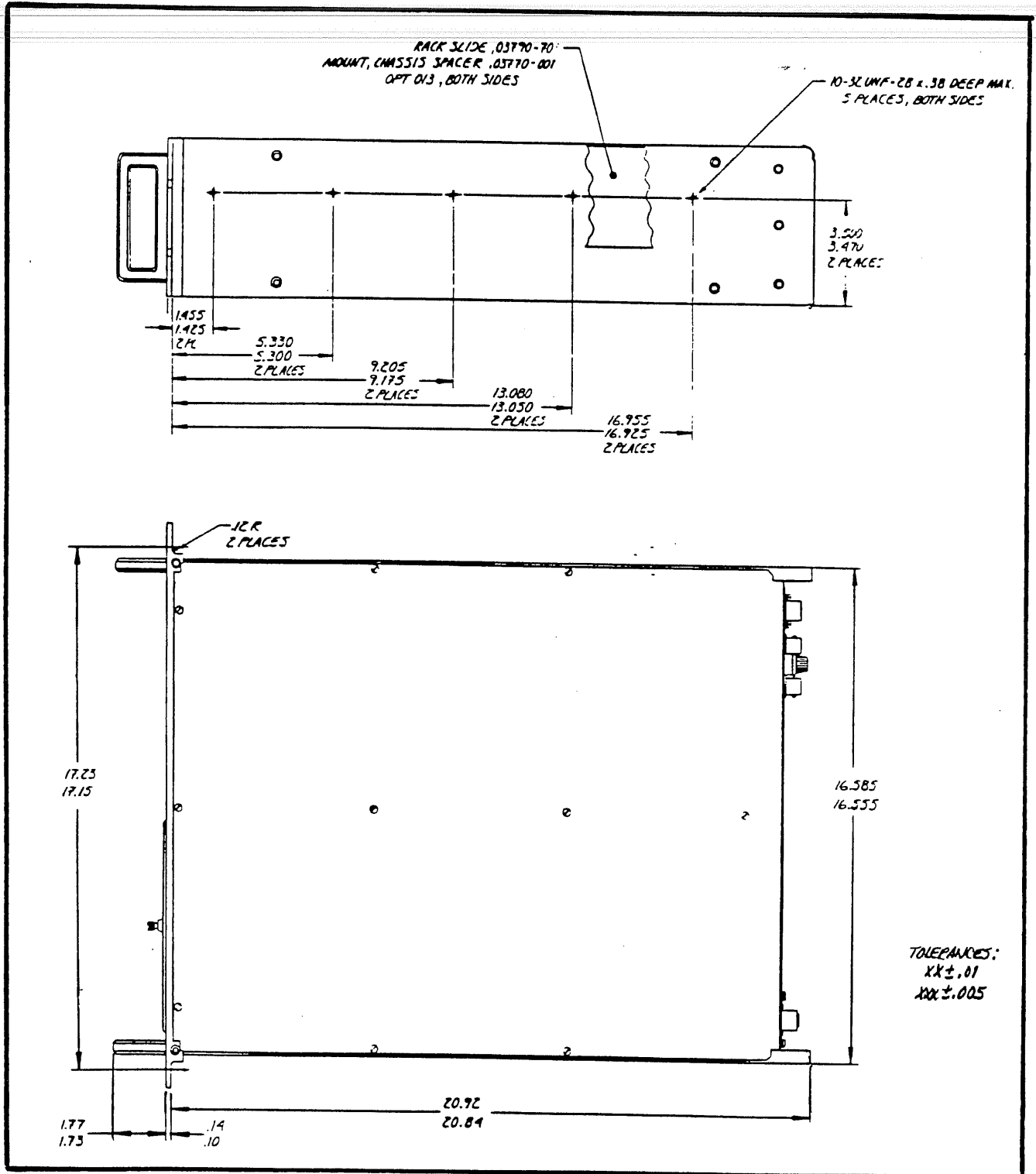
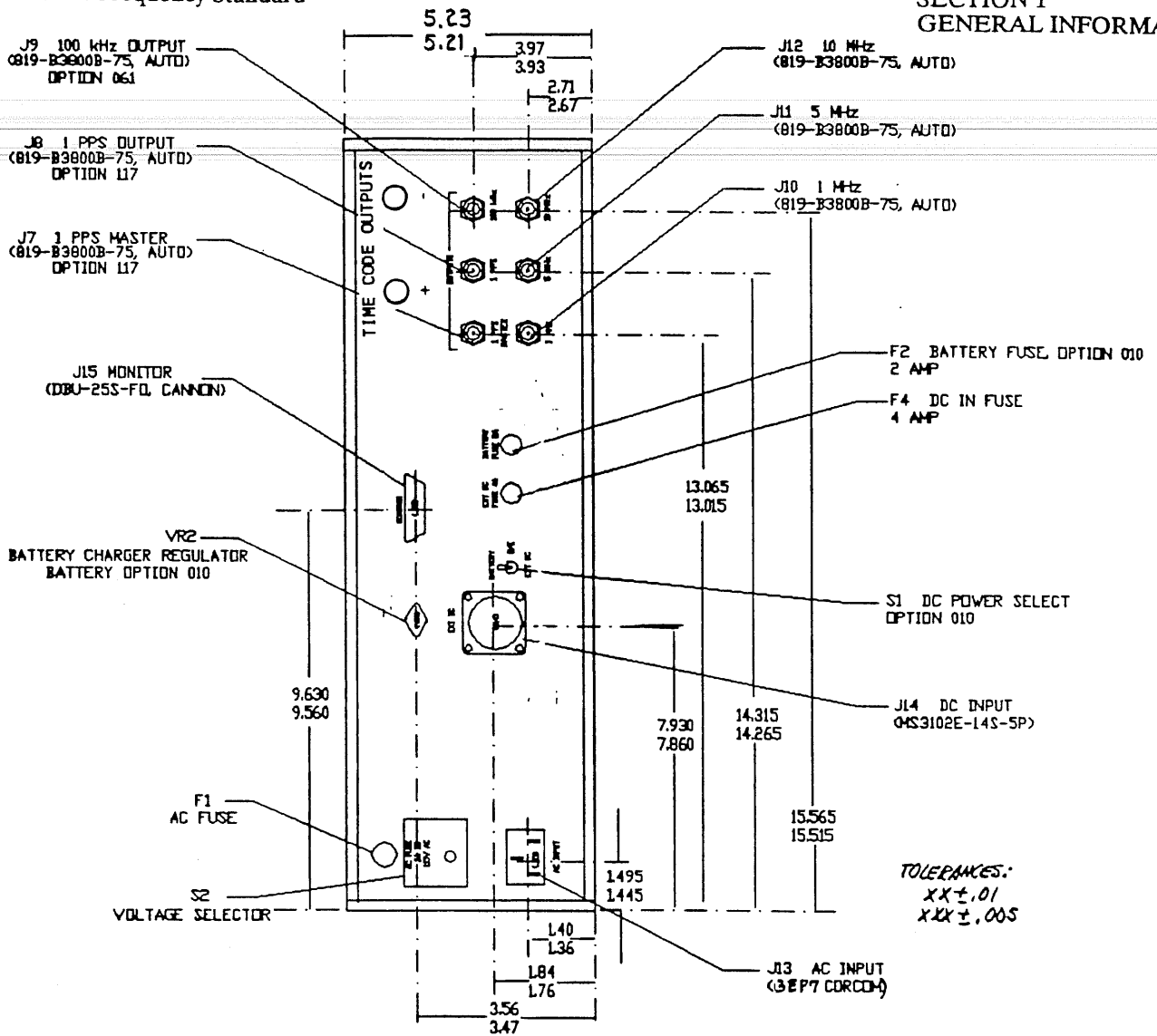


FIGURE 1-6 (cont'd) INTERFACE CONTROL DRAWING, FTS 4060



Rear Panel Connector Pin Assignments

J15 MONITOR		J13 AC INPUT		J14 DC INPUT	
PIN	FUNCTION	PIN	FUNCTION	PIN	FUNCTION
1	RELAY CONTACT 1 N.O.	1	115 V AC	A	22 to 30 V dc
2	RELAY CONTACT 2 N.C.	2	NEUTRAL	B	NO CONNECTION
3	RELAY CONTACT 3 COM.	3	SAFETY GROUND	C	GROUND
4	MONITOR ALARM			D	NO CONNECTION
5	OPERATION ALARM			E	NO CONNECTION
7	Qz OVEN				
8	Cs OVEN				
9	BEAM CURRENT				
11	CONTROL VOLTAGE				
12	ION PUMP CURRENT				
13	GROUND				
20	CHARGE CURRENT				
21	SUPPLY VOLTAGE				
22	DEGAUSS HIGH				
23	DEGAUSS LOW				

• AVAILABLE WITH TELECOM OPTIONS ONLY

FIGURE 1-6 (cont'd) INTERFACE CONTROL DRAWING

## 1.6.3 Electrical Connections

The FTS 4060 may be powered from an external ac source, 115 or 230 V ac. **BE SURE TO SELECT THE CORRECT VOLTAGE (115 or 230) ON THE REAR PANEL VOLTAGE SELECTION SWITCH BEFORE APPLYING POWER.** The instrument may also be powered by an external dc source (22 to 30 V). Before connecting ac power, check to see that the correct fuses are installed:

AC Power:	2 A SB at 115 V ac 1 A SB at 230 V ac
Ext DC:	4 A
Battery:	2 A (with Option 010 only)

Refer to Figure 1-6 for the location and contact designation for both external ac and dc power connectors.

The MONITOR connector provides analog outputs for the monitors listed on the front panel as well as the cesium beam tube ion pump current. The connector also has two contacts designated for C-field degaussing. Refer to Figure 1-6 for the contact designations.

**NOTE:** Degaussing is not normally required in most applications, unless the FTS 4060 is exposed to strong magnetic fields (greater than 10 gauss). If degaussing is desired, refer to an operation manual for a cesium beam tube degausser, or call the factory for assistance.

1.6.4 Chassis Rack Slides (Option 013)

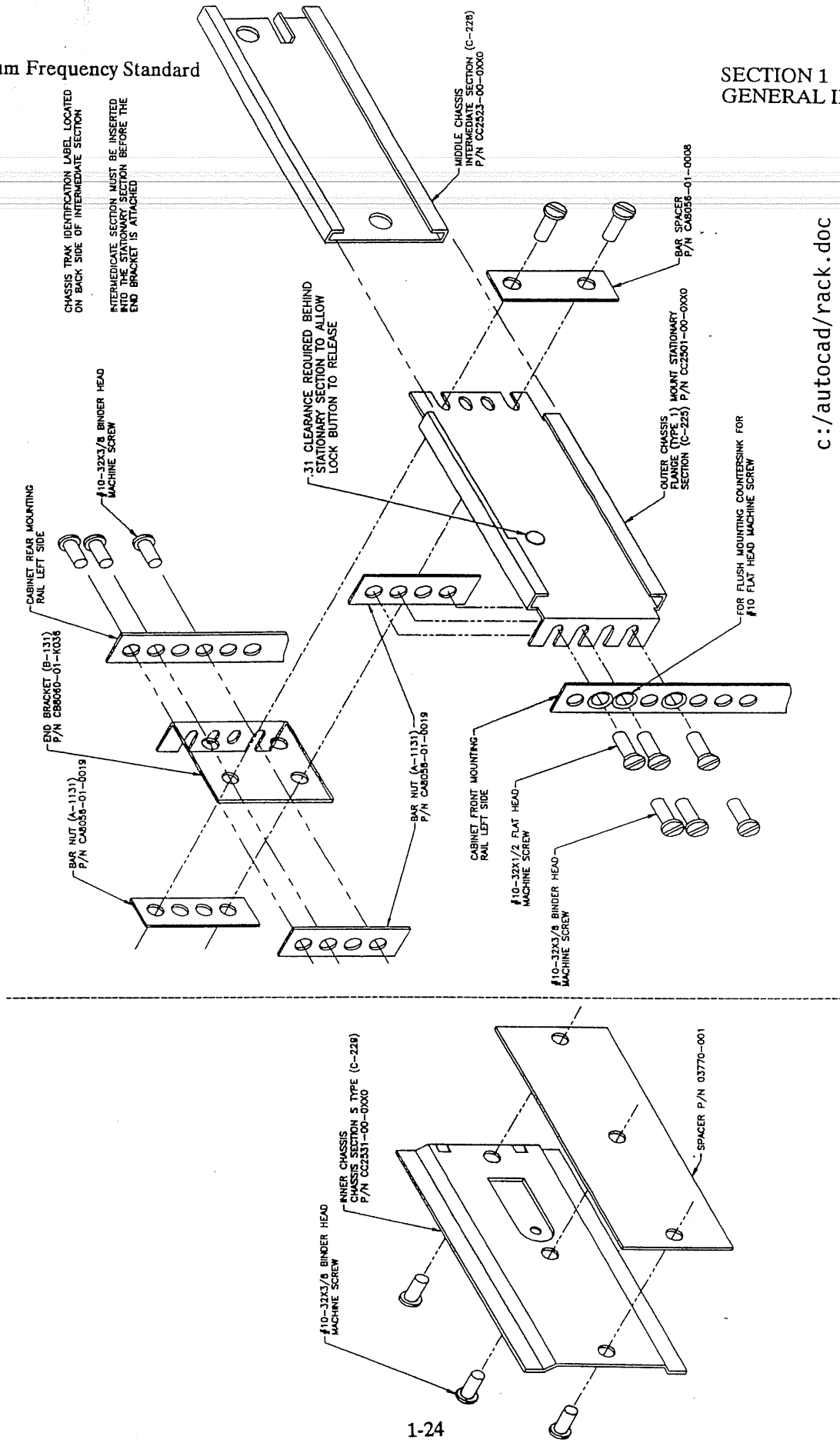
An FTS 6013 Rack Slide Accessory kit is recommended for mounting the FTS 4060 to a 19 inch rack assembly.

Included in the FTS 6013 are:

Rack Slides;	part number 03790-701
Connecting Hardware;	part of 03790-701
Rack Slide Spacers (2);	part number 03770-001

1.6.4.1 Mounting Procedure

- 1) Separate the inner chassis sections from each rack slide assembly.
- 2) Attach connecting hardware to chassis sections. See Figure 1-7 Rack Slide Assembly Diagram for placement of hardware.
- 3) Place four machine screws (#10-32x3/8) in the first four holes of both inner chassis sections. Leave the hole behind the stop tab open on each assembly.
- 4) Place an aluminum spacer (part number 03770-001) over the four exposed screws on each inner chassis section.
- 5) Attach both inner chassis sections and spacers, starting with the second hole from the front panel, to the sides of the FTS 4060.
- 6) Attach the outer and middle chassis sections to the rack and adjust the connecting hardware so that the outer and middle chassis sections will align to the FTS 4060.
- 7) Slide the FTS 4060 onto the tracks of the mounted rack sections. When the slides lock, depress the stop tabs and push the FTS 4060 the rest of the way into the rack.



c:/autocad/rack.doc

Figure 1-7 Rack Slide Assembly Diagram



**SECTION 2. OPERATION****2.1 INTRODUCTION**

This section describes procedures for turn-on, monitoring and for controlling pulse synchronization, alignment and other adjustments of the FTS 4060 Cesium Frequency and Time Standard.

**2.2 TURN-ON PROCEDURE**

Except for the application of ac power, no specific user actions are required to turn-on the FTS 4060 and obtain the specified rf output signals. However, monitor and control functions are provided and are described below. Read the entire procedure and tables below before executing the turn-on steps. Refer to Figures 2-1 and 2-2 for an illustration of the front and rear panels of the FTS 4060.

- 1) Apply ac power to the instrument.
- 2) Set the following operating controls:
  - a. Set the MOD ON/OFF switch to ON.
  - b. Set the LOOP CLOSED/OPEN switch to CLOSED.
- 3) Allow the FTS 4060 to warm-up for the specified warm-up time (refer to Table 1-1). Frequency lock will be indicated by illumination of the LOCK indicator.
- 4) Depress the ALARM pushbutton switch to turn off the ALARM indicator.
- 5) Set the rear panel standby power switch to the preferred position for long term operation (refer to paragraph 2.8).

Table 2-1 MONITORS AND INDICATORS lists expected values for the five analog monitors and four indicators during and after warm-up. The monitor voltages are also available at the rear panel MONITOR connector.

**2.2.1 TURN ON PROCESS**

Note: The following description is not part of the turn-on procedure but is provided to describe the main events of the turn-on process.

After turn-on from a "cold" start (25 °C) the temperature of the cesium and quartz crystal ovens must be raised to their operating points. The cesium oven reaches it's operating point (90 °C) in about 10 minutes. The quartz crystal oven reaches it's operating point at 80 °C in about 20 minutes.

### 2.2.1 TURN-ON PROCESS (continued)

When the system monitors are within preset limits and as the oscillator approaches its nominal operating frequency, the autolock routine begins looking for the cesium resonance. Once the central peak of the resonance has been identified, the autolock routine monitors the frequency drift rate of the oscillator until it reaches an acceptable rate. When the oscillator drift rate is acceptable, the servo lock routine is initiated, the LOCK indicator turns on, and warm-up is completed.

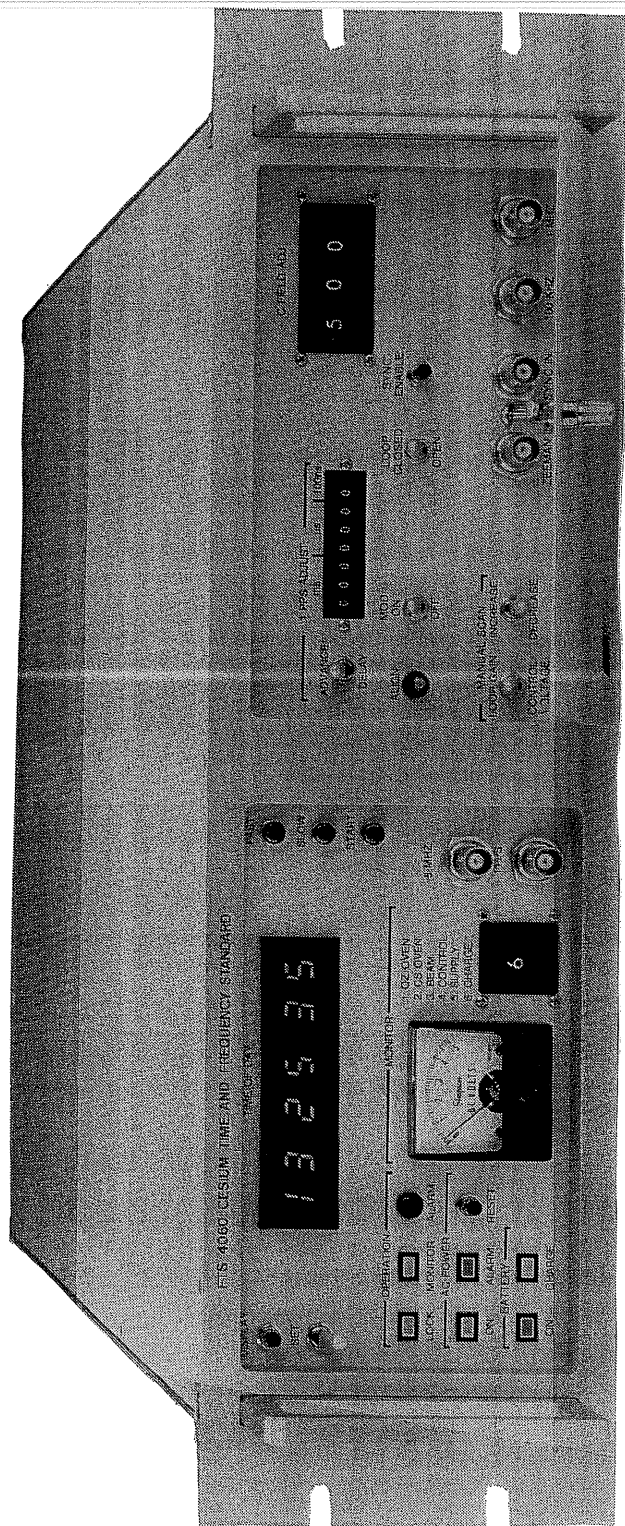
Note: During warm-up and autolock, user operation of the front panel controls is denied by the micro-processor. To gain control of the instrument, refer to paragraph 2.6.5 Autolock Override.

### 2.3 TURN-OFF AND RESTARTING

To turn off the FTS 4060, follow the steps below:

- 1) Set the rear panel standby power switch to EXT DC (this action disconnects the internal battery if supplied).
- 2) Remove EXT DC power.
- 3) Remove ac power.

If power to the FTS 4060 is interrupted, restart the instrument using the turn-on steps above, as applicable. If the instrument is turned off for only a few minutes, frequency lock will be achieved in much less than the specified warm-up time.



**FIGURE 2-1 FTS FRONT PANEL**  
(shown with Options 061, 116, 117)

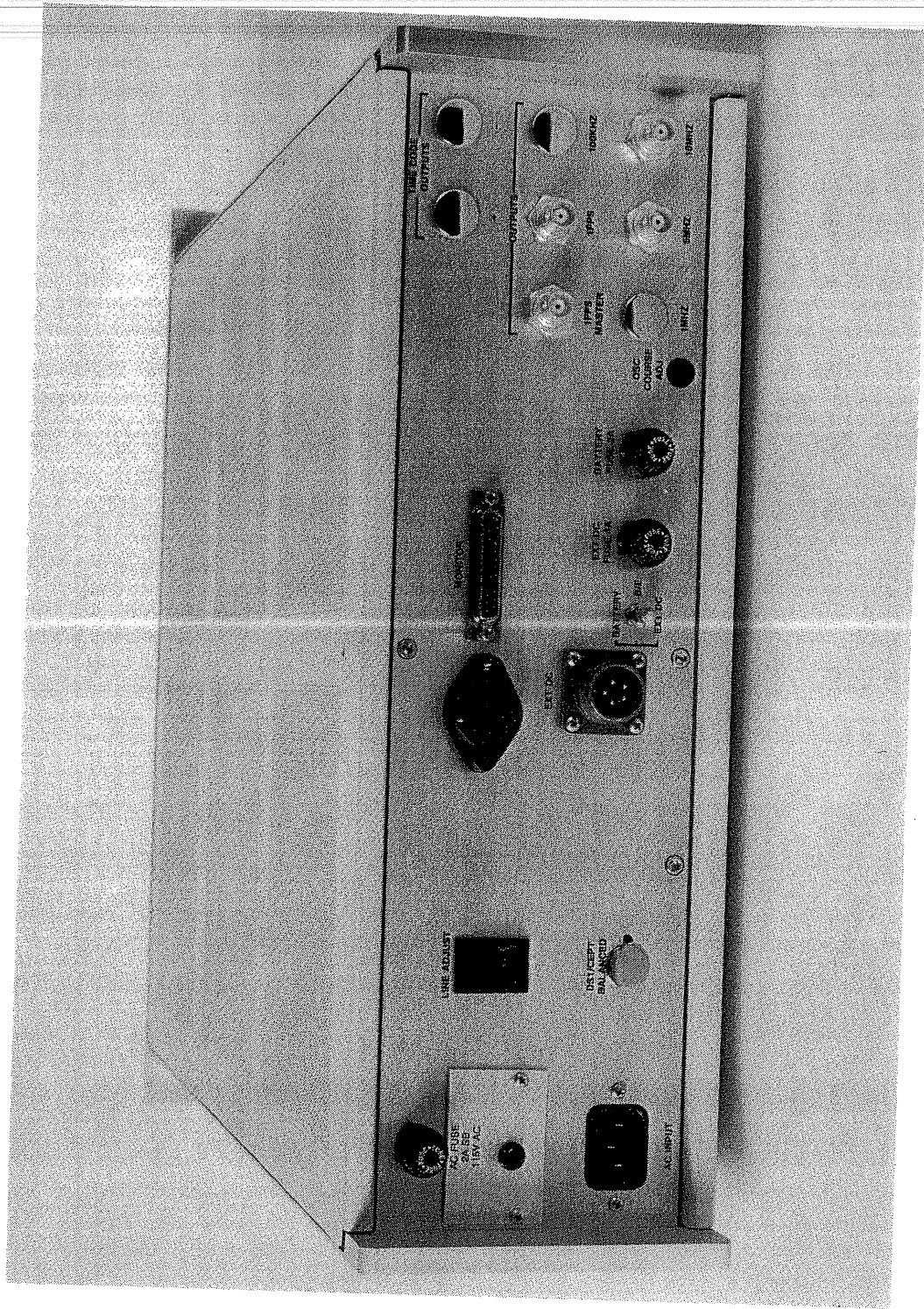


FIGURE 2-2 REAR PANEL  
(shown with Options 061, 010)

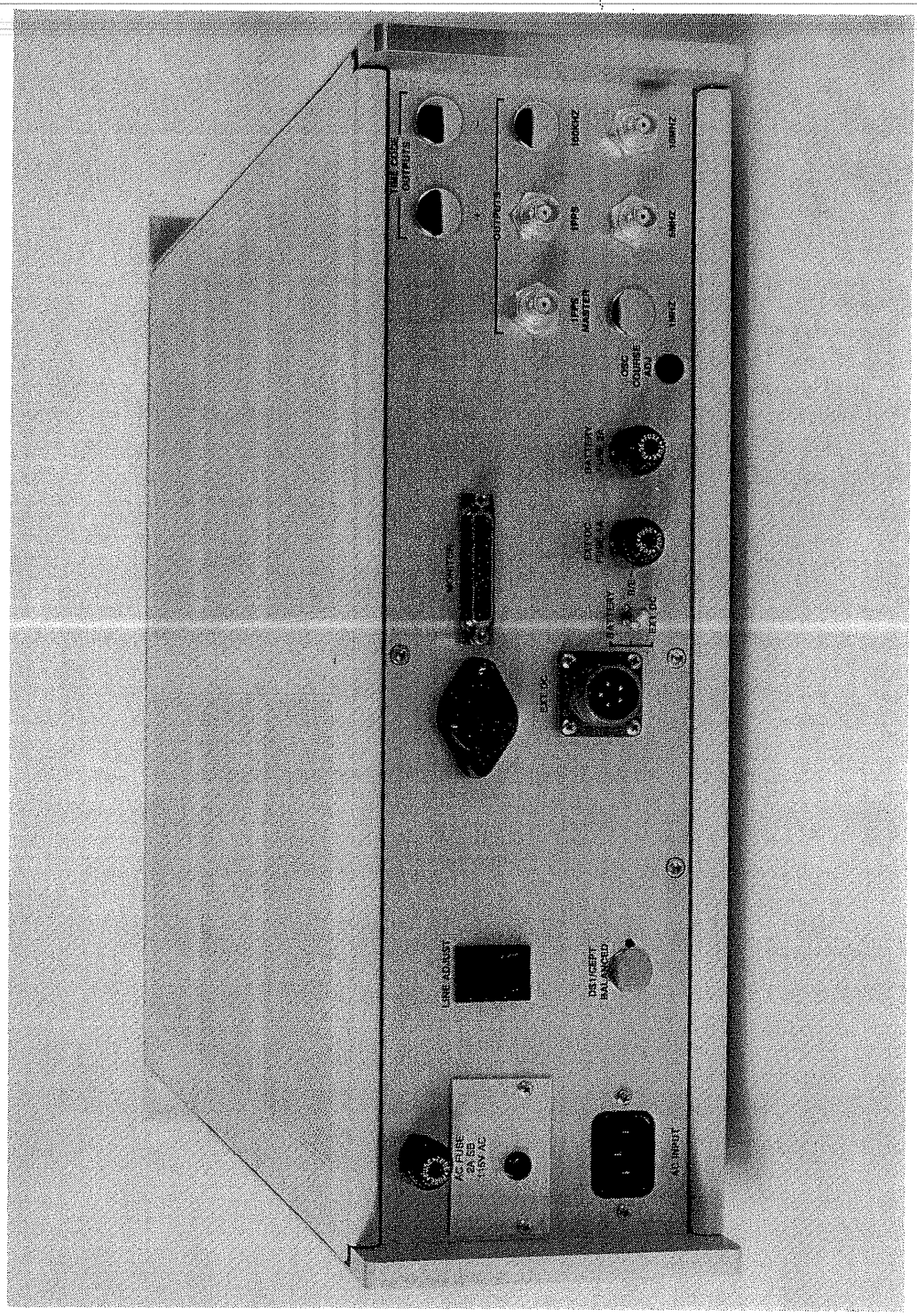


FIGURE 2-2 REAR PANEL  
(shown with Options 061, 010)



TABLE 2-1 MONITORS AND INDICATORS

REAR-PANEL MONITOR CONNECTOR*	MONITOR POSITION & FUNCTION	INITIAL READING (after turn-on)	NORMAL READING (after warm-up)	NOTES
1	Telecom Relay Contact			Available with telecom options (063 or 064) only. Normally open at no alarm state.
2	Telecom Relay Contact			Available with telecom options (063 or 064) only. Normally closed at no alarm state.
3	Telecom Relay Contact			Available with telecom options (063 or 064) only. Common for Pins 1 & 2 relay contacts (contact rating max 10 A at 30 V)
4	Monitor Alarm Remote TTL	N/A	TTL High	This is a TTL output which follows the "Monitor" LED indicator on the front panel (see page 2-7, MONITOR).
5	Operation Alarm Remote TTL	TTL Low	TTL High	This is a TTL output which follows the "ALARM" LED indicator on the front panel (see page 2-7, MONITOR).
7	1. QZ OVEN	0 + 0.2	3.5 ±0.5	Represents the power input to the quartz crystal oven in the oscillator. The monitor voltage will fall as the ambient temperature is raised.
8	2. CS OVEN	3.7 ±0.5	1.4 ± 0.3	Represents the operating temperature of the cesium oven. The monitor decreases as the cesium oven warms up.
9	3. BEAM	0 to 5	2.5 ±1.0	Represents the cesium beam tube output current. The value varies from unit to unit; it may change as much as 30% over the temperature range and should rise when the modulation is turned off. A gradual decrease of the reading with time is normal.
11	4. CONTROL	0 to 5	0.6 to 4.4	Represents the control voltage applied to the oscillator. A gradual change during normal operation is indicative of the quartz crystal aging. The monitor is set to approximately mid-scale at the factory and will vary with aging of the quartz crystal.
12	ION PUMP CURRENT (rear panel only)	0 to 2	<0.2	Represents the ion pump current which indicates the vacuum level in the cesium beam tube. A gradual increase of this over the reading life of the instrument is normal.

\* All voltages measured at the rear panel MONITOR connector are referenced to contact 13, ground.

TABLE 2-1 MONITORS AND INDICATORS (cont'd)

REAR PANEL MONITOR CONNECTOR*	MONITOR POSITION & FUNCTION	MONITOR READING	NOTES
21	5. SUPPLY	AC: 3.0 ± 0.3 DC: 2.2 to 3.0	Represents the dc voltage applied to the cesium frequency standard (scale factor 10:1).
20	6. CHARGE	Fast: >4 Trickle: <2	Represents the charge current supplied to the battery when operating on external ac power (scale factor: 50 mA full scale when on trickle charge; 500 mA full scale when on normal charge).

\*All voltages measured at the rear panel MONITOR connector are referenced to contact 13, ground.

TABLE 2-1 MONITORS AND INDICATORS (cont'd)

INDICATOR FUNCTION	NOTES
LOCK	<p>Turns on when the frequency control loop is stable. Three conditions must exist to satisfy this indicator switch:</p> <ul style="list-style-type: none"> <li>▪ the frequency control loop is closed and modulation is on;</li> <li>▪ all 14 internal analog monitors are within preset limits (refer to paragraph 3.2.5.2);</li> <li>▪ the frequency offset (closed loop) due to oscillator drift, is less than approximately <math>5 \times 10^{-9}</math>.</li> </ul>
MONITOR	<p>Turns on to warn that either the BEAM current or CONTROL voltage monitors are outside of preset limits, indicating that adjustment is required. Refer to paragraph 2.6.3 to adjust beam current. The preset limits are:</p> <p style="text-align: center;">CONTROL VOLTAGE: 0.6 and 4.4 * BEAM CURRENT: 1.4 and 5.0 *</p> <p>The FTS 4060 will continue to operate within specification if the LOCK indicator also remains on. Sets J15 pin 4 low when alarmed.</p>
ALARM	<p>Latches on until reset to warn that at least one of three conditions for LOCK (see above "LOCK") has been violated since the last RESET action, even if only momentarily. The indicator also functions as the RESET switch. The ALARM indicator turns on if the BEAM current monitor is <math>&lt;0.5</math> or <math>&gt;6.0</math>.* Sets J115 pin 5 low when alarmed.</p>
AC POWER ON	<p>Turns on when ac power is applied to the rear panel input.</p>
AC POWER ALARM	<p>Latches on until reset to warn that ac power has been interrupted. The indicator is on at turn-on until reset.</p>
BATTERY ON	<p>Turns on when ac power is interrupted and the instrument is operating on EXT DC or BATTERY.</p>
CHARGE	<p>Turns on during fast charge; turns on momentarily at 30 s intervals during trickle charge; remains off after several days of trickle charging. AC power must be applied for battery charger to function.</p>
ALIGNMENT	<p>Turns on during the execution of the alignment routine to indicate that ALIGNMENT has been selected and is in progress (refer to paragraph 2.6.4).</p>

\* NOTE: Measurements are at either the front panel meter or rear panel "D" connector.



## 2.4 OPERATIONAL CHECK

After the FTS 4060 has been operating for its specified warm-up time, check the following parameters to verify proper operation:

- 1) CONTROL VOLTAGE - check the control voltage and verify that the control loop has locked near the last-locked control voltage.
- 2) BEAM CURRENT - while monitoring beam current, set the LOOP switch to OPEN, and momentarily set the MOD switch to OFF. The beam current should increase about 50% and then decrease when the MOD switch is reset to ON. Return the LOOP switch to CLOSED and reset the ALARM indicator.
- 3) Check all other monitors and status indicators. Refer to Table 2-1 MONITORS AND INDICATORS. Use Table 2-2 MONITOR LOG to record periodic measurements.
- 4) If another reference standard of known accuracy is available, a measurement of the FTS 4060 frequency offset can be made. Use the FTS 6101/001 and a chart recorder to obtain an 8 hour phase record between the reference standard and the device under test. The frequency difference may be calculated by dividing the phase change (in seconds) by the elapsed time (8 hours = 28800 seconds). For example, an offset of  $5 \times 10^{-12}$  produces a phase change of 144 ns.

DATE/TIME	DATA TAKEN BY	FREQUENCY OFF-SET	COMMENT	1.QZ OVEN	2.CS OVEN	3.BEAM CURRENT MODULATION ON/OFF	4.CONTROL	5 SUPPLY	6.CHARGE

TABLE 2-2 MONIOR LOG

## 2.5 PULSE SYNCHRONIZATION AND TIME SETTING

The steps required to synchronize the 1 pps output to a reference standard are outlined below:

- 1) Connect the 1 pps output of the reference standard to the SYNC connector of the FTS 4060.
- 2) Depress the SYNC ENABLE pushbutton for at least 2 seconds.

The 1 pps output of the FTS 4060 is now synchronized to within  $\pm 150$  ns of the reference standard.

### 2.5.1 Time Setting Procedure (Option 116)

The TOD Display (Option 116) provides hours, minutes and seconds in a 24-hour format. The units of seconds is synchronous with the 1 pps master output.

To set the time-of-day, perform the following steps, referring to the illustration in Table 2-1.

- 1) After the FTS 4060 is warmed up, synchronize the 1 pps output to a reference pulse, if desired (refer to paragraph 2.5).
- 2) Place the SET switch to SET (up position). Pull out the switch handle to unlock it.
- 3) Depress the FAST pushbutton switch until the hours displayed on the front panel advances to 1 hour before the real-time hour.
- 4) Depress the SLOW pushbutton switch until the hours displayed on the front panel advances to the real-time hours and the minutes advances to at least 1 minute past the real-time minutes.
- 5) Place the SET switch to the down position. This action disables the set switches and enables the START pushbutton switch.
- 6) When the real time-of-day equals the time displayed, depress the START pushbutton switch to start incrementing the display. The procedure is completed.

The LED display is illuminated continuously while the FTS 4060 is operating from external ac power. During operation on the internal standby battery or external dc, accurate timekeeping is preserved; however, the display is automatically turned off to conserve battery power. The display may be temporarily enabled by depressing the DISPLAY pushbutton switch.

2.5.2 1 PPS Advance/Delay (Option 116 or 117)

The 1 pps moveable outputs may be advanced or delayed by setting the toggle switch on the front panel. The "up" position is for advancing the pulse and the "down" position is for delaying the pulse. The amount of advance or delay can be selected by entering the desired interval on the front panel thumbwheel switches. See Figure 2-3 1 PPS ADVANCE/DELAY for an illustration of the ADVANCE and DELAY features.

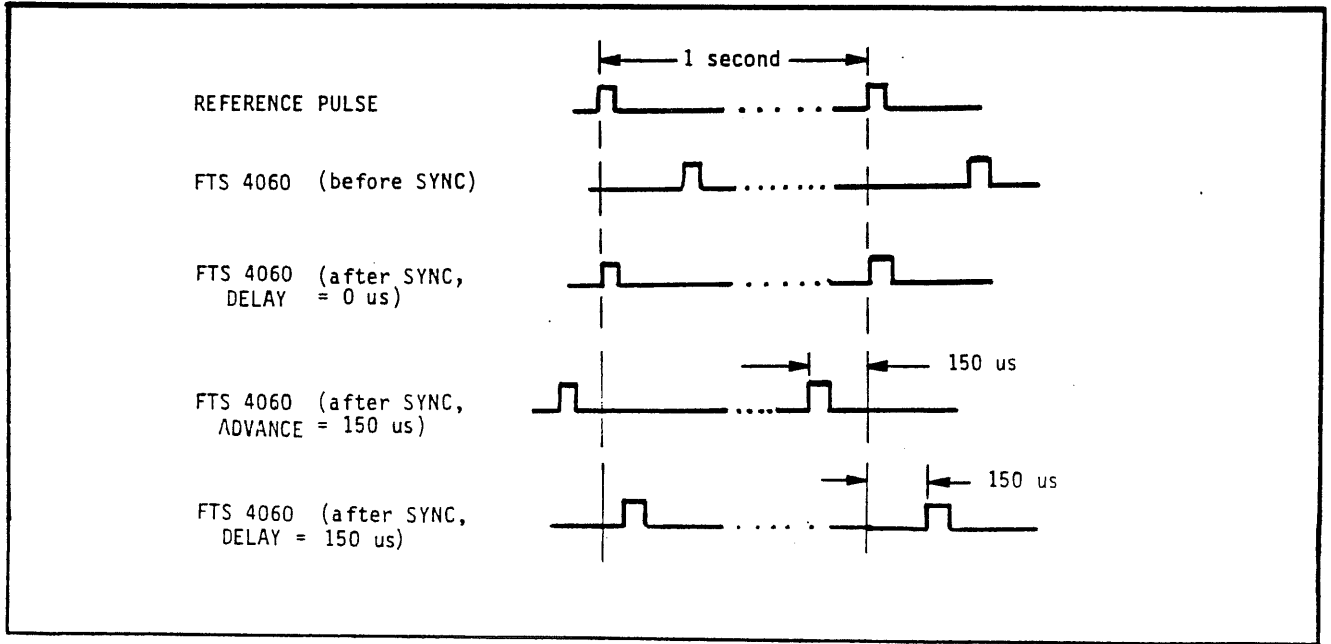


FIGURE 2-3 1 PPS ADVANCE/DELAY

2.5.2.1 1 PPS Advance/Delay Setting Procedure (Option 116 or 117)

- 1) Set advance/delay toggle switch to desired position. Set switch in "up" position labeled ADVANCE to advance the pulse or in "down" position labeled DELAY to delay the pulse.
- 2) Enter the amount of advance or delay by setting the seven thumbwheel switches, on the front panel, to the interval required. Resolution is in increments of 0.1 microsecond steps. The advance or delay interval is immediately executed as the thumbwheel switches are adjusted.

2.5.2.2 1 PPS Advance/Delay Verification

The 1 PPS advance or delay can be verified by the use of a time interval counter. The master 1 PPS signal is attached to channel "A" of the counter and the movable 1 PPS signal is attached to channel "B" (refer to Figure 2-4 1 PPS Advance/Delay Test Set-up). Trigger the counter on channel "A". The measurement should read within 0.1 microsecond of the setting selected. Remember that when the pulse is advanced, the counter reading is 1 second minus the switch setting. Use the 5 MHz output (or 10 MHz, whichever is required by the counter) from the FTS 4060 for the frequency reference to the time interval counter.

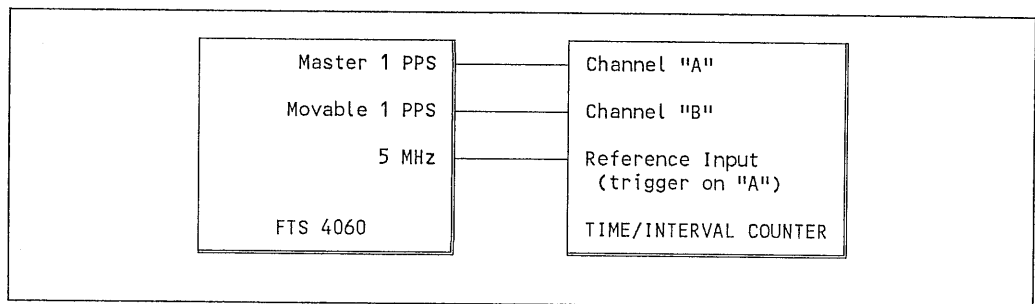


FIGURE 2-4 1 PPS ADVANCE/DELAY TEST SET-UP

2.6 OPERATIONAL CONTROLS

The six operational controls described in this paragraph are provided for convenience, and are not required to achieve the specified performance characteristics of the FTS 4060. Refer to Figure 2-5.

2.6.1 Fine Frequency Adjustment C-Field

The frequency of the FTS 4060 can be varied during closed loop operation by changing the magnetic field strength in the cesium beam tube C-field. Using the C-field adjustment, the frequency of the FTS 4060 may be adjusted to match the frequency of another standard, if desired.

The normal C-field setting is near the center of the adjustment range. A frequency change of approximately  $\pm 1 \times 10^{-11}$  (50 uHz at 5 MHz) can be entered by adjusting the thumbwheel switch settings to all 9's or all 0's. The smallest incremental change in frequency is  $2 \times 10^{-14}$ . Most applications will require the use of only the two most-significant switches,  $2 \times 10^{-12}$ /increment and  $2 \times 10^{-13}$ /increment. Note that a higher switch setting will result in a higher frequency output.

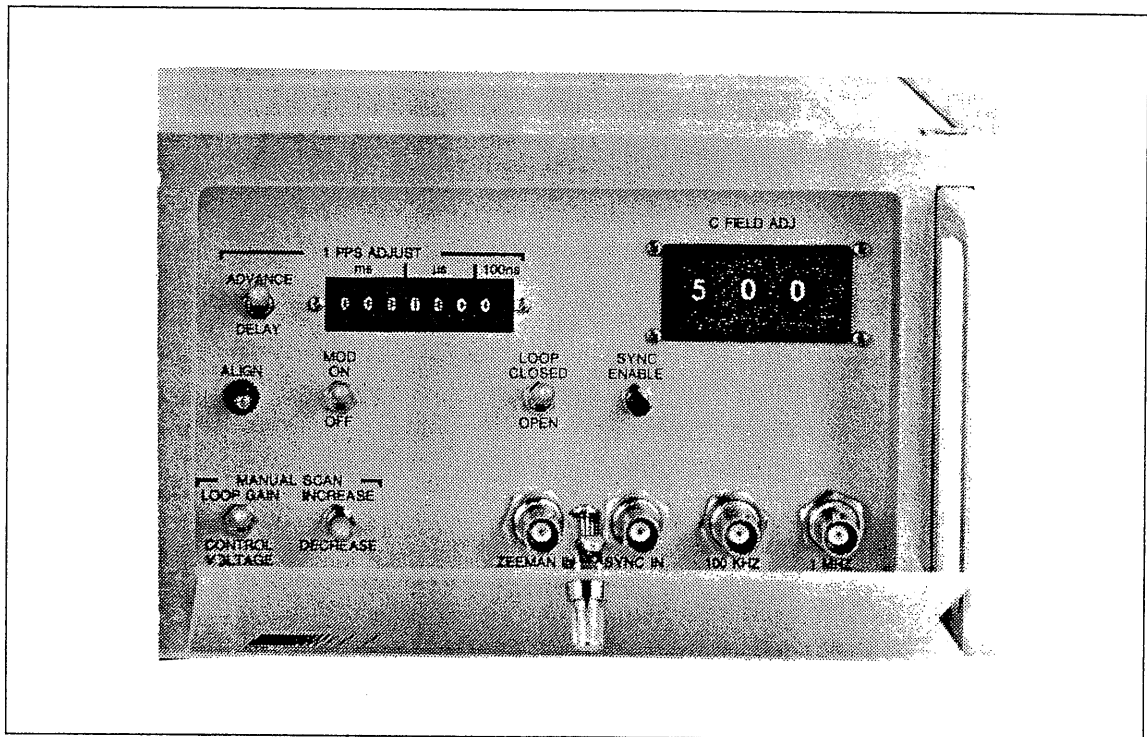


FIGURE 2-5 OPERATIONAL CONTROLS

## 2.6.2 Coarse Frequency Adjustment

The frequency of the quartz crystal oscillator can be varied over a range of  $\pm 1 \times 10^{-7}$  (0.5 Hz at 5 MHz) by changing the control voltage. As the frequency is changed, a portion of the beam current resonance may also be observed.

To change the frequency or to observe the cesium resonance, use the control voltage manual scan procedure outlined below:

- 1) Observe the CONTROL voltage monitor and record the on-frequency control voltage.
- 2) Set the LOOP switch to OPEN. Note that the LOCK indicator turns off and the ALARM indicator on.
- 3) Set the MANUAL SCAN switch to CONTROL voltage.
- 4) Observe the BEAM current monitor.
- 5) Toggle the SCAN switch to INCREASE or DECREASE the control voltage while observing the BEAM current monitor response.
- 6) After scanning, set the CONTROL voltage near the reading noted in step 1 above. Set the MODULATION switch to ON and the LOOP switch to CLOSED.

Note: If the on-frequency control voltage is not known, press the ALIGN pushbutton. The microprocessor will initiate the autolock routine and automatically find the on-frequency control voltage.

## 2.6.3 Cesium Beam Current Gain Adjustment

The gain of the cesium beam current can be varied using two methods. The first is automatically adjusted during the operation of the instrument via a gain control servo in the Microprocessor PCB. This process compensates for beam tube signal decay. The second method is via the manual adjustment of a variable resistor (R5) on the Interface PCB and is only required if the cesium beam current measures less than 1.4 volts and the MONITOR LED is illuminated.

The primary purpose for adjusting the beam current is to keep the level within the operational limits of the servo loop (0.5 to 6.0, modulation on, as observed on the BEAM current monitor). The MONITOR LED indicator provides an early warning when the beam current level is outside a monitor range of 1.4 to 5.0. The MONITOR LED indicator also illuminates when the control voltage is outside a monitor range of 0.6 to 4.4. When the MONITOR LED indicator turns on, check both monitors. This alarm is brought to the rear panel connector at J15 Pin 4. A +5 V output at this pin signifies normal operation; a low output indicates the MONITOR LED is illuminated.

If the control voltage is out of range, refer to paragraph 2.7. Otherwise, adjust the gain to reset the beam current level to its optimum level (2.5 modulation on). This procedure is usually required once-or-twice in the space of a few years.

## 2.6.3 Cesium Beam Current Gain Adjustment (cont'd)

To manually adjust the gain, follow the steps below:

- 1) Remove the bottom cover of the unit.
- 2) With the unit powered and locked, measure the BEAM current output using a voltmeter at E26 (+) and E23 (GND), reference Figures 2.5 and 2.6.
- 3) Locate the variable resistor R5 on the Interface PCB (refer to Figure 2-5).
- 4) Slowly, (approximately 1 turn per 5 seconds), adjust R5 clockwise to INCREASE or counter-clockwise to DECREASE the current gain, until the voltmeter is adjusted to a reading of  $1.8 \text{ V} \pm 0.2 \text{ V}$ .

Note 1: This adjustment may be made without degrading the stability of the output signals, if the adjustment is made within about 100 s and there are no large environmental changes during the adjustment (position, temperature, vibration).



Adjusting R5 clockwise will increase the gain.  
Adjusting R5 counter clockwise will decrease the gain.

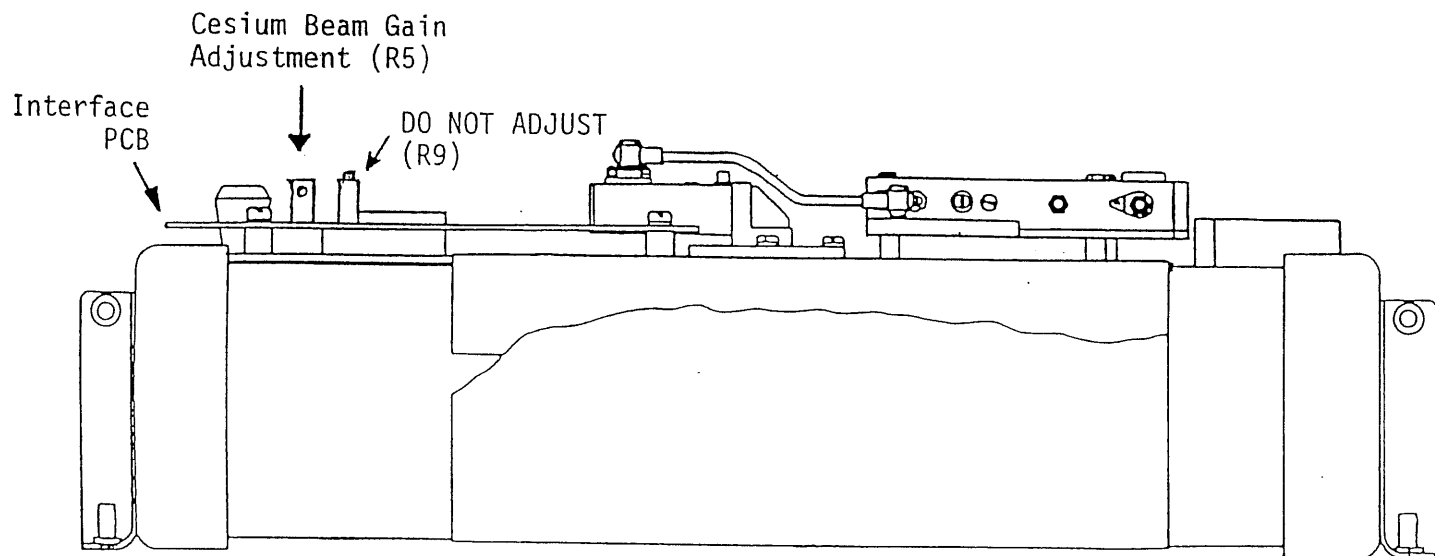


Figure 2-5A Manual Cesium Beam Signal Gain Adjustment

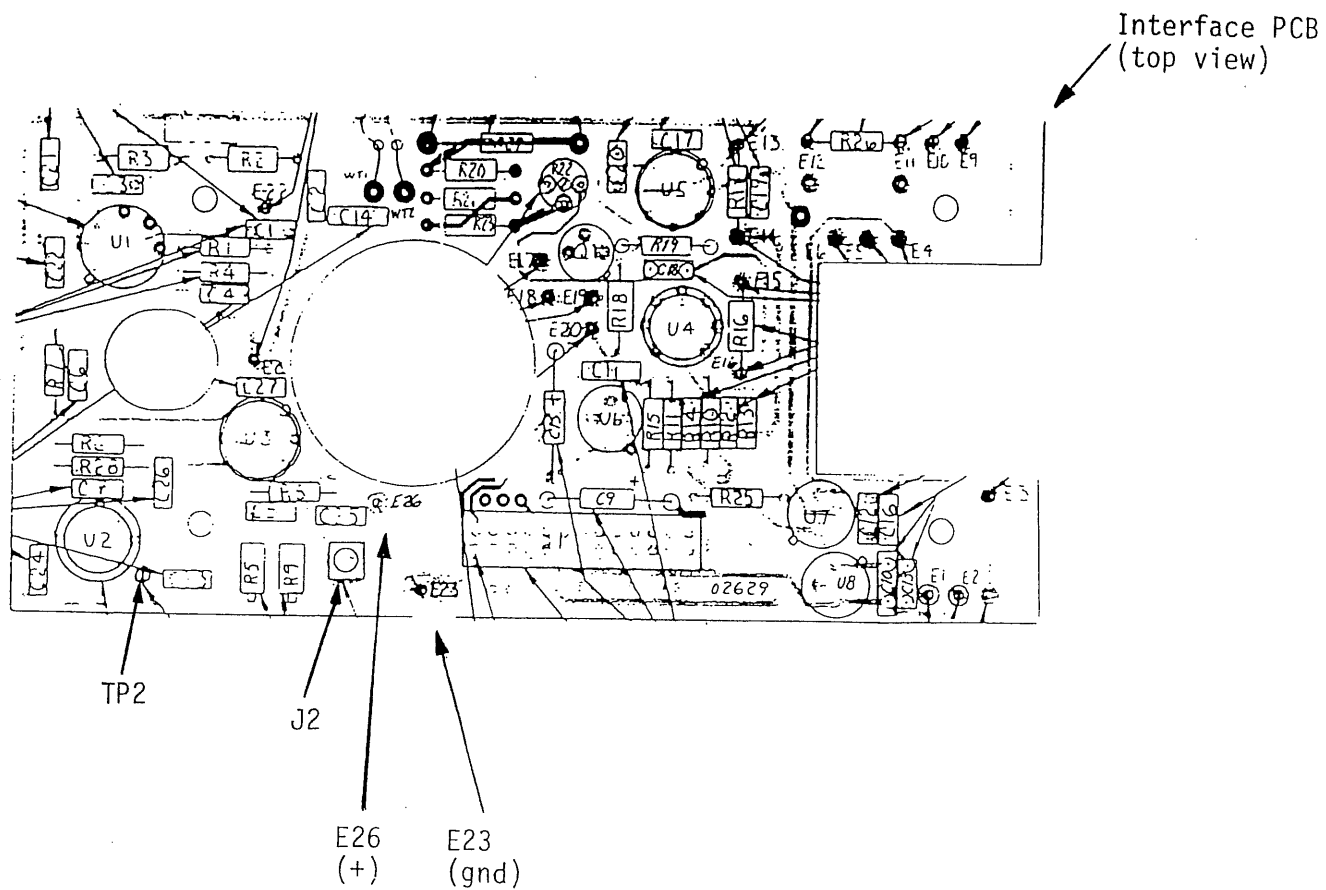


Figure 2-5B Cesium Beam Current Gain Adjustment

## 2.6.4 Alignment, Microprocessor-Controlled

**CAUTION**

**During the following procedure, the output frequency of the FTS 4060 will vary over a range of  $2 \times 10^{-7}$ .**

The FTS 4060 may be realigned automatically by using the ALIGN pushbutton. Use the ALIGN feature to:

- re-initiate the autolock routine (find and verify the correct resonance)
- set the beam current gain automatically (to set the beam current gain manually, refer to paragraph 2.6.3)

If the MONITOR LED indicator is on, it indicates that either the BEAM current monitor is  $<1.4$  or  $>5.0$  V, or the CONTROL voltage monitor is  $<0.6$  or  $>4.4$  V. The ALARM indicator will also turn on when the BEAM current monitor is  $<0.5$  V or  $>6.0$  V. This alarm is brought to the rear panel "D" connector at J15 pin 5. A +5 V output at this pin signifies normal operation; a low output indicates an OPERATION alarm.

To automatically adjust the beam current level, follow the steps below. If the CONTROL voltage is out of range, refer to paragraph 2.7.

- 1) Set the loop switch to OPEN. Note that the LOCK indicator turns off and the ALARM indicator turns on.
- 2) Push the ALIGN pushbutton switch. Note that the ALIGN indicator turns on and remains on until the alignment is completed.
- 3) Set the LOOP switch to CLOSED. When the LOCK indicator turns on, alignment is completed. The procedure duration varies, depending upon details of signal level, from approximately 1 to 3 minutes.
- 4) Reset the ALARM.

Note 1: BEAM current or CONTROL voltage may be monitored to observe the effects of the autolock routine on either parameter.

Note 2: Following the alignment routine and re-lock, the frequency control loop will operate with a fast loop response for 30 minutes and then switch to a slower loop response.

Note that when the control voltage is less than 0.6 V or greater than 4.4 V, the autolock routine is unable to identify the proper lock conditions. Do not use the ALIGN function in this case; at the earliest practical occasion, the CONTROL VOLTAGE should be recentered as described in Appendix A.

2.6.5 Autolock Override

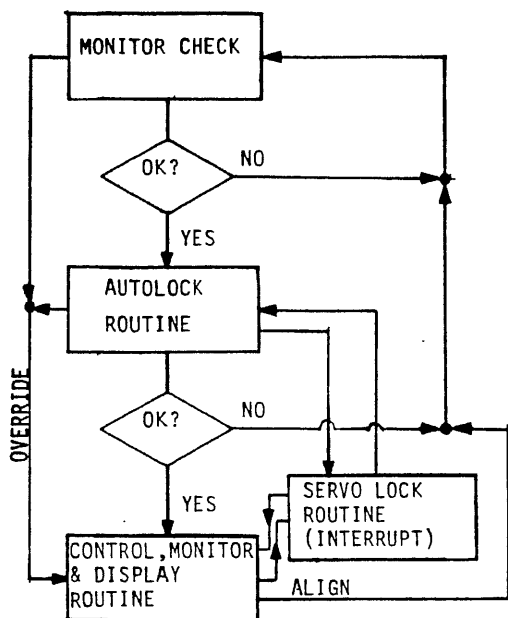


FIGURE 2-6 SOFTWARE FLOW CHART

During the autolock routine (initiated by instrument turn-on or use of the ALIGNMENT feature), control of the cesium frequency control loop is retained by the microprocessor. The front panel controls do not affect internal operation. If all the conditions for a successful autolock routine are not met (refer to paragraph 3.2.5.1), the user may desire to regain control of the FTS 4060 to evaluate the situation. To override the autolock routine, follow the steps below:

- 1) Set the LOOP switch to OPEN.
- 2) Simultaneously, push both the reset pushbutton switch (red indicator) for the OPERATION ALARM and the ALIGN pushbutton switch (yellow indicator).

Control is now returned to the front panel (only when the LOOP switch is OPEN). Refer to Figure 2-6. Note that the MONITOR indicator remains on even if the frequency control loop is locked. To reset the MONITOR indicator, perform the ALIGNMENT routine (refer to paragraph 2.6.4).

Note that both cesium beam current and oscillator control voltage must be manually adjusted following an autolock override. The override should not be employed without investigation as to the cause of autolock failure. Failure of autolock indicates significant system level uncertainties which usually preclude proper operation of the FTS 4060 (See paragraph 3.2.5.1).

## 2.7 CONTROL VOLTAGE CENTERING ADJUSTMENT

The on-frequency CONTROL VOLTAGE of the oscillator changes slowly during the life of the instrument as the quartz crystal ages. The CONTROL VOLTAGE monitor is adjusted at the factory to the center (2.5) of its range (0 to 5).

When the CONTROL VOLTAGE monitor moves outside the range of 0.6 to 4.4, the MONITOR LED indicator is illuminated giving early warning that an adjustment is required. However, the FTS 4060 will continue to perform as specified for more than six months until it reaches 0 or 5 on the CONTROL VOLTAGE monitor.

**Note that when the control voltage is less than 0.6 V or greater than 4.4 V, the autolock routine is unable to identify the proper lock conditions. Do not use the ALIGN function in this case; at the earliest practical occasion, the CONTROL VOLTAGE should be recentered as described in Appendix A.**

## 2.8 OPERATION ON EXT DC OR INTERNAL BATTERY

When ac power is interrupted, the FTS 4060 may operate on either EXTERNAL DC or INTERNAL BATTERY (Option 010). Set the three position switch on the rear panel to the center position, B/E (BATTERY and/or EXT DC). With the switch in the center position, the following power source utilizations are possible when ac power is removed:

- EXT DC only for EXT DC supply voltage between 26 and 30 V.
- BATTERY only for EXT DC supply voltage less than the battery voltage, 22 to 26 V.
- Current sharing between EXT DC and BATTERY, when the two sources are at a similar voltage level, between 22 and 26 V.

When ac power is removed, the front panel BATTERY indicator is turned on, indicating that power is being supplied by either the EXT DC or the BATTERY. Position 5 SUPPLY on the front panel monitor represents the voltage supplied by either EXT DC or BATTERY, whichever is higher.

## 2.8.1 External DC Only (Internal Battery Off)

To disconnect the internal battery, set the 3-position switch on the rear panel to EXT DC (down). When ac power is removed, power may be supplied by only the EXT DC source, between 22 and 30 V.

## 2.8.2 Internal Battery Only (EXT DC Off)

To disconnect the EXT DC input, set the 3-position switch on the rear panel to BATTERY (up). When ac power is removed, power may be supplied by only the battery.

## 2.8.3 Battery Replacement

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When the batteries need to be replaced, refer to the following procedure and Figure 2-7:

---

- 1) Remove the top cover.

**WARNING**

**LETHAL VOLTAGES ARE PRESENT UNDER THE TOP COVER. TAKE SPECIAL PRECAUTIONS NOT TO CONTACT THE LINE VOLTAGE AT THE REAR PANEL OR THE POWER SUPPLIES.**

**WARNING**

**THE BATTERIES ARE CAPABLE OF DELIVERING SHORT CIRCUIT CURRENTS IN EXCESS OF 200 AMPERES. SHORT CIRCUITING A BATTERY WILL PRODUCE SPARKS AND CAUSE THE BATTERY WIRING TO OVERHEAT RESULTING IN PERSONAL INJURY. DO NOT SHORT CIRCUIT THE BATTERIES.**

- 2) Disconnect the spade clips (4) at the battery terminals.
- 3) Unscrew the captive fastener on the battery bracket.
- 4) Slide the battery bracket toward the rear of the instrument until it reaches the cut-away slot in the center partition. Remove the battery bracket.
- 5) Remove the two battery packs.
- 6) Install two new battery packs. Do not reconnect the battery spade clips until after the battery bracket is installed and refastened.
- 7) Reconnect the battery spade clips, giving special attention to the correct polarity. Refer to Figure 2-7.

**CAUTION**

**MAKING CONNECTIONS WITH THE WRONG POLARITY OR SHORTING TERMINALS OR SPACE CLIPS TO THE CHASSIS MAY DAMAGE THE INSTRUMENT.**

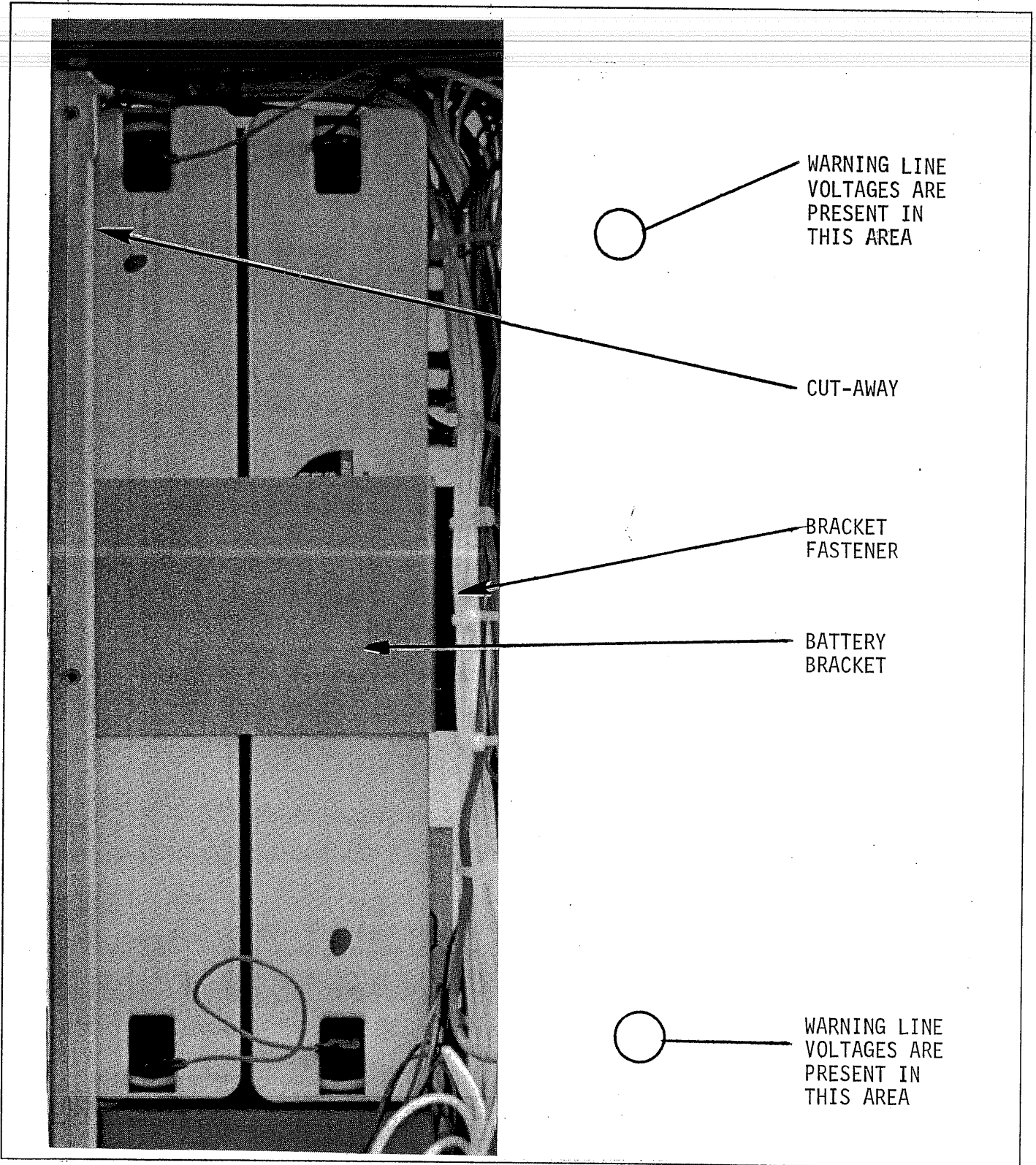


FIGURE 2-7 BATTERY REPLACEMENT



**SECTION 3. THEORY OF OPERATION****3.1 INTRODUCTION**

The FTS 4060 Cesium Frequency and Time Standard generates sinusoidal signals that are:

- accurate
- spectrally pure
- stable

The accuracy is obtained by comparing the output frequency of a quartz crystal oscillator to the atomic resonance of cesium. Spectral purity (absence of all frequencies in the output signal except the fundamental frequency) is obtained by using a high performance quartz crystal oscillator to create the desired output signal. Stability (maintaining the specified frequency over a specified time interval) is derived from the quartz resonator for short term intervals and from the cesium resonator for long-term intervals. The sinusoidal signals are used to generate a precise pulse -- a 1-pulse-per-second (1 pps) signal that is used to maintain accurate Time-of-Day (TOD) in the front panel clock display (Option 116).

The FTS 4060 utilizes a microprocessor to:

- evaluate the error signal generated by the cesium beam tube and provide a correction voltage to the quartz crystal oscillator.
- monitor and control system parameters such as the cesium beam current.
- adapt to changing environmental conditions including automatic turn-on.

The various components of the FTS 4060 are illustrated in Figure 3-1. Table 3-1 is a list of all the major subassemblies with their reference designators and parts numbers. The CFS Module, A1, is powered from one of three sources: ac power, external dc power, or internal battery. The Charger/Monitor Assembly, A3, provides automatic switching between ac and dc power, charging current for the battery and other monitor and control functions. The CFS Module provides a 5 MHz signal directly to the rear panel as well as a 10 MHz signal that is used to produce the other rf output signals and the 1 pps signal. The Time-of-Day (TOD) Display is driven by the 1 pps signal.

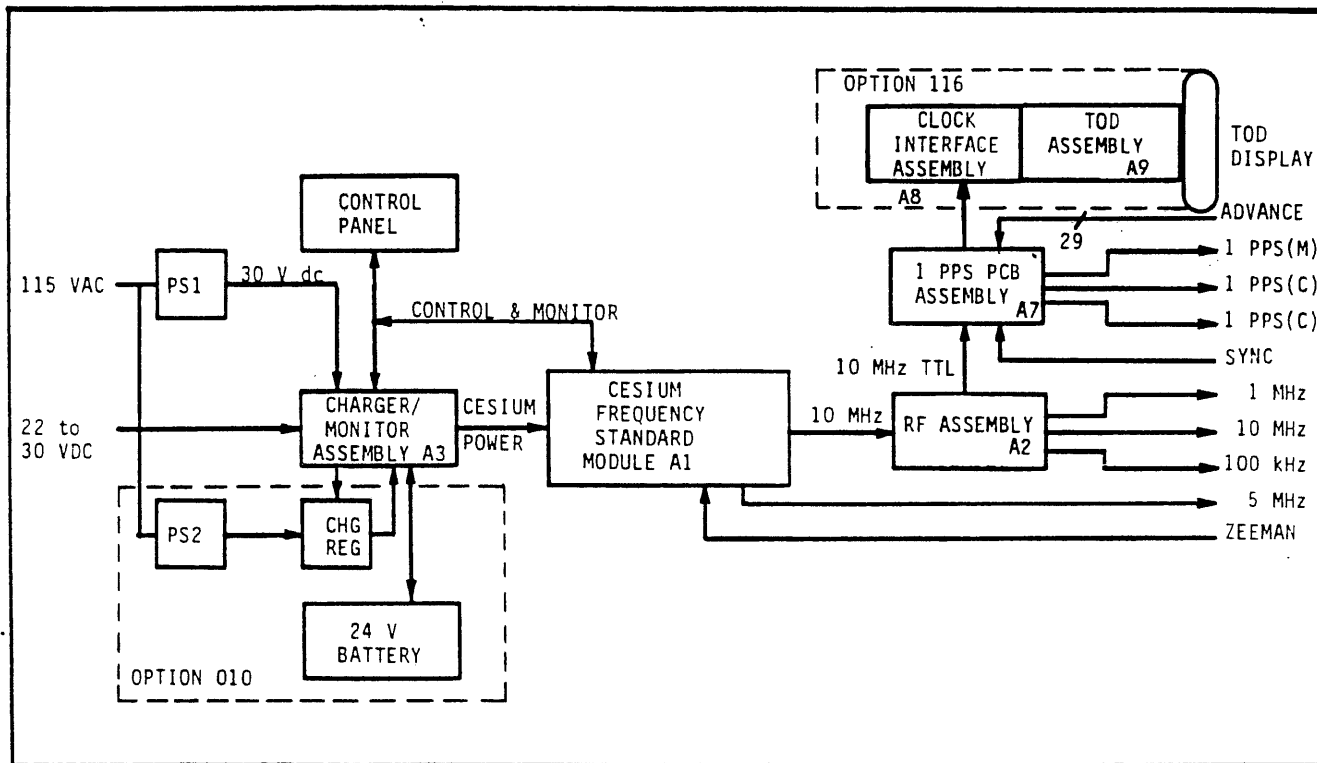


FIGURE 3-1 BLOCK DIAGRAM, FTS 4060

TABLE 3-1 ASSEMBLIES AND REFERENCE DESIGNATORS

REFERENCE DESIGNATOR	ASSEMBLY NAME	FTS PART NO.
A1	Cesium Frequency Standard Module	02613-513
A1A1	Cesium Beam Tube Assembly	02693-501
A1A2	Mother Board PCB Assembly	02617-504
A1A3	Microprocessor PCB Assembly	02623-505
A1A4	12.6 MHz Synthesizer PCB Assembly	02626-501
A1A5	Distribution Amplifier Assembly	08468-501
A1A6	Oscillator Assembly	05818-511
A1A7	Low Frequency Multiplier Assembly	02643-501
A1A8	Power Supply Assembly	07845-501
A1A9	Input Filter PCB Assembly	03705-501
A2	RF Assembly (w/Opt 116,117) (w/Option 061,061&116,061&117)	05099-502 05099-501
A2A1	Multiplier/Divider Assy (w/Opt 116,117) (w/Option 061,061&116,061&117)	01470-504 01470-503
A2A2	100 kHz Assy (w/Opt 061,061&116,061&117)	01682-502
A2A3	RF Buffer Assy (w/Opt 061,061&116,061&117)	05088-501
A3 or A3	Alarm/Buffer Assembly	05164-501
	Charger/Monitor Assembly (w/Option 010)	05210-501
A11	Control Panel Assembly (w/Option 116 or 117) 1 PPS Thumbwheel PCB Assembly (Option 116 or 117 only)	05206-501 05206-502 05042-501
A5	(not used)	
A8	Monitor Panel Assembly (w/Option 116)	05204-501 05204-502
A9	Clock Interface PCB Assembly (w/Option 116) TOD PCB Assembly (w/Option 116)	03739-501 01420-501
A7	1 PPS Advance/Delay PCB Assembly (w/Option 116 or 117)	07784-501

### 3.2 CESIUM FREQUENCY STANDARD (CFS) MODULE

A block diagram of the CFS module is illustrated in Figure 3-2. The Oscillator Assembly A1A6 originates the primary oscillating signal. The Distribution Amplifier Assembly A1A5 receives the oscillator output and provides the user rf output signal and timing signals to other internal subassemblies. The 10 MHz output signal of the Distribution Amplifier is multiplied to the frequency of the cesium resonance, detected by the Cesium Beam Tube Assembly A1A1, and analyzed for frequency error by the circuits on the Microprocessor PCB Assembly A1A3. The on-frequency control voltage is stored in the microprocessor memory and is changed as required to maintain the correct output frequency.

#### 3.2.1 Oscillator Assembly A1A6

The fundamental output of the CFS module is a 5 or 10 MHz signal obtained directly from the high quality crystal oscillator via the Distribution Amplifier Assembly A5. The oscillator uses a precision quartz crystal with very low aging ( $\Delta f/f < 1 \times 10^{-10}/\text{day}$ ). A proportionally controlled oven maintains the crystal at its operating point over a wide range of ambient temperatures. Refer to Figure 3-3.

#### 3.2.2 Distribution Amplifier Assembly A1A6

The Distribution Amplifier Assembly accepts the 10 MHz oscillator output and generates:

- 10 MHz sinusoidal user output.
- 10 MHz sinusoidal output for frequency multiplication to the cesium resonance at 9192 MHz.
- 2.5 MHz TTL for the phase-locked 12.6 MHz synthesizer.

The outputs are derived by frequency division of the 10 MHz signal and then buffered by TTL drivers or filtered and amplified for sinusoidal outputs. Refer to Figure 3-4.

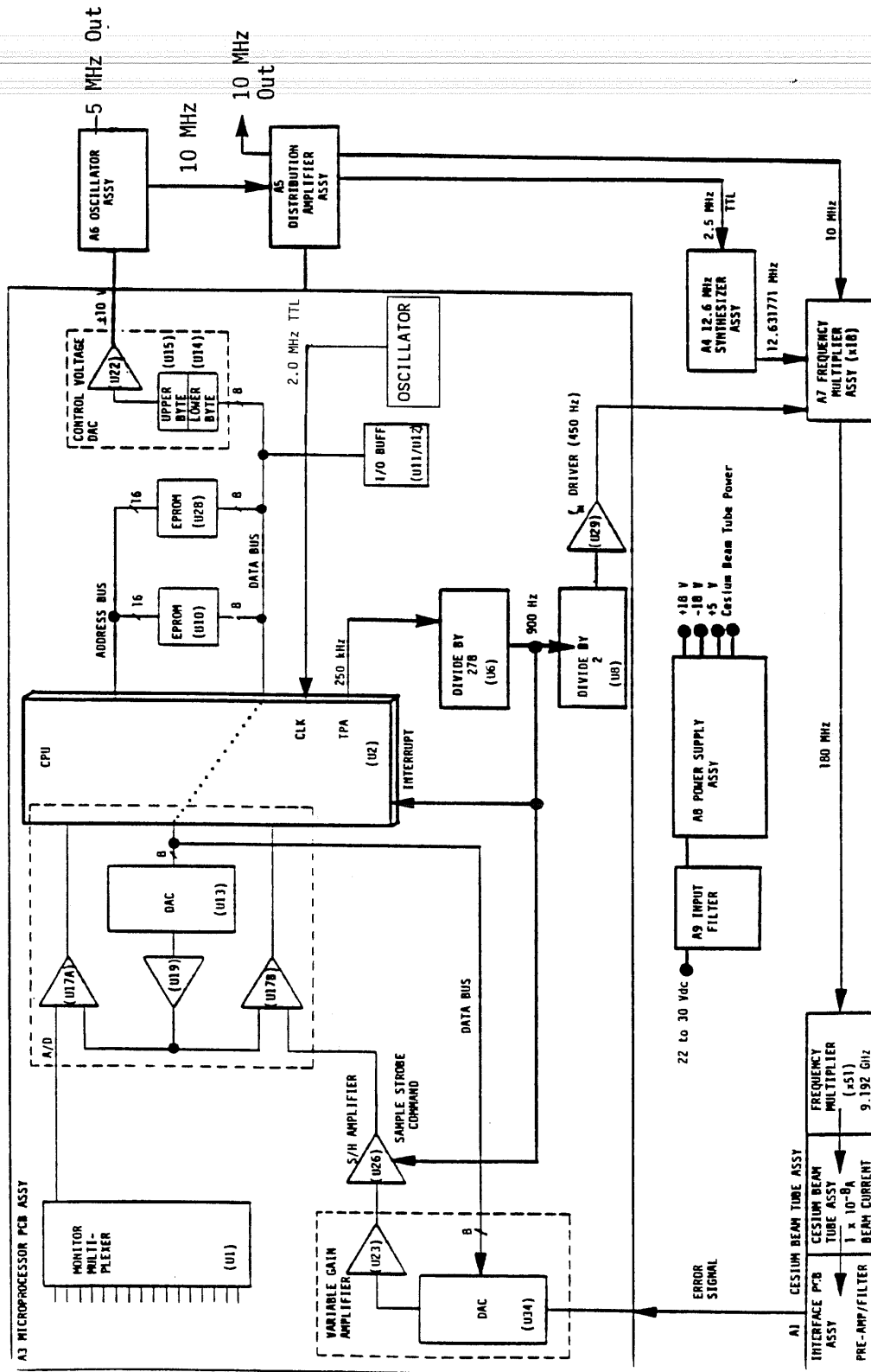


FIGURE 3-2 CFS MODULE BLOCK DIAGRAM

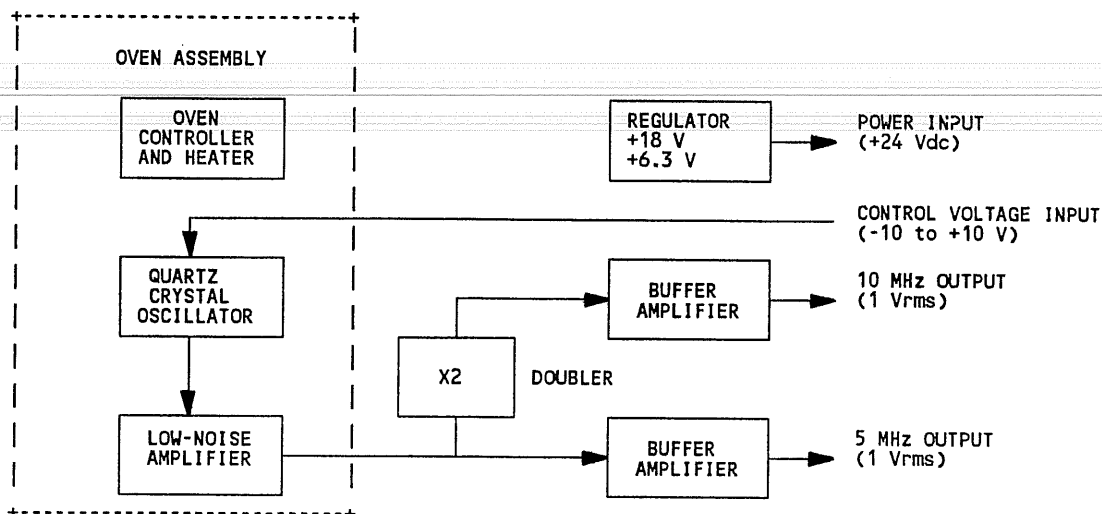


FIGURE 3-3 OSCILLATOR BLOCK DIAGRAM

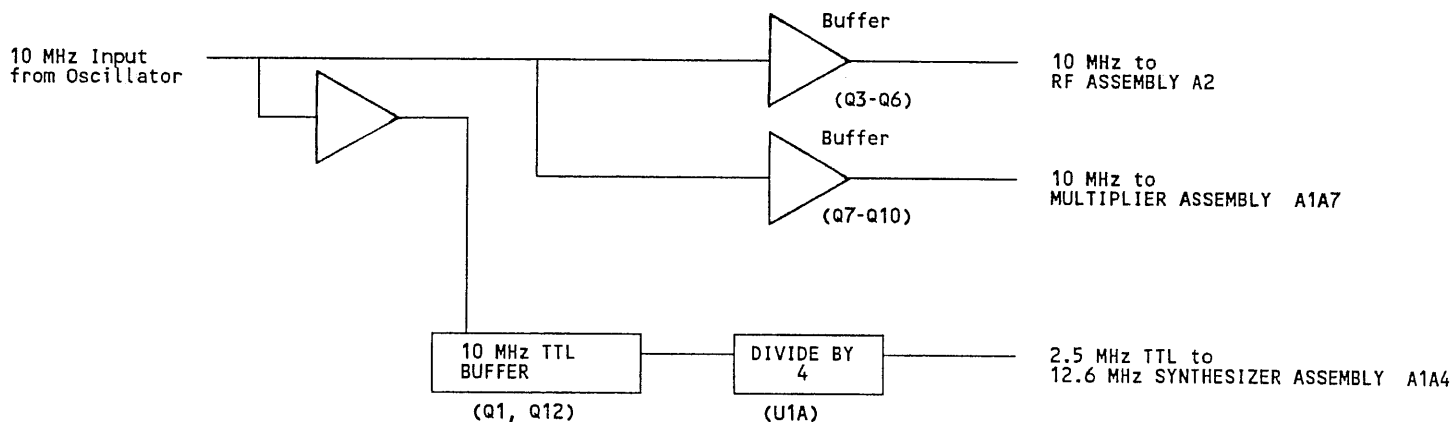


FIGURE 3-4 DISTRIBUTION AMPLIFIER BLOCK DIAGRAM

### 3.2.3 Frequency Multiplier A1A7

The Frequency Multiplier multiplies the 10 MHz sinusoidal output signal of the Distribution Amplifier to 180 MHz. In addition, three other signals are mixed into the spectrum at different levels. Refer to Figure 3-5. In the first stage, the frequency of the incoming 10 MHz signal is tripled to 30 MHz. This is accomplished by squaring the signal in a differential amplifier filtering the third harmonic at the output. A second differential amplifier stage and filter follows to increase power and signal purity. A second tripler and filter are then used to multiply the signal to 90 MHz followed by a single transistor buffer amplifier and filter. This stage is also used to mix in the Zeeman frequency as required. The 90 MHz signal is fed to a single transistor output doubler and filter. This stage produces a 10 dBm signal into a 50 ohm load at the output through a 6 dB, 50 ohm attenuator, providing isolation and a well-defined output impedance.

The 450 Hz squarewave phase modulation is inserted at the output of the first tripler by varying the bias voltage on a varactor diode which varies the tank circuit capacitance. The 12.6 MHz sideband modulation is introduced at the input of the output doubler. The 180 MHz signal, with its complex phase-modulation spectrum, is fed to the x51 multiplier on the Cesium Beam Tube Assembly.

### 3.2.4 Cesium Beam Tube Assembly A1A1

The Cesium Beam Tube Assembly contains three integrated subassemblies:

- a high frequency multiplier,
- the cesium beam tube, and
- interface circuits.

The frequency multiplier and interface circuits are attached to the cesium beam tube to normalize input and output signals, and provide for modularity and ease of replacement.

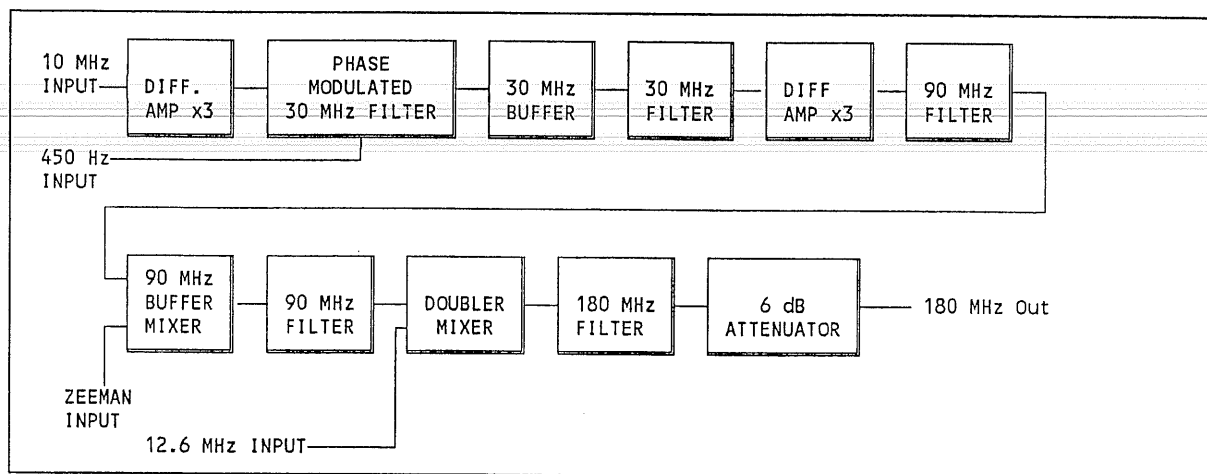


FIGURE 3-5 FREQUENCY MULTIPLIER BLOCK DIAGRAM



## 3.2.4 Cesium Beam Tube Assembly A1A1 (cont'd)

The 180 MHz signal from Frequency Multiplier assembly A7 is multiplied by 51 in the high frequency multiplier to the frequency of the cesium resonance. The 9180 MHz carrier signal and sidebands spaced at 12.6 MHz above and below the carrier are all phase modulated at the 450 Hz rate. The first upper sideband, at 9192.6 MHz is used to excite the microwave cavity within the cesium beam tube.

The cesium beam tube can be modeled as a very high Q resonator -- approximately 20 million -- at 9,192,631,770 Hz, the resonant frequency of atomic cesium. The tube has a dc current output that is proportional to the frequency offset from the cesium resonance. The dc beam current response is illustrated in Figure 3-6.

Figure 3-7 illustrates the internal components of the cesium beam tube. A reservoir of cesium is heated to approximately 90°C in the cesium oven. A specially designed opening in the cesium oven creates a collimated beam of cesium atoms. The cesium beam passes through a state selector magnet ("A" magnet) with an intense magnetic field gradient. The magnetic field gradient separates the beam into components according to the magnetic energy state of the atoms. The atoms in the desired state are directed into the C-field region -- a magnetically shielded area with a homogeneous field strength of about 60 milligauss. A waveguide structure within the C-field provides for the interaction between the cesium atoms and the microwave signal at 9192.6 MHz. If the microwave signal is at the correct frequency, the cesium atoms are stimulated to make a transition to a different energy state. The atomic beam then passes through a second intense magnetic field gradient ("B" magnet) which directs atoms that have made a transition into the detector.

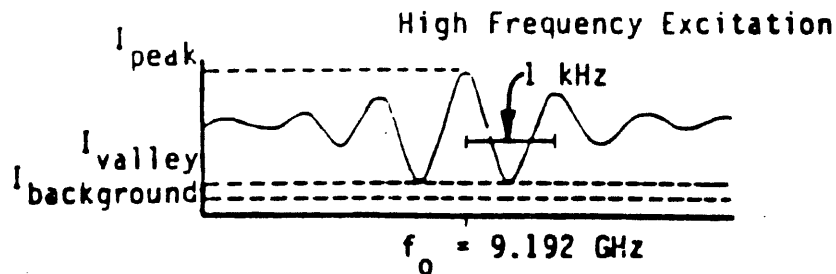


FIGURE 3-6 BEAM CURRENT RESPONSE

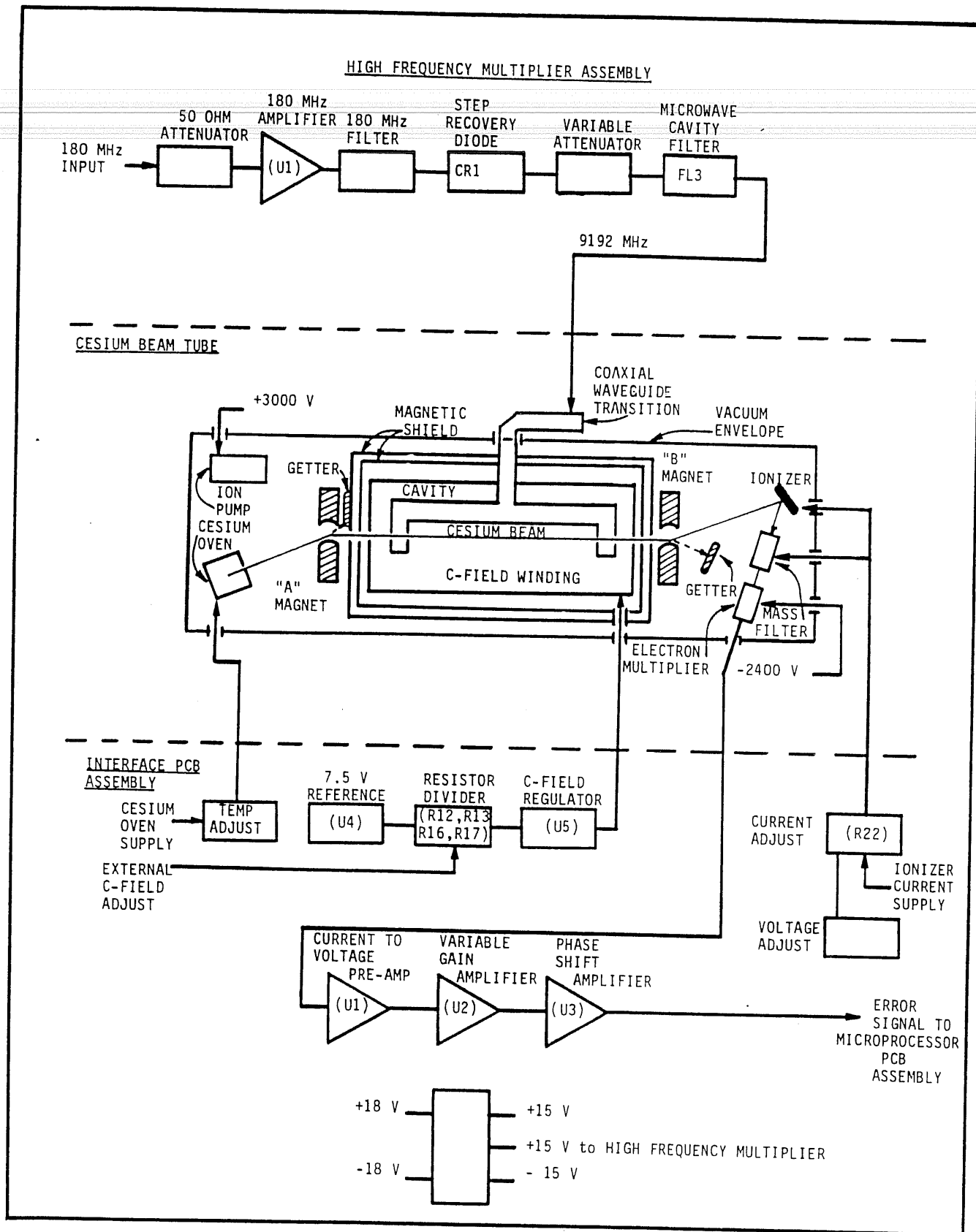


FIGURE 3-7 CESIUM BEAM TUBE BLOCK DIAGRAM

### 3.2.4 Cesium Beam Tube Assembly A1A1 (cont'd)

The detector has three parts: an ionizer filament, a mass filter, and an electron multiplier. When the beam of atoms hits the ionizer filament the atoms are ionized (stripped of one electron). The resulting ions are accelerated by an electric field through a homogeneous magnetic field that filters out all elements with atomic mass different from cesium. The filtered beam of cesium ions is directed into the collector of the electron multiplier, which amplifies the current output to approximately  $10^{-8}$ A.

The vacuum within the cesium beam tube is maintained at a pressure of less than  $10^{-8}$  torr by the ion pump. The ion pump traps gas atoms by ionizing and then accelerating these atoms into a tantalum cathode. The required electric field is provided by a dc supply voltage of approximately 3,000 V.

The cesium beam output current is amplified and filtered at the modulation frequency by the interface assembly. The phase of the beam current error signal is also adjusted to normalize the error signal developed in the cesium beam tube. Additional interface circuits control the C-field supply current and the power required to heat the cesium oven to its desired temperature.

### 3.2.5 Microprocessor PCB Assembly A1A3

The output of the cesium beam tube develops an error signal at the modulation frequency  $f_m$  that is proportional to the offset between the microwave frequency and cesium resonance frequency. After pre-amplification/filtering (to enhance the error signal at  $f_m$ ) and phase adjustment (to compensate for the phase difference in modulation input and error signal output of the cesium beam tube), the error signal enters a microprocessor-controlled amplifier. This amplifier automatically adjusts the error signal gain at turn-on and whenever the user selects the ALIGNMENT feature. The purpose of the automatic gain-adjust amplifier is to compensate for long-term changes in cesium beam current level. Refer to Figure 3-2.

## 3.2.5 Microprocessor PCB Assembly A1A3 (cont'd)

After the initial signal conditioning, the error signal at  $f_m$  is sampled at a frequency  $2 f_m$  by the sample-and-hold (S/H) commutating filter, which rejects the second-harmonic component of the error signal. The output of the S/H amplifier is a square wave whose peak-to-peak value is proportional to the frequency deviation of the applied microwave signal from the atomic resonance frequency. The microprocessor digitizes this peak-to-peak value in an analog-to-digital (A/D) conversion routine, using a successive approximation technique to arrive at the digital value for each half-cycle of error signal. Since the A/D conversion is synchronous with the sample-and-hold command at  $2 f_m$ , the polarity of the error signal is detected, providing the sign (+/-) for correction of the frequency deviation.

The oscillator control voltage is latched in the registers of a 16-bit digital-to-analog converter (DAC). The value of the DAC input word is stored in memory in a 24-bit (three 8-bit bytes) word. Only the most significant 16-bits are sent to the control voltage DAC. When an error signal is detected, its digital value (8-bit word) is summed with the 24-bit control voltage word. As a result of the summing operation, a new 24-bit control word is created in memory. The 16 most-significant bits of this word are read by the control voltage DAC, resulting in a new analog control voltage, which corrects the frequency error of the quartz oscillator. This operation is repeated for each cycle of the modulation signal.

The modulation signal is derived from a quartz crystal oscillator IC located on the Microprocessor PCB Assembly, (2.0 MHz), the microprocessor timing pulse (250 kHz) and a digital divider/buffer.

The frequency control loop takes a specific amount of time to respond to the frequency error detected by the cesium beam tube. The time taken to reduce the error signal to one-third of its original value is called the loop time constant (LTC). During warm-up, when the quartz oscillator is drifting at a rapid rate, a faster LTC is used. During normal operation, the LTC is automatically increased, improving the short-term frequency stability of the frequency standard. The LTC during normal operation is 5 s. During warm-up the LTC is 0.08 s.

3.2.5.1 Automatic Lock Routine

The cesium atomic resonance exhibits three satellite resonances on either side of the main resonance. To prevent lock to a satellite resonance (and a resulting frequency error of  $1 \times 10^{-7}$  or greater), an auto-lock routine is implemented to identify the correct resonance. See FIGURE 3-8 SOFTWARE FLOWCHART. After the instrument has warmed up from turn-on, the microprocessor scans the resonances that are within the electrical tuning range of the quartz oscillator -- usually about three. After recording maximum and minimum values of beam current and identifying the control voltage at maximum beam current (central peak), the microprocessor performs the following tasks:

- adjusts gain to an acceptable level
- verifies that an acceptable peak-to-valley beam current ratio exists
- verifies that the control voltage is within acceptable limits
- verifies that the oscillator drift rate has slowed to an acceptable level
- verifies the operation of the modulation circuits
- verifies acquisition of the correct atomic resonance

If each of these tasks are completed successfully, the frequency standard begins normal operation. Since the quartz oscillator is drifting at a higher rate just after turn-on, an internal clock keeps the frequency control loop in a fast response mode (LTC = 0.08 s) for 30 minutes after lock is achieved. Thereafter, the loop operates at a response rate of 5 s.

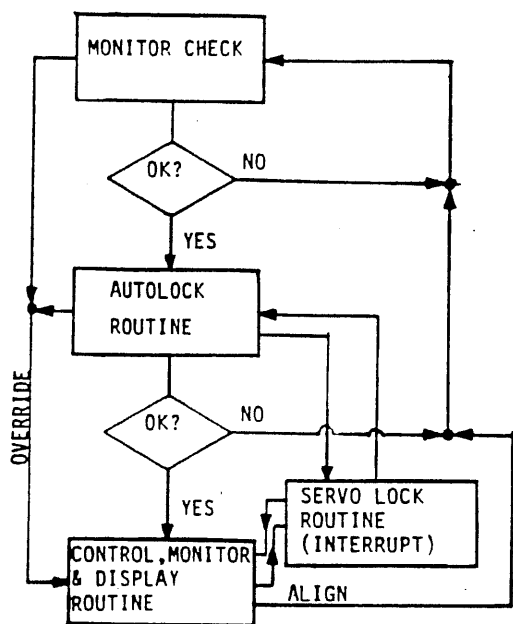


FIGURE 3-8 SOFTWARE FLOWCHART

## 3.2.5.2 Monitoring

The microprocessor examines 16 monitor circuits to determine if critical systems parameters are within acceptable limits. The following parameters are monitored:

## Cesium beam tube parameters

- \*Beam current
- Ion pump voltage
- Ion pump current
- Electron multiplier voltage
- C-field current
- \*Cesium oven temperature

## Quartz crystal oscillator parameters

- \*Crystal oven power
- \*Control voltage

## RF signals

- 180 MHz signal level
- 12.6 MHz digital lock
- 12.6 MHz analog lock

## Power supplies

- + 5 V
- +18 V
- 18 V

## Internal chassis temperature

## Oscillator frequency drift rate

The OPERATION LOCK indicator turns on when the internal monitors are within acceptable limits, the LOOP and MOD functions are CLOSED and ON, and the oscillator drift rate is within acceptable limits.

If any of the above parameters is out of an acceptable range, the OPERATION LOCK indicator turns off, and the ALARM indicator turns on. The MONITOR indicator provides an early warning that either the cesium beam current or the control voltage is nearing limits that will trigger the ALARM indicator. The MONITOR indicator lights when adjustment of either parameter is required. The four parameters that are marked with an asterisk (\*) are brought out to the front panel MONITOR meter and the rear panel MONITOR connector. The ion pump current is also brought out to the rear panel MONITOR connector.

### 3.2.5.3 Microprocessor-controlled Alignment

If the cesium BEAM current monitor decreases to below 1.0, the MONITOR indicator will turn on indicating the need to realign the beam current amplifier. This may be accomplished by opening the loop and initiating the ALIGNMENT routine.

The ALIGNMENT routine initiates the following action:

- the autolock procedure is activated, as described above, including the adjustment of cesium beam current gain.

Lock is achieved with the beam current reset to a normal level.

### 3.2.6 12.6 MHz Synthesizer PCB Assembly A1A4

The synthesizer's 12.6 MHz voltage-controlled crystal oscillator (VCXO) is phase-locked to the 2.5 MHz TTL output of the Distribution Amplifier A5 through a digital phaselock loop. The 12.6 MHz signal is digitally divided by 3451 to generate a 3.66 kHz phase detector input signal. Similarly, the 2.5 MHz TTL signal is divided by 683 to yield a second 3.66 kHz reference for the phase-detector. Finally, the digital output of the phase-detector is integrated and used to correct the 12.6 MHz VCXO frequency. The analog tuning voltage and the lock status of the 12.6 MHz synthesizer are monitored by the microprocessor. Refer to Figure 3-9.

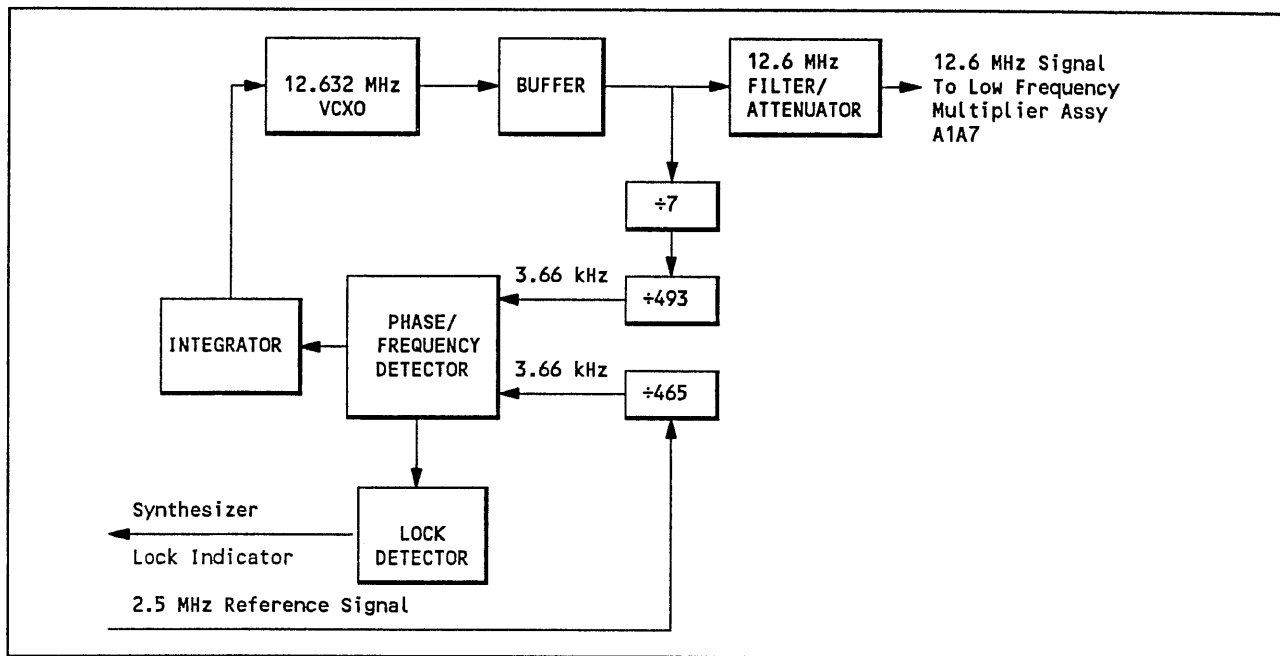


FIGURE 3-9 SYNTHESIZER BLOCK DIAGRAM



### 3.2.7 Power Supply Assembly A1A8 and Input Filter PCB Assembly A1A9

The power supply converts 26 V dc input power to several dc and ac voltages required by the cesium standard. Figure 3-10 is a block diagram of the power supply. Table 3-2 is a list of the input/output specifications. The supply consists of five principal subunits. Each subunit is a form of switching regulator, all which operate synchronously from a common clock at a frequency (80 kHz) chosen to avoid interference with other circuits in the cesium standard module.

The +5 V, +18 V regulators are each individually protected by a fuse at the input, and a current limit at the output. The cesium oven regulator is protected by a fuse at its input and as well as a current-limiting circuit that is used to proportionately control the cesium oven temperature, as well as protect from current overload. The -18 V and ionizer current supplies are derived from the +18 V supply by a transformer-coupled inverter operating at 40 KHz. Regulation, current limiting and overvoltage protection are provided by the +18 V regulator.

The cesium beam tube ion pump requires an unregulated supply voltage of approximately +3 kV. The electron multiplier requires a regulated voltage of -2.4 kV. Both of these high voltages are supplied by diode voltage-multiplier circuits, which are generated by a switching transistor through a step-up transformer. The transistor is driven by a 40 kHz signal obtained from the -18 V supply.

The Input Filter Assembly A9 minimizes the susceptibility of the CFS Module to perturbation by noise or other undesired signals at the modulation frequency or its harmonics. The filter also attenuates conducted EMI on the input power line generated by the Power Supply Assembly at approximately 40 and 80 kHz.

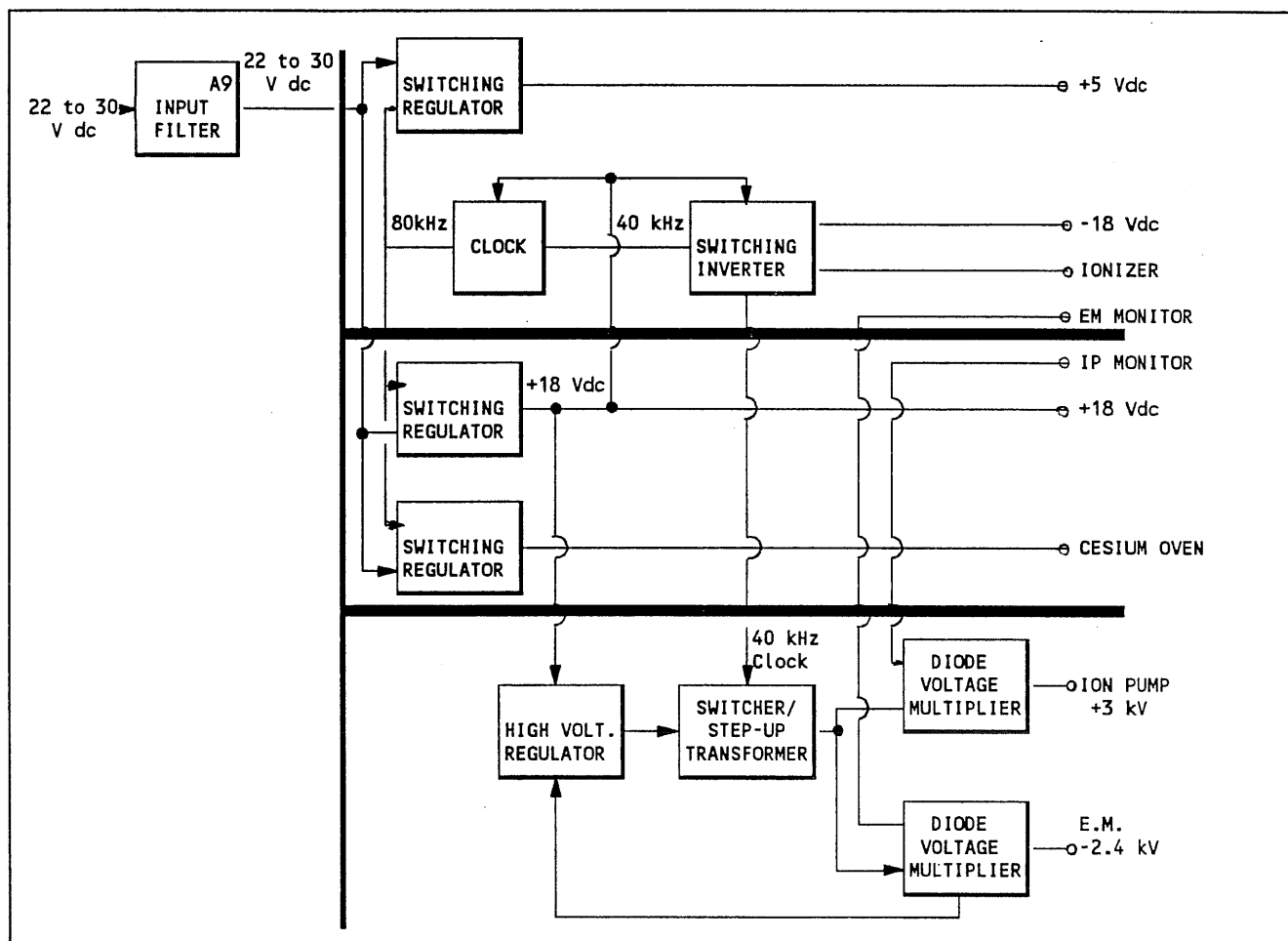


FIGURE 3-10 CFS MODULE POWER SUPPLY, BLOCK DIAGRAM

TABLE 3-2 SPECIFICATIONS, CFS MODULE POWER SUPPLY, FTS 5030

<p><b>INPUT</b> Nominal Input Voltage Voltage Range  Warm-up After warm-up</p>	<p>26 V 22 to 30 V dc Power Requirements 50 W max 20 W</p>
<p><b>OUTPUT</b> Electronics + 18 V <math>\pm</math> 5% + 5 V <math>\pm</math> 5% -18 V <math>\pm</math> 5% Cesium Beam Tube Ionizer Oven  Ion Pump Electron Multiplier</p>	<p>260 mA, 1 A limit 275 mA, 1 A limit 75 mA  1.4 V p-p, 2 A rms, 40 kHz square wave 2.5 W into 10 ohm load, 1 A limit during warm-up +3.5 kV <math>\pm</math> 5%, &lt; 70 <math>\mu</math>A -2.4 kV <math>\pm</math> 5%, 60 <math>\mu</math>A</p>

### 3.3 FREQUENCY DISTRIBUTION AND TIME GENERATION

#### 3.3.1 Buffered RF Outputs

The Cesium Frequency Module (CFS) has two rf signals (one each at 5 MHz and 10 MHz) that are used to generate the rf and timing output-signals of the 4060. The 5 MHz signal is routed directly to the rear panel output connector. The 10 MHz signal is filtered and buffered to provide a sinusoidal 10 MHz output signal. The 10 MHz signal is also squared and buffered to provide a 10 MHz TTL drive signal. Frequencies at 1 MHz and 100 kHz (Option 061) are developed by frequency division of the 10 MHz TTL signal. The resultant signals are filtered, buffered, and routed to the rear panel. Refer to Figure 3-11.

#### 3.3.2 1 PPS, TOD Display and 1 PPS Advance/Delay

The 10 MHz TTL signal also drives a divide-by- $10^7$  counter to produce a 1 pps, 20 us timing pulse. The pulse is split and buffered to produce two 10 V peak output signals.

An external reference pulse may be used to synchronize the 1 pps output signal to within  $\pm 150$  ns of the reference pulse. The reference pulse clears the counters on the rising edge of the first reference pulse and releases the counters on the rising edge of the second reference pulse.

The 1 pps signal also drives the front panel time-of-day (TOD) display (Option 116). Clock setting features include FAST, SLOW, and START. The clock format is 24 hours and displays time in hours, minutes, and seconds. The display is multiplexed for minimum power consumption.

When Option 116 or 117 is included, the 1 pps master signal is also fed to the advance/delay circuitry which, clocked at 10 MHz, advances or delays (depending upon the toggle switch position) the pulse in another cascaded counter, by the number selected in the front panel thumbwheel switches. For example, if a one millisecond delay is selected, the counters finish counting the 1 s interval 1 ms later than the master 1 pps signal. If a 1 ms advance is selected, the counters finish counting the 1 s interval 1 ms before the master 1 pps signal. The advanceable/delayable 1 pps signal is buffered and routed to the front and rear panels.

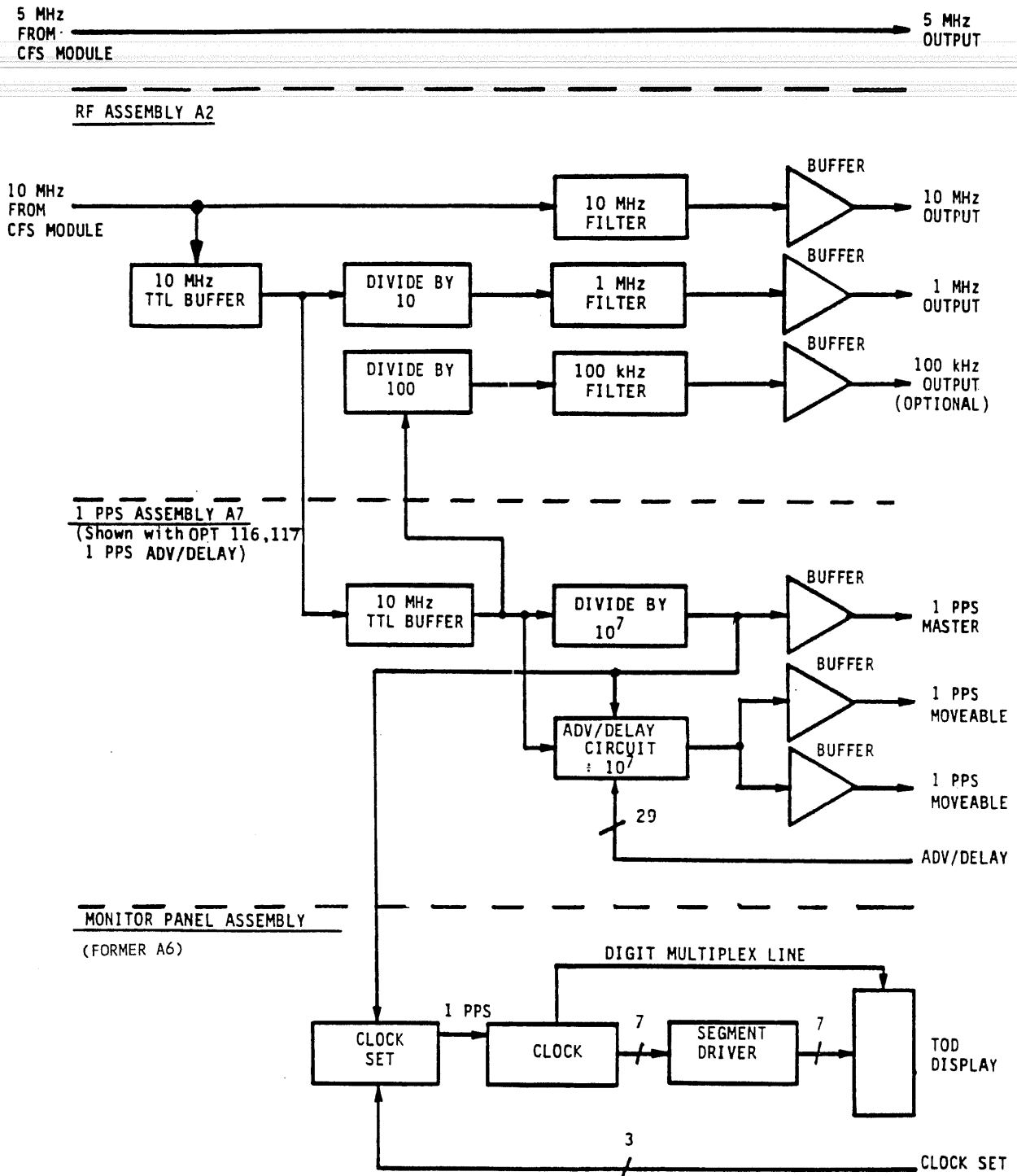


FIGURE 3-11 RF SIGNAL DISTRIBUTION AND TIME GENERATION  
(shown with Options 061, 116, 117)

### 3.4 POWER SUPPLY OPERATION, FTS 4060

Power for the CFS Module, 26 V dc, is furnished by a regulated power supply operating from a 115 or 230 V ac, 47 to 400 Hz power source. The power supply is a conventional linear series-regulated module that is completely self-contained.

### 3.5 BATTERY AND AUTOMATIC CHARGER, OPTION 010

The Option 010 Battery and Automatic Charger consists of a 24 V battery, which will provide a minimum of 1 h of instrument operation in the event of ac power loss. The option also includes battery-charging and control circuits.

The controller automatically connects standby power if ac power is interrupted and disconnects when primary power is restored. If power is connected to the rear panel EXT DC connection and B/E (BATTERY or EXT DC) is selected on the rear panel switch, power is supplied by the standby source with the higher voltage. If the standby sources are equal, current is supplied by both sources. Either EXT DC or BATTERY may be selected exclusively by setting the rear panel switch up or down.

The internal battery is a 12-cell, sealed, lead-acid battery with a rated capacity of 5 Ah. The battery is conservatively rated for 1 h of operation at 25 °C; the normal current drain of the FTS 4060 is approximately 1.3 A at 24 V.

The battery-charger power supply is a 31 V dc module operating from 115 or 230 V ac, 47 to 400 Hz. The supply is a conventional linear, series-regulated module capable of providing up to 1 A.

The battery charger is comprised of a printed-circuit board and a current regulator mounted on the rear panel of the FTS 4060. The charger normally supplies a trickle-charging current of about 15 mA to the battery pack. Periodically, at about 25 to 35 second intervals, the charger tests the state of the batteries by briefly increasing the charging voltage. If the battery is nearly fully charged, only a very short pulse of battery current will result and the charger level will return to trickle; the yellow LED light will flash, indicating that the pulse has occurred, and a current increase may be momentarily noticed on the MONITOR meter if the selector switch is in the BATTERY CHARGE position.

If the battery is discharged, the increase in battery voltage will cause a large increase in the charging current and the charger will lock in to the fast-charge mode. The fast-charge cycle begins a constant current charging rate of about 500 mA. After approximately 3 to 4 hours, the battery charger will switch to a constant voltage mode for an additional 5 to 7 hours and then automatically revert to a trickle charge to top off the battery. The full charge cycle is completed in 12 to 16 hours. Refer to Figure 3-12.

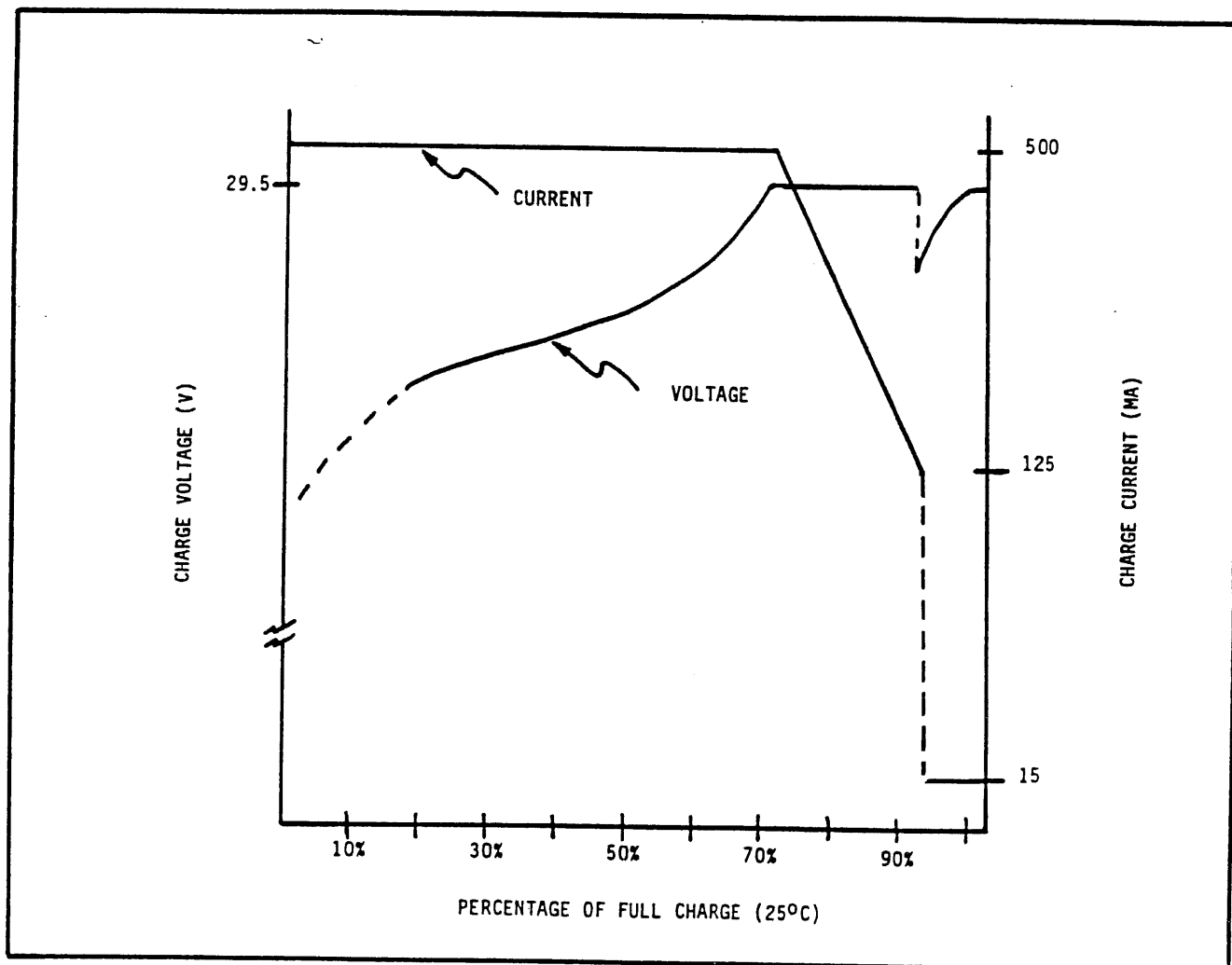


FIGURE 3-12 BATTERY CHARGE CYCLE

**ADDENDUM FOR THE FTS 4060  
CESIUM TIME AND FREQUENCY STANDARD  
OPERATING MANUAL P/N 07516-001-00000  
Applicability: Option 062**

SUMMARY

Option 062 makes the following changes to the FTS 4060:

- An additional, independantly buffered, 10 MHz output is provided on the front panel.
- An additional, parallel, 5 MHz output is provided on the front panel.
- Two parallel 1 MHz outputs are provided. One, 1 MHz output is located on the front panel, the other is located on the rear panel.
- A 100 kHz output is provided on the rear panel.

CHANGES TO THE OPERATING MANUAL

The following changes are made to the FTS 4060 operating manual for Option 062:

- Interpret references to the 100 kHz output location as being to the rear panel and references to the 10 MHz output signal as being to both front and rear panels.
- Interpret references to Option 061 as Option 062 with the exception of the the 100 kHz and 10 MHz output locations.



**ADDENDUM FOR THE FTS 4060  
CESIUM TIME AND FREQUENCY STANDARD  
OPERATING MANUAL P/N 07516-001-00000  
Applicability: Option 018, Time Code Generator**

1.0 GENERAL DESCRIPTION

Option 018 is a Time Code Generator (TCG) which converts the displayed time into an 8421 BCD formatted word. The TCG output is capable of driving a standard interface as specified in MIL-STD-188-114.

The time code is synchronized to the movable 1 PPS (slave) signal. The time code output can be advanced or delayed by adjusting the movable 1 PPS.

Table A-1 lists specifications for the Time Code Generator.

TABLE A-1, SPECIFICATIONS, TIME CODE GENERATOR

TIME CODE OUTPUT

Amplitude high	2.5 V minimum
low	0.5 V maximum
Pulse Width	20 ms $\pm$ 1 ms
Format	8421 BCD (10s of hours 1st)
Time Code (+)	Positive logic
Time Code (-)	Negative logic

2.0 TIME CODE OUTPUT

The time code meets the requirements as specified in MIL-F-28811A(EC), paragraph 3.4.12.2.1. The output consists of a twenty four bit serial 8421 BCD word. The most significant bit of tens of hours, is output first and the least significant bit of ones of seconds, is output last. At the completion of the 24 bit word, the signal holds a mark (high) until the beginning of the next code word. The bit rate is 50 bits per second. Figure A-1 illustrates the time code.

Example: Selected time is 12:34:56

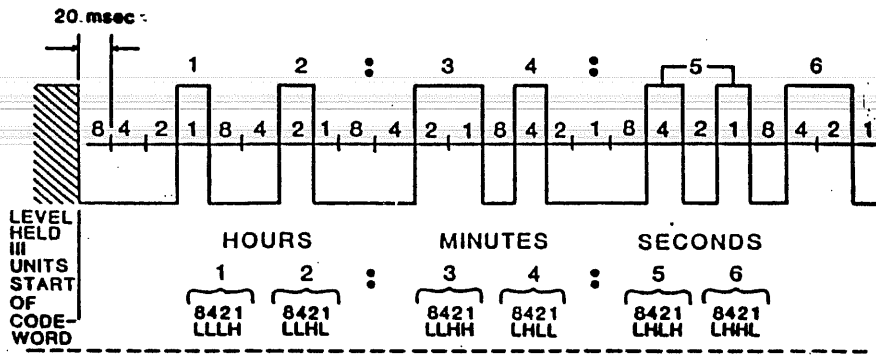


FIGURE 1, 24 BIT BINARY CODED DECIMAL

### 3.0 OPERATION

Operation of the Time Code Generator is automatic upon turn-on of the instrument. Refer to Section 2.5 in the FTS 4060 Operating Manual for instructions on time setting and synchronization to an external reference.

#### 3.1 Time Code Advance/Delay

The time code output can be advanced or delayed in  $0.1 \mu\text{s}$  steps. The 1 PPS ADJUST switches control the amount of advance or delay. Refer to Section 2.5.2 in the FTS 4060 Operating Manual for a description of the Advance/Delay feature (Option 116) and its operational controls.

Note: Insure that all 1 PPS ADJUST switches are set to zero if no displacement of the time code is desired.

#### 3.2 Time Code Verification

The presence of a time code output can be verified using an oscilloscope.

Connect the Time Code (+) output to the scope input and connect the 1 PPS MASTER output to the scope's external trigger input. Set the oscilloscope sweep to 10 ms/div and the trigger to external.

The oscilloscope will display an entire digit (4 bits; 20 ms/bit) of the Time Code output. To view the tens of hours, set the 1 PPS ADJUST switches to all zeros. The scope should display a 4-bit BCD format with the first 20 ms representing the "8" bit, the next 20 ms representing the "4" bit, and so on. Refer to Figure 1 for an illustration of the Time Code Word. Verify that the byte corresponds to the decimal tens of hours on the FTS 4060's Time-of-Day display.

Each digit of the Time-of-Day display can be checked by adding 80 ms of advance per digit. For example: To check the 10s of minutes, set the 1 PPS ADJUST switches to 160 ms and ADVANCE repeat the procedure in the preceding paragraph. The entire Time Code Word can be checked by advancing to each digit. Note that when examining the ones and tens of seconds, the digit display on the oscilloscope is noticeably incrementing.

#### 4.0 FUNCTIONAL DESCRIPTION

The Time Code Generator (A10) receives the time of day in 4-bit (8421 BCD form) digits from the Time Of Day Assembly (A9). Tens of hours are received first and ones of seconds are received last. Time information is entered into six shift registers. Shift register loading is synchronized by enabling each register sequentially so that the most significant digit (tens of hours) loads into the most significant shift register. Synchronization is achieved by importing a 10 kHz signal from the 1 PPS Assembly, A7, as a timing signal, and using a decoder to sequentially activate the shift register by strobing their enable inputs.

A 1 PPS signal is applied to the Time Code Generator and enables shift register loading at the start of each pulse. The shift register is clocked at 50 Hz and outputs its contents one bit at a time starting with the most significant bit of the tens of hours. After the 24th bit, the output holds at a continuous logic "1" until the next 1 PPS reactivates the shift register.

The 100 Hz, from the 1 PPS Assembly, is used to clock the shift registers. The bit rate is 50 bits per second (50 Hz) and is derived by configuring the shift register to shift on every other clock pulse.

The shift register output is applied to a differential amplifier that buffers the Time Code (+) and a Time Code (-) output. Output levels are TTL.

Refer to Figure 2 for a block diagram of the Time Code Generator.

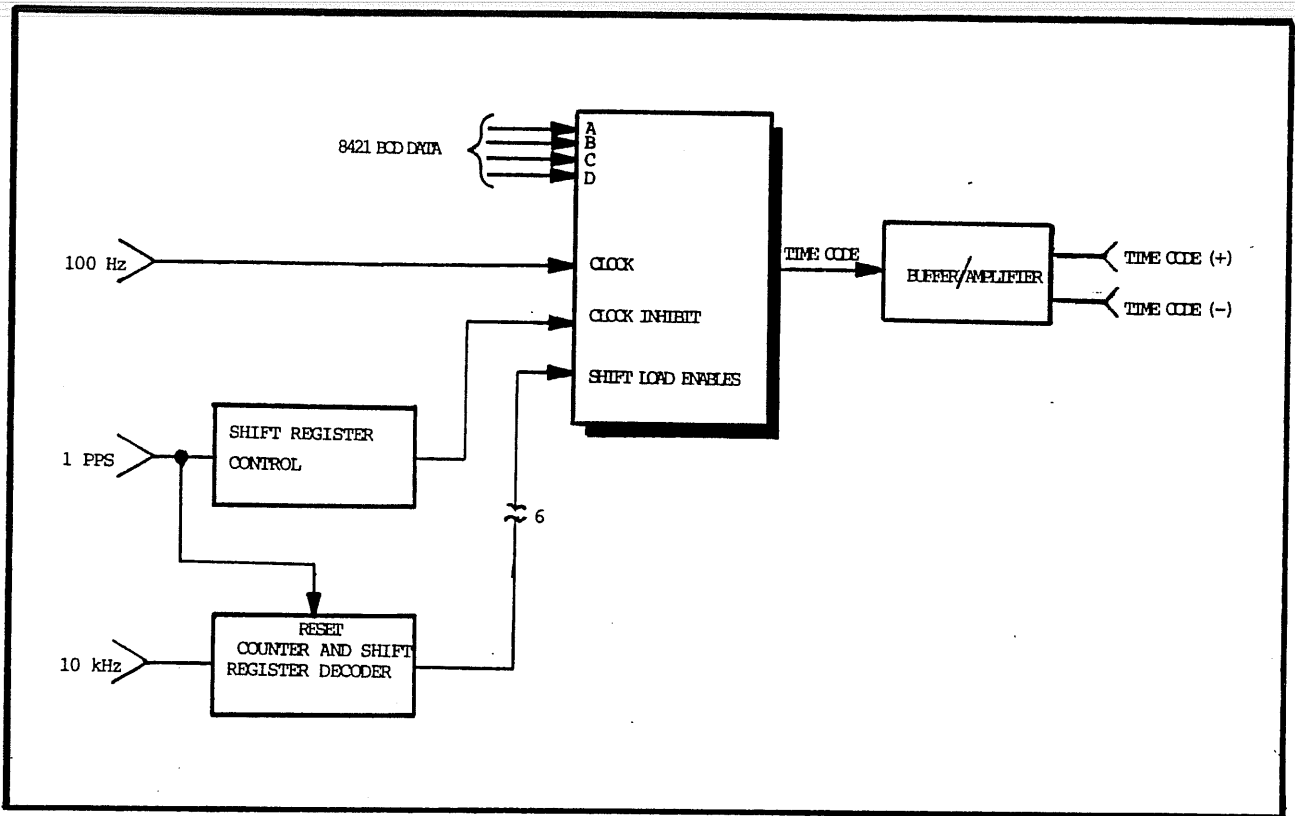


FIGURE 2, TIME CODE GENERATOR BLOCK DIAGRAM

**ADDENDUM FOR THE FTS 4060  
CESIUM TIME AND FREQUENCY STANDARD  
OPERATING MANUAL P/N 07516-001-00000**

Applicability: Option 063, DS1 Frequency Synthesizer

## 1.0 GENERAL INFORMATION

This addendum provides supplemental information to the FTS 4060 Operating Manual when Option 063 is included. Information presented in the manual is applicable to the Model FTS 4060/063 with the following exceptions:

- Ignore all references to a 1 pps output
- Ignore all references to the Time-of-Day clock display and controls
- Ignore all references to the Advance and Delay feature
- Ignore references to the 100 kHz and 1 MHz outputs
- Ignore all references to Options 116 and 117

Option 063 is not available with Option 061, 116 or 117.

## 1.1 GENERAL DESCRIPTION

Option 063 adds a DS1 Telecommunications Synthesizer PCB Assembly, A7, to the FTS 4060. With Option 063, the FTS 4060 can serve as a stand alone Stratum 1 Master Clock or as a component of a master clock system.

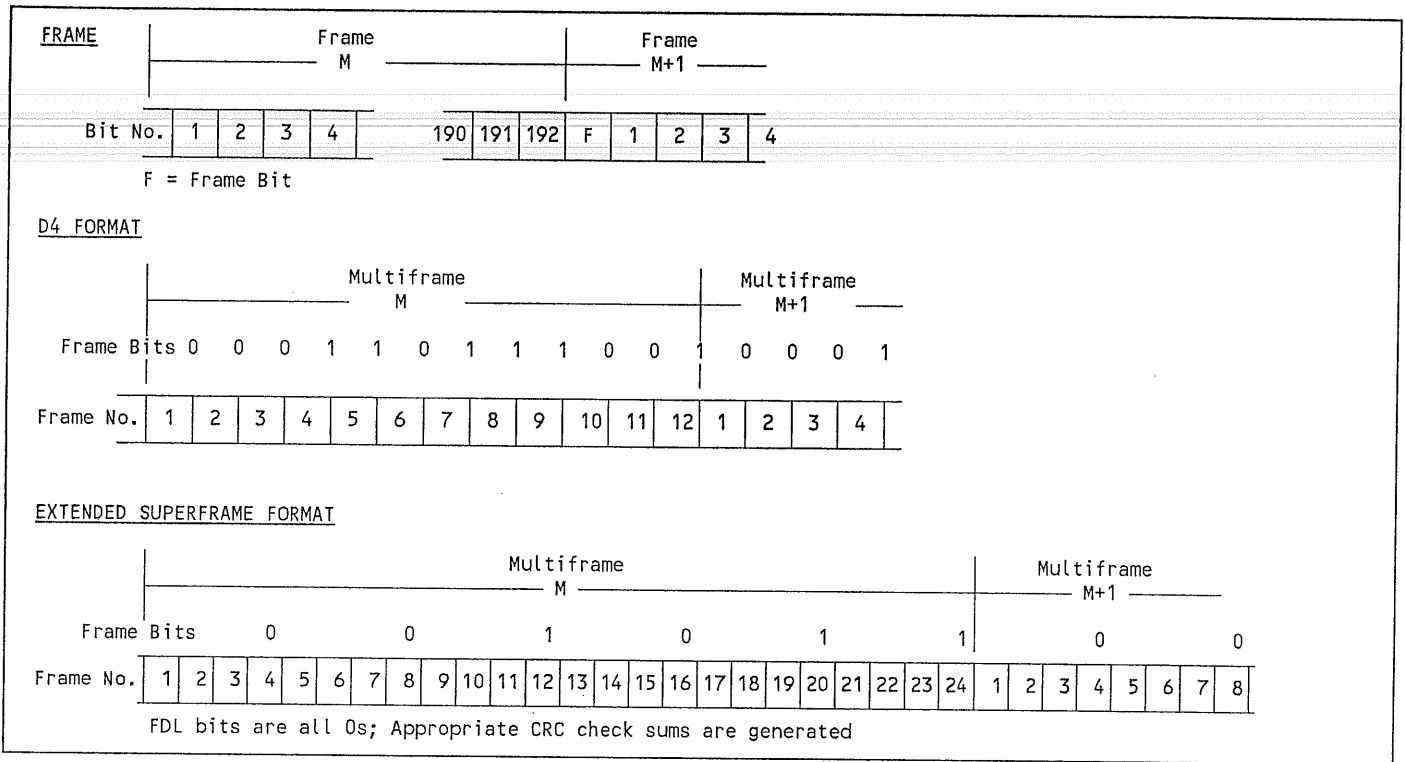
The Telecommunications Synthesizer Assembly, A7, replaces the 1 PPS Advance/Delay PCB, A7. This precludes the use of the Clock Interface PCB, A8, and Time-of-Day PCB, A9, Assemblies used with Options 116 and 117.

Option 063 adds the following outputs to the rear panel of the instrument:

- A balanced 1.544 MHz, framed all ones, DS1 signal.
- An 8 kHz, TTL signal synchronous with the DS1 Frame Markers.
- A 1.544 MHz TTL clock.

All three outputs are phase-locked to a 10 MHz reference input provided by the Cesium Frequency Module, A1.

The DS1 output is switch selectable (via a DIP switch on the PCB) to provide either a D4 or Extended Superframe (ESF) format. Figure A1 provides an illustration of the D4 and ESF formats. The DS1 output is adjustable for matching cable length to the DSX1 cross connect template at the end of the cable.



**Figure 1 Frame, D4 and Extended Superframe Formats**

The following input is added to the rear panel:

**Frame Synchronization**

This input allows the DS1 and Frame Alignment output signals to be synchronized to an external reference.

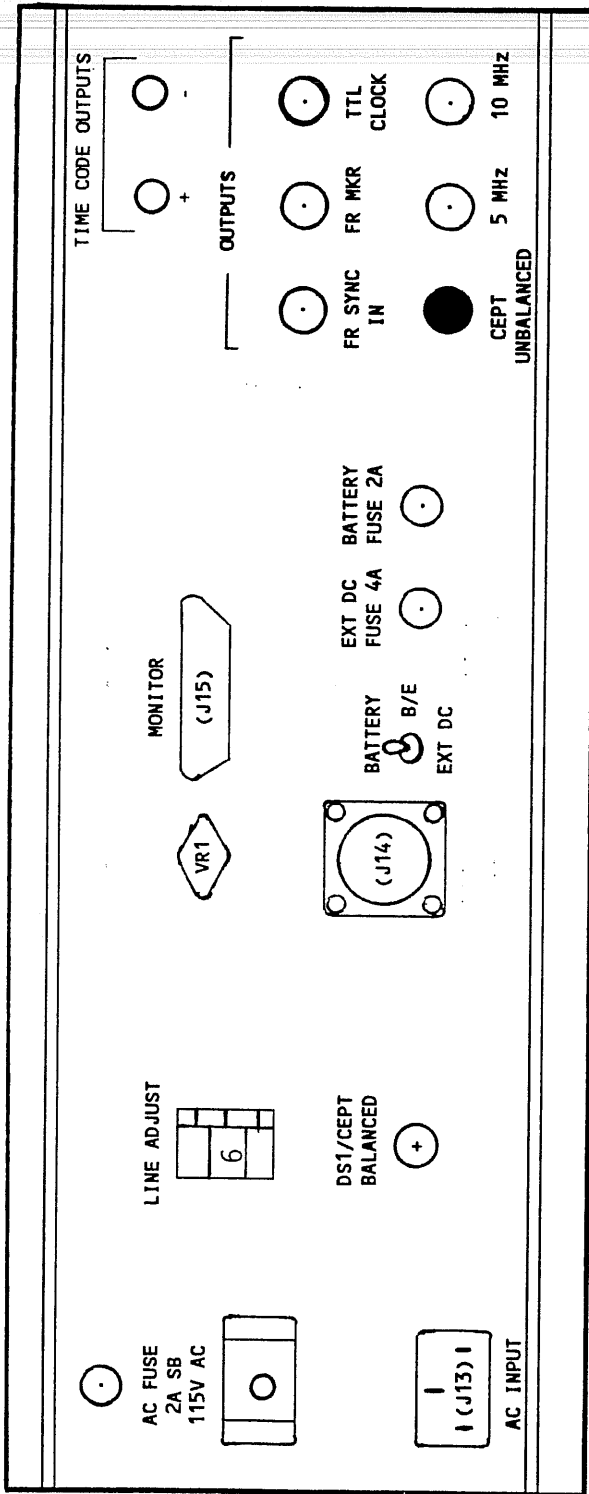
A contact closure summary alarm is added to the rear panel MONITOR connector.

The following control is added to the rear panel of the FTS 4060:

- A Line Length Adjust switch for adjusting the DS1 output signal shape and amplitude.

Table 1 is a list of specifications applicable to Option 063 and supplements Table 1-1 in the manual. Figure 2 is an illustration of the rear panel and should be referred to in place of Figure 1-4 (rear panel illustration) and Figure 2-2.

Note: Figure 2 shows connections that are not available with this option. These connections are shaded on the illustration.



PIN	FUNCTION
1	Relay Contact 1 NO
2	Relay Contact 2 NC
3	Relay Contact 3 COM
4	Monitor Alarm
5	Op Alarm
7	QZ Oven
8	Cs Oven
9	Beam Current
11	Control Voltage
12	Ion Pump Current
13	Ground
20	Charge Current
21	Supply Voltage
22	Degauss High
23	Degauss Low

PIN	FUNCTION
A	-48 V dc (Opt 048)
A	22 to 30 V dc
B	No Connection
C	Ground
D	No Connection
E	No Connection

PIN	FUNCTION
A	AC Power
B	Neutral
C	Safety Ground

DS1 CONNECTOR  
WECO-310; Tip, Ring, and Sleeve

Switch Setting	Line Length Selected (feet)
4	0 - 150
3	150 - 275
2	275 - 550
1	550 - 655

Figure 2 FTS 4060 Rear Panel with Options (048, 063, 064)

**Table 1 Specifications, DS1 Synthesizer**

**OUTPUTS**

**DS1**

Signal Type	DS1, balanced
Frequency	1.544 MHz
Format	Framed all 1's (D4 or ESF)
Jitter	<0.05 U.I.
Connector	WECO 310 Plug
Maximum Cable Length	655 feet

**Frame Marker**

Signal Type	TTL
Frequency	8 kHz
Connector	BNC

**TTL clock**

Signal Type	TTL
Frequency	1.544 MHz
Connector	BNC

**INPUTS**

**Frame Synchronization**

Signal Type	TTL compatible, active low
Frequency	8 kHz or submultiple of 8 kHz
Connector	BNC

**MONITORS**

**Summary Alarm**

Type of Alarm	Contact Closure
Contact Rating (maximum)	10 A at 30 V dc
Connector	J15 pins 1, 2, & 3; rear panel

**CONTROLS**

**Cable Select**

D4/ESF	8-Position Thumbwheel Switch, rear panel 2-Position DIP switch, on PCB
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## 2.0 OPERATION

### 2.1 CONNECTIONS

All Option 063 external connections are made at the FTS 4060 rear panel. The FRAME SYNC input, FRAME MARKER output, and TTL CLOCK output use BNC connectors. The DS1 output uses a WECO-310-compatible jack.

The 10 MHz output is also routed to the DS1 Synthesizer Assembly. Shorting the 10 MHz output removes the frequency reference to the DS1 Synthesizer, causing an Operational Alarm.

The Summary Alarm relay contacts are available at pins 1, 2, and 3 of the rear panel MONITOR connector.

### 2.2 OPERATING INSTRUCTIONS

#### 2.2.1 Cable Selection

After cable connections are made, set the rear panel CABLE SELECT switch to the nominal position for cable length used (maximum length is 655 feet). Refer to Table 2 or to the rear panel for a chart relating nominal switch position to cable type/length.

Table 2 Cable Select

Switch Setting	Line Length Selected (feet)	Cable Type
4	0 - 150	ABAM, PIC, &
3	150 - 275	
2	275 - 550	
1	550 - 655	PULP

Switch positions 0 and 5-8 are not used.

#### 2.2.2 Synchronizing

The frame alignment of the DS1 output can be synchronized to an external reference. It is suggested that a TTL pulse with a repetition rate of 8 kHz (or a submultiple of 8 kHz) signal be used for synchronization because the frames repeat at an 8 kHz rate.

To synchronize, briefly apply the reference signal to the rear panel BNC connector labeled FR SYNC IN.

Another FTS 4060/063 may be used as a reference by connecting its FR MKR output to the FR SYNC input to the unit being synchronized.

### 2.2.3 D4/Extended Superframe Selection

The DS1 format may be switched to D4 or ESF by setting the switch assembly (located on the Synthesizer Assembly) as shown in Table 3.

**WARNING:** Remove power to the FTS 4060 before opening the cover.

**CAUTION:** The FTS 4060 contains components that are static sensitive. Use proper static precautions when touching any internal parts. To access the Synthesizer Assembly, remove the bottom cover to the FTS 4060.

Table 3 DS1 Format Jumper Positions

TB4			TB5		
6	5	4	6	5	4
1	2	3	1	2	3

D4: TB4 2-5 shorted  
TB5 2-5 shorted

ESF: TB4 all removed  
TB5 all removed

## 2.3 MONITORING

System operating status is monitored in the same manner as described in the manual with the following changes:

- The MONITOR ALARM is available on the MONITOR connector (J15) at pin 4. A logic "1" at this connection signifies normal operation of the cesium module; a logic "0" signifies a "Monitor" condition (refer to the manual for an explanation of this condition).
- The OP ALARM is available on the MONITOR connector (J15) at pin 5. A logic "1" at this connection signifies normal operation of the cesium module; a logic "0" signifies an "Alarm" condition (refer to the manual for an explanation of this condition).
- An alarm originating from the DS1 Synthesizer Assembly activates the front panel OP ALARM LED indicator (See Section 2.3.1 for causes of this alarm).
- An alarm originating from the Cesium Standard which causes the OPERATION LED to extinguish will disable the DS1 output.
- Operational status of the DS1 Synthesizer is available at the rear panel MONITOR connector at pins 1, 2, and 3.

When the DS1 Synthesizer is in normal operational condition, pin 1 is open and pins 2 and 3 are shorted to each other. In a DS1 Alarm condition, pins 1 and 3 are shorted and pins 2 to 3 are open.

### 2.3.1 DS1 Alarm

A DS1 alarm can be caused by:

- Loss of internal 10 MHz reference input signal to the assembly,
- Loss of DS1 Synthesizer phase-lock, or
- Loss of the DS1 output signal.

If any of the above conditions occur, the front panel OP ALARM indicator lights (which also sets pin 5 of J15 low) and a relay on the assembly is activated.

If the cesium module is operational and the fault exists only with the DS1 Synthesizer Assembly, the LOCK and OP ALARM indicators are both lit. When the OP ALARM indicator is lit and the LOCK indicator is not lit, the problem is most likely related to the cesium module (refer to the FTS 4060 Service Manual for further explanation).

The relay contacts are available at the rear panel MONITOR connector for connection to a remote alarm.

## 3.0 THEORY OF OPERATION

### 3.1 FUNCTIONAL DESCRIPTION

The DS1 Synthesizer consists of:

- A Digital Phase-locked Synthesizer
- DS1 Format Generator and Synchronization Circuit
- Frame Detector Circuit
- Alarm Circuitry.
- Power Converter

Refer to Figure 3 for a block diagram of the DS1 Synthesizer Assembly.

#### 3.1.1 Digital Synthesizer

The digital synthesizer section phase-locks a 6.176 MHz VCXO to a 10 MHz reference signal that is supplied by the Cesium Frequency Module, A1. Both the 6.176 MHz and the 10 MHz signals are digitally divided, phase compared, and integrated to provide a control voltage to the VCXO.

The first divide-by-four stage yields a 1.544 MHz signal. This signal is distributed to:

- The DS1 Format Generating Circuitry to provide the T1 clock
- The rear panel as a buffered 1.544 MHz TTL output.

#### 3.1.2 DS1 Format Generator and Synchronization Circuit

##### 3.1.2.1 DS1 formatting

The required DS1 formatted TTL output is provided by a Serial Receiver/Transmitter driven by the 1.544 MHz clock signal. The formatted data is applied to a T1 Line Interface device.

The Line Interface device transforms the TTL signal (from the serial transmitter) into the appropriately shaped Alternating Mark Inverted (AMI) pulse. The line length select switch provides a BCD input for the pulse shape selected.

##### 3.1.2.1 DS1 synchronization

The Receiver/Transmitter accepts an external SYNC signal (see Table 1 for specifications) and synchronizes the start of the frame to the sync reference. Synchronization occurs on the next clock pulse after the SYNC input has returned to a logic "1".

### 3.1.3 Frame Detector

The Frame Detector accepts a five-bit BCD word from the Receiver/Transmitter that is the binary value of the channel being transmitted. At the start of the next frame, logic circuitry detects a binary "00000" and provides a Frame Marker output pulse.

### 3.1.4 Alarm Circuitry

Alarm circuitry is provided by relay contacts that are brought to the FTS 4060's rear panel MONITOR connector. The relay is activated by a loss of the 10 MHz reference input signal, a loss of the 6.176 MHz phase-lock, a loss of the DS1 output signal, or a loss of the cesium standard OPERATION LED.

### 3.1.5 Power Converter

The DS1 Synthesizer Assembly accepts +5 V dc from the FTS 4060's 5 V regulator (VR1) and converts it to 12 V dc. A DC to DC IC regulator is used.

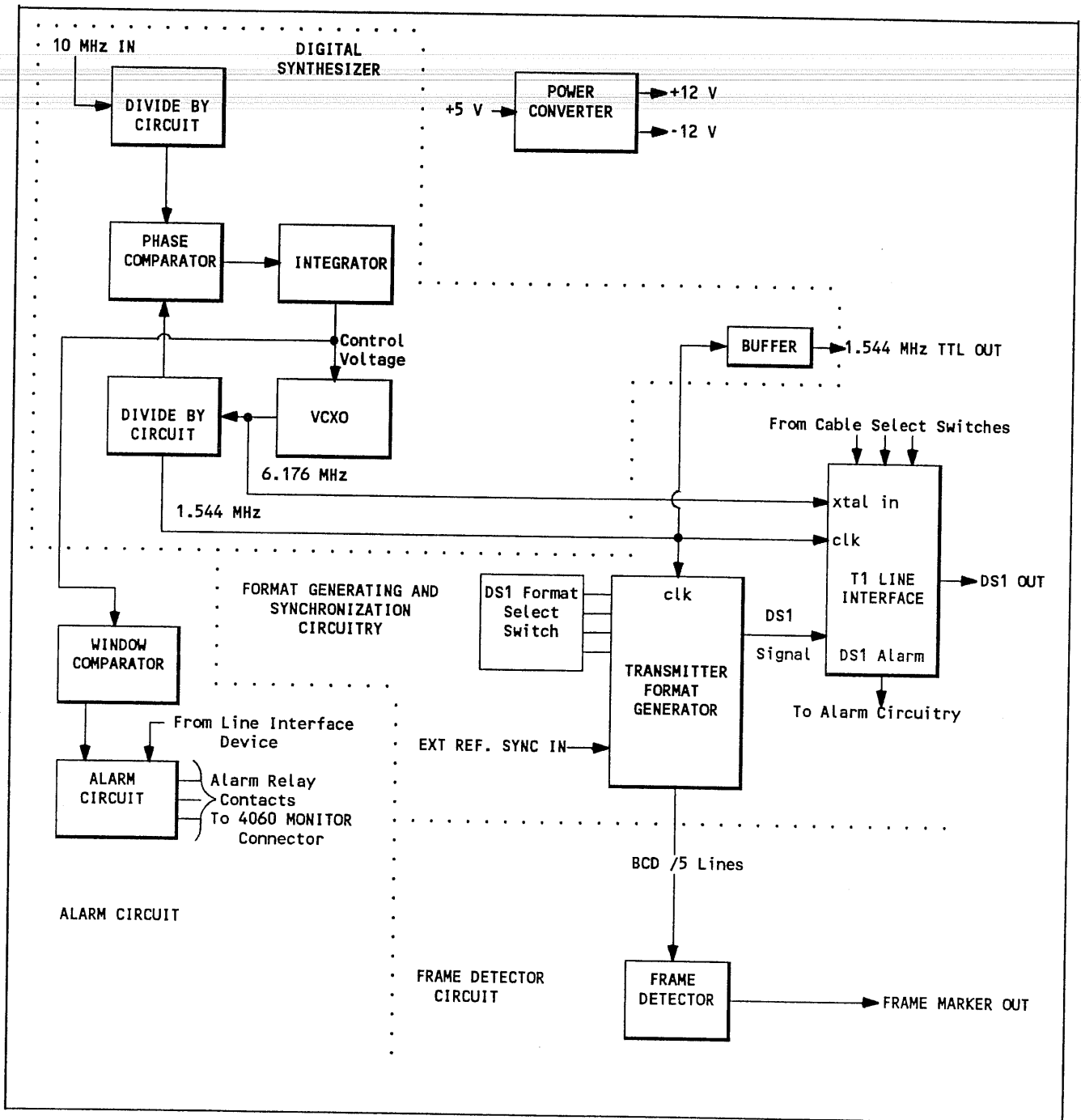


Figure 3 DS1 Synthesizer Assembly Block Diagram

**ADDENDUM FOR THE FTS 4060  
CESIUM TIME AND FREQUENCY STANDARD  
OPERATING MANUAL P/N 07516-001-00000**

Applicability: Option 064, CEPT Frequency Synthesizer

1.0 SCOPE

This addendum provides supplemental information to the FTS 4060 Operating Manual when Option 064 is included. Information presented in the manual is applicable to the Model FTS 4060/064 except that the following features are not available:

- The 1 pps, 100 kHz and 1 MHz outputs
- The Time-of-Day clock display and controls
- The Advance and Delay

2.0 OPTION DESCRIPTION

Option 064 adds a CEPT Telecommunications Synthesizer PCB Assembly to the FTS 4060. With Option 064, the FTS 4060 can serve as a Stratum 1 Master Clock or as a component of a master clock system.

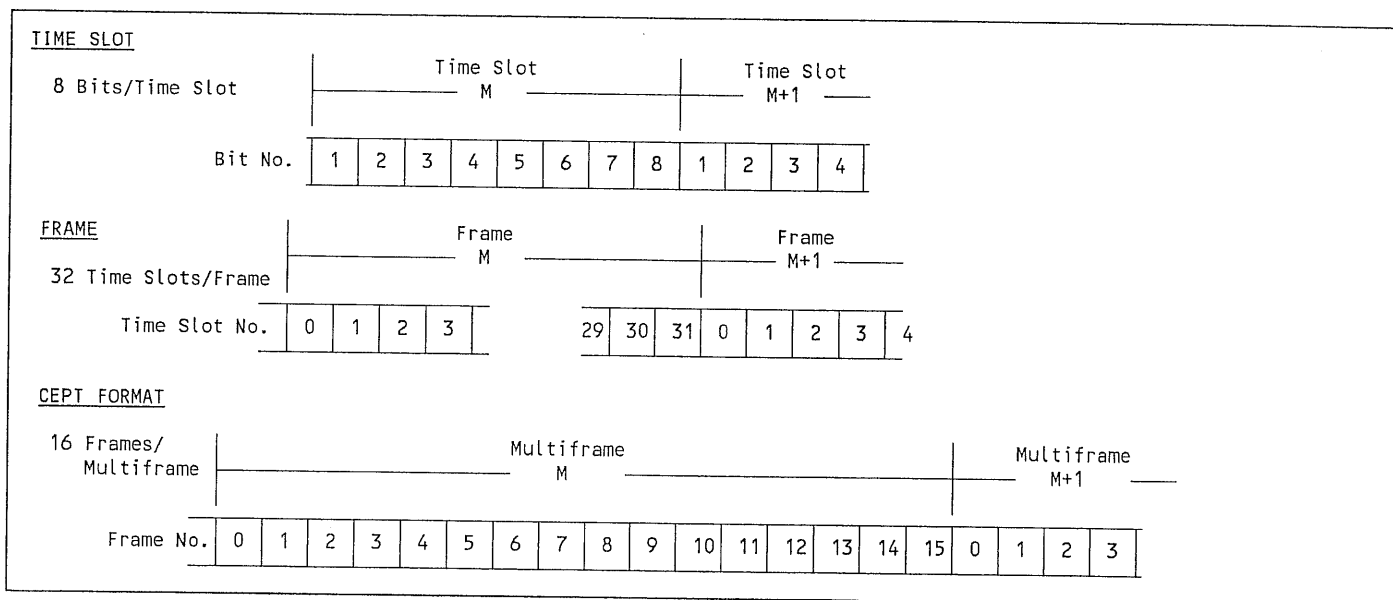
The Telecommunications Synthesizer Assembly, A11, replaces the 1 PPS Advance/Delay PCB, A7. This precludes the use of the Clock Interface PCB, A6A1, and Time-of-Day PCB, A6A2, Assemblies used with Options 116 and 117.

Option 064 adds the following outputs to the rear panel of the instrument:

- A balanced or unbalanced 2.048 MHz CEPT signal.
- An 8 kHz, TTL signal synchronous with the CEPT Frame Markers.
- A 2.048 MHz TTL clock.

All three outputs are phase-locked to a 10 MHz reference input provided by the Cesium Frequency Module, A1.

Figure 1 provides an illustration of CEPT format.



**Figure 1 Time Slot, Frame, and CEPT Formats**

The following are added to the rear panel:

- FRAME SYNCHRONIZATION input for synchronizing the CEPT and FRAME ALIGNMENT outputs to an external reference.
- A contact closure summary alarm.
- A Line Length Adjust switch for adjusting the CEPT output signal shape and amplitude.

Table 1 is a list of specifications applicable to Option 064 and supplements Table 1-1 in the manual. Figure 2 is an illustration of the rear panel and should be referred to in place of Figure 1-4 (rear panel illustration) and Figure 2-2.

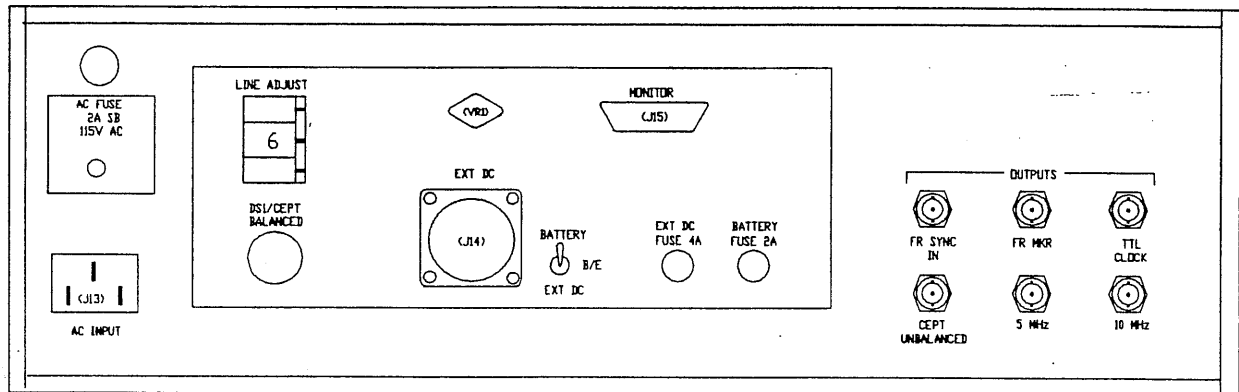


Figure 2 FTS 4060 Rear Panel with Options (048, 063, 064)

## 2.1 Functional Description

Refer to Figure 3 for a block diagram of the CEPT Synthesizer Assembly.

The synthesizer phase-locks a VCXO to a 10 MHz reference signal supplied by the Cesium Frequency Module, A1. Both the VCXO and the 10 MHz signals are digitally divided, phase compared, and integrated to provide a control voltage to the VCXO.

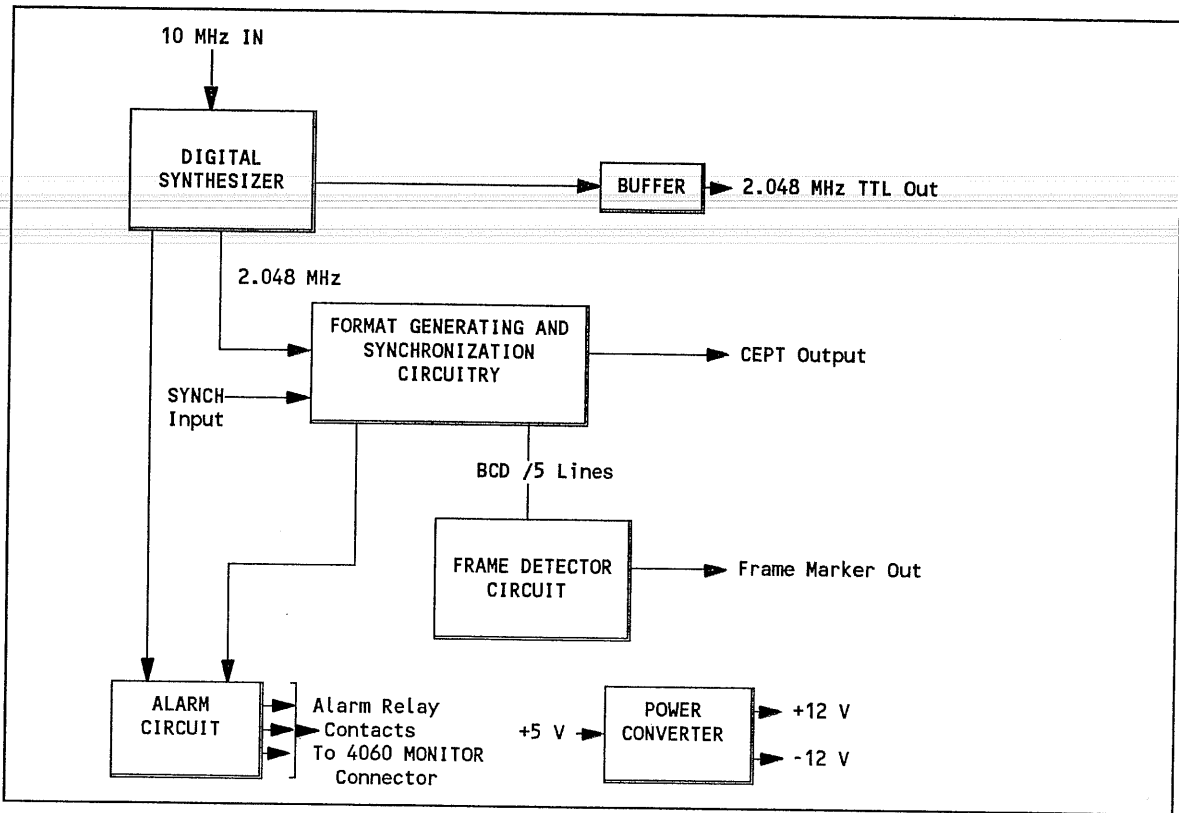
The output of the VCXO is digitally divided to produce a 2.048 MHz signal. This signal is:

- Supplied to the rear panel as a buffered TTL output
- Formatted and output as either a balanced or unbalanced CEPT signal.

A Frame Detector circuit determines the start of each frame and provides a Frame Marker output pulse with each occurrence.

The CEPT Synthesizer Assembly accepts +5 V dc from the FTS 4060's 5 V regulator (VR1) and converts it to  $\pm 12$  V dc. A DC/DC IC regulator is used.





**Figure 3 CEPT Synthesizer Assembly Block Diagram**

## 2.2 SPECIFICATIONS

**Table 1 Specifications, CEPT Synthesizer**

<u>OUTPUTS</u> CEPT Signal Type Frequency Format Jitter Connector Balanced Unbalanced Maximum Cable Length	CEPT, balanced or unbalanced 2.048 MHz Framed all 1's <0.05 U.I. 120 $\Omega$ , WECO 310 Jack 75 $\Omega$ , BNC 655 feet
Frame Marker Signal Type Frequency Connector	TTL 8 kHz BNC
TTL clock Signal Type Frequency Connector	TTL 2.048 MHz BNC
<u>INPUTS</u> Frame Synchronization Signal Type Frequency Connector	TTL compatible, active low 8 kHz or submultiple of 8 kHz BNC
<u>MONITORS</u> Summary Alarm Type of Alarm Contact Rating (maximum) Connector	Contact Closure 10 A at 30 V dc J15 pins 1, 2, & 3; rear panel
<u>CONTROLS</u> Cable Select	8-Position Thumbwheel Switch, rear panel

## 3.0 INSTALLATION

### 3.1 Connections

All Option 064 external connections are made at the FTS 4060 rear panel. The FRAME SYNC input, UNBALANCED CEPT output, FRAME MARKER output, and TTL CLOCK output use BNC connectors. The balanced CEPT output uses a WECO-310-compatible jack.

The 10 MHz output is also routed to the CEPT Synthesizer Assembly. Shorting the 10 MHz output removes the frequency reference to the CEPT Synthesizer, causing an Operational Alarm.

The Summary Alarm relay contacts are available at pins 1, 2, and 3 of the rear panel MONITOR connector. See Table 2 for connector pin assignments.

**Table 2 J15 Monitor Connector Pin Assignments**

CONNECTOR J15 (MONITOR)			
PIN	FUNCTION	PIN	FUNCTION
1	Relay Contact 1	11	Control Voltage
2	Relay Contact 2	12	Ion Pump
3	Relay Contact 3	13	Ground
4	Monitor Alarm	20	Charge Current
5	Op Alarm	21	Supply Voltage
7	Qz Oven	22	Degauss High
8	Cs Oven	23	Degauss Low
9	Beam Current		

### 3.2 Cable Selection

After cable connections are made, ensure that the rear panel CABLE SELECT switch is set to position 7. Positions 0-6 and 8 are reserved for other options and may affect the quality of the CEPT signal if selected.

## 4.0 OPERATING INSTRUCTIONS

### 4.1 Synchronizing

The frame alignment of the CEPT output can be synchronized to an external reference. See Table 1 for input signal requirements.

To synchronize, briefly apply the reference signal to the rear panel BNC connector labeled FR SYNC IN. Another FTS 4060/064 may be used as a reference by connecting its FR MKR output to the FR SYNC input to the unit being synchronized. Synchronization occurs on the next clock pulse after the SYNC input has returned to a logic "1".

### 4.2 MONITORING

Instrument status is monitored as described in the manual with the following changes:

- The MONITOR ALARM is available on the MONITOR connector (J15) at pin 4. A logic "1" at this connection signifies normal operation of the cesium module; a logic "0" signifies a "Monitor" condition (refer to the manual for an explanation of this condition).
- The OP ALARM is available on the MONITOR connector (J15) at pin 5. A logic "1" at this connection signifies normal operation of the cesium module; a logic "0" signifies an "Alarm" condition (refer to the manual for an explanation of this condition).
- An alarm originating from the Cesium standard which causes the OPERATION LED to extinguish will disable the CEPT output.
- An alarm originating from the CEPT Synthesizer Assembly activates the front panel OP ALARM LED indicator (See Section 2.3.1 for causes of this alarm).
- Operational status of the CEPT Synthesizer is available at the rear panel MONITOR connector at pins 1, 2, and 3.

When the CEPT Synthesizer is in normal operational condition, pin 1 is open and pins 2 and 3 are shorted to each other. In a CEPT Alarm condition, pins 1 and 3 are shorted and pins 2 to 3 are open.

### 4.3 CEPT Alarm

A CEPT alarm can be caused by:

- Loss of internal 10 MHz reference input signal to the assembly,
- Loss of CEPT Synthesizer phase-lock, or
- Loss of the CEPT output signal.

If any of the above conditions occur, the front panel OP ALARM indicator lights (which also sets pin 5 of J15 low) and a relay on the assembly is activated.

If the cesium module is operational and the fault exists only with the CEPT Synthesizer Assembly, the LOCK and OP ALARM indicators are both lit. When the OP ALARM indicator is lit and the LOCK indicator is not lit, the problem is most likely related to the cesium module (refer to the FTS 4060 Service Manual for further explanation).

The relay contacts are available at the rear panel MONITOR connector for connection to a remote alarm.

**Addendum for the FTS 4060  
Cesium Time and Frequency Standard  
Operating Manual P/N 07516-001-00000**

Applicability: Option 048, -48 Vdc Power Input

**1.0 SCOPE**

This addendum describes changes in the FTS 4060 made to meet the requirements of Option 048.

**2.0 DESCRIPTION**

Option 048 allows the FTS 4060 to operate from an external DC power source of -42 to -60 V dc (-48 V dc nominal). The power source should be capable of delivering up to 2 Amps. Table 1 provides specifications for this option.

The -48 V input replaces the external DC input referred to in the manual (+22 to +30 V dc). The internal battery and charger (Option 010) cannot be combined with Option 048. Ignore all references to Option 010 in the manual.

**Table 1 Specifications, -48 V dc Input**

Parameter	Specification
Input Voltage Range	-42 to -60 V dc
Input Power	60 W (fully loaded)
	28 W
Connector, J14	MS3102A-14S-5P
Mating Connector	MS3106A-14S-5S
Fuse	4 Amp, 0.25" x 1.25"

**3.0 CONNECTIONS**

Apply a power source meeting the above specifications, to connector J14. This connector is labeled EXT DC and is located on the rear panel. The connector pin assignments are listed in Table 2. Refer to this table for pin assignments instead of the J14 Connector Table contained within Figure 1-4 of the manual.

**Table A-2 J14 Pin Assignments**

Pin	Function
A	-42 to -60 V dc
B	N/C
C	Ground
D	N/C
E	N/C

**4.0 OPERATION FROM EXTERNAL DC POWER**

These instructions replace Section 2.8 of the operating manual when Option 048 is included.

To operate from DC power, the three-position DC source select switch (rear panel) must be in the B/E (center) or EXT DC (down) position. When this switch is in the BATTERY (up) position, external DC power is disconnected from the FTS 4060.

When both AC and DC power are applied, the FTS 4060 is powered from the AC source. When AC power is removed, the instrument automatically switches to operate from external DC and the AC ALARM and BATTERY indicators light.

The SUPPLY MONITOR (switch position 5) should read  $2.4 \pm 0.3$  V when operating from DC power.

## Appendix A

### FTS 4060 Cesium Time and Frequency Standard Control Voltage Centering Adjustment

## PROCEDURE TO RETUNE THE OSCILLATOR IN AN FTS 4060

### A1.0 INTRODUCTION

This procedure provides the necessary instruction to adjust the coarse manual oscillator tuning in an FTS Model 4060 Cesium Beam Frequency Standard. This procedure is necessitated by the intrinsic quartz oscillator aging which makes it necessary to perform a periodic manual re-centering of the quartz oscillator tuning control.

For earlier configurations of the FTS 4060, the oscillator must be removed for control voltage adjustment. For later units, the oscillator coarse frequency control is accessible from the rear panel. In the later case, refer to para. A2.3.

**NOTE:** Use the flow chart (sheet A1) as a guide to the steps necessary for proper adjustments.

### A1.1 Background

The FTS 4060 Cesium Frequency Standard contains, as do all atomic frequency standards, a quartz oscillator. The electronics of the 4060 serves to lock this oscillator to a cesium resonance, thereby achieving great frequency accuracy and stability which are independent of the aging and environmental sensitivities which the quartz oscillator would exhibit in a stand alone configuration.

The oscillator has two adjustments which control its frequency: a coarse manual control and a fine electrical control. The coarse manual control allows the oscillator frequency to be re-centered after an extended period of operation. The fine electrical control allows the 4060 servo to provide continuous corrections to the oscillator while the instrument is operational.

This procedure addresses the process of adjusting the coarse manual control in such a fashion as to re-center the electrical fine control. A flowchart of this procedure is shown in Figure A-5.

### A1.2 Personnel Qualifications

The person performing this procedure should be skilled in the maintenance, adjustment and repair of electronic equipment. This person should be trained in the necessary safety procedures which are associated with the repair of electronic equipment.

This person should also be trained in the ESD precautions which are necessary to prevent electrostatic discharge damage to the FTS 4060 electronics. An ESD wrist strap should be worn at all times while handling the internal subassemblies of the FTS 4060.

### A1.3 Required tools

The tools required are:

- a Philips screwdriver,
- a 5/32" Allen hex wrench,
- a small slotted (jewelers) screwdriver or equivalent tuning tool (e.g. Johanson 8777) suitable for adjusting a potentiometer

three FTS extender cables:

- 5030 power cable extender FTS P/N 07749-501
- 5030 monitor cable extender FTS P/N 07751-501
- 5030 oscillator cable extender FTS P/N 07750-501
- Masking tape suitable for marking cables which are disconnected

## Appendix A

### FTS 4060 Cesium Time and Frequency Standard Control Voltage Centering Adjustment

#### A2.0 Equipment Disassembly

The quartz oscillator is located on a structural panel of the FTS Model 5030 Cesium Beam Frequency Standard Module. The 5030 module is mounted inside the FTS Model 4060. Access to the quartz oscillator is discussed below.

#### A2.1 FTS Model 5030 Module Removal

With the FTS Model 4060 stabilized (operation for 4 hours if beginning from a cold start) read and record the control voltage on the front panel meter. If the control voltage reading is less than 0.6 V or greater than 4.4 V, the 4060 will not be able to properly perform autolock if power is removed and reapplied. Even if this is the case disassemble the 4060 as described below; this condition is addressed in A2.4 below.

Remove power including removal of battery fuse.

Remove Top and Bottom covers

With unit oriented in the normal operating position, remove the four 5030 module mounting screws from the 4060 (see Fig A-1).

Disconnect power, coax and monitor cables from the 5030; remove the 5030 module from the 4060 chassis.

#### A2.2 Oscillator Removal

Disconnect the connectors to the 5030 processor board (see Figure A-2):

one flat ribbon cable

two coax cables; mark one of these cables (upper or lower, left or right) to allow proper identification of which cable goes where during reassembly

one shielded twisted pair cable

Remove the four screws which retain the processor board

Remove the processor board

Remove the three screws which mount the oscillator (The oscillator is identified in Figure A-3).

For 4060/201 units, the oscillator configuration is similar but not identical to that shown in Figure A-3 and A-4. The following procedure may still be used, in this case.

Gently rotate the oscillator away from its mounting position

Remove the ribbon cable connector to the oscillator; leave the coax cables connected to the oscillator.

Install an oscillator extender cable (FTS P/N 07750-501) between the oscillator and the ribbon cable (where the oscillator is normally attached) on the 5030.

Reinstall the processor board and attach all its connectors. Take particular care that the two coax cables are connected to the proper connectors on the processor board. It is not necessary to reinstall the processor board mounting screws at this time.

**Appendix A**  
**FTS 4060**  
**Cesium Time and Frequency Standard**  
**Control Voltage**  
**Centering Adjustment**

Connect the 5030 to the 4060 using the two extender cables (FTS P/N 07749-501 and FTS P/N 07751-501).

A2.3 Oscillator Adjustment

Arrange the electronics neatly on a bench.

**WARNING:**

**LETHAL VOLTAGES ARE PRESENT UNDER THE TOP COVER. TAKE SPECIAL PRECAUTIONS NOT TO CONTACT THE LINE VOLTAGE AT THE REAR PANEL OR THE POWER SUPPLIES.**

Apply power to the 4060.

Wait for the 4060 to warm up and stabilize. This will take approximately 30 minutes if the unit has been depowered for less than an hour. If the unit does properly acquire lock and illuminate the lock indicator within 1.5 hours, go to step A2.4 below.

Assuming that the 5030 has properly achieved lock, set the front panel monitor to observe the CONTROL voltage (position 4). Slowly adjust the oscillator coarse frequency control (a small potentiometer located on the oscillator cover near the power connector, see Figure A-4) with a small slotted screw driver to achieve a mid-scale reading (2.5 volts) on the 4060 front panel (CONTROL voltage, position 4) meter. For later 4060 units, this control is accessible from the rear panel. No disassembly if the unit is required in this case. If the 4060 has been depowered for an extended period (e.g several months in storage), it is advisable to allow the oscillator to fully stabilize overnight (or preferably over a weekend) before the final adjustment is made to center the control voltage.

To reassemble the 4060, proceed to step A2.5 below.

A2.4 4060 Failure to Lock

If the 4060 does not properly acquire lock this most probably indicates that the oscillator center frequency is outside the lock capture range. In this case the front panel control voltage indicator (position 4) of the 4060 will be executing a ramp from low to high with a rapid return. If the CONTROL voltage (position 4) is ramping, go to paragraph A2.4.1. If this behavior is not observed after one hour of operation the instrument has detected a problem with its internal monitors. In this case verify that the disassembly and cable insertion instructions were properly carried out as detailed above. If this does not rectify the situation contact FTS Technical Service for assistance.

A2.4.1 Setting the Beam Current Gain

A ramping CONTROL voltage indicates that the oscillator fine electrical tuning is outside the lock capture range. The internal 4060 microprocessor must be overridden to gain manual control (see section 2.6.5 in the main body of this manual).

- a) Open the 4060 servo loop and turn OFF the MOD switch using the front panel controls. Simultaneously press and release the OPERATION ALARM and the ALIGN pushbuttons. The control voltage should stop ramping.
- b) SCAN the CONTROL VOLTAGE from the 4060 front panel (see section 2.6.2 in the main body of this manual) while observing the front panel BEAM current monitor (switch position 3) for the resonance pattern shown in Figure 3-6 (see also section 3.6.2 in the main body of this manual).
- c) Adjust the CONTROL VOLTAGE to center the meter response on a peak of the BEAM CURRENT resonance.
- d) Adjust the LOOP GAIN gain (see section 2.6.3 in the main body of this manual) to achieve a mid-scale reading of the BEAM current on the meter.



## Appendix A

### FTS 4060 Cesium Time and Frequency Standard Control Voltage Centering Adjustment

#### A2.4.2 Centering the Fine Electrical Oscillator Tuning Control

While monitoring the oscillator CONTROL voltage monitor (position 4) adjust the oscillator CONTROL VOLTAGE from the front panel to achieve a mid-scale reading of 2.5 volts. The BEAM current reading will change during this process.

#### A2.4.3 Centering the Coarse Manual Oscillator Tuning

While observing the cesium BEAM current monitor from the front panel (position 3) adjust the coarse manual oscillator tuning control on the cover of the oscillator (see Figure A-4). As the coarse tuning control is rotated from full clockwise to full counter-clockwise and back, the resonance pattern of Fig 3-6 will be observed. Readjust the LOOP GAIN if necessary to achieve a useful display. Adjust the coarse control to center the response on the central (highest) resonance peak. Verify that the central peak has been selected by observing that the adjacent valleys are of equal depth. Return the coarse adjustment to the top of the central resonance peak. After the oscillator has been successfully re-centered, press the front panel ALIGN pushbutton, set the MOD switch to ON and set the LOOP switch to CLOSED. The 4060 will perform a microprocessor controlled alignment (see section 2.6.4 in the main body of this manual). The LOOP GAIN will be automatically set. The oscillator CONTROL voltage monitor (position 3) will return to mid-scale (approximately 2.5 volts) if the adjustment described above has been performed properly.

#### A2.5 Reassembly of the 4060

Depower the 4060 and remove the three adaptor cables. Disconnect the processor cables and remove the processor board. Reconnect the oscillator to the 5030 and install the oscillator mounting screws. Reinstall the Processor board including its cables and mounting screws.

Reinstall the 5030 into the 4060, reconnecting its electrical cabling as required.

Replace the 4060 covers and reapply power to the 4060. Replace the battery fuse. After unit stabilization, verify that the unit has properly acquired lock and that the oscillator control voltage is properly centered.

This completes the adjustment of the coarse manual oscillator tuning control.

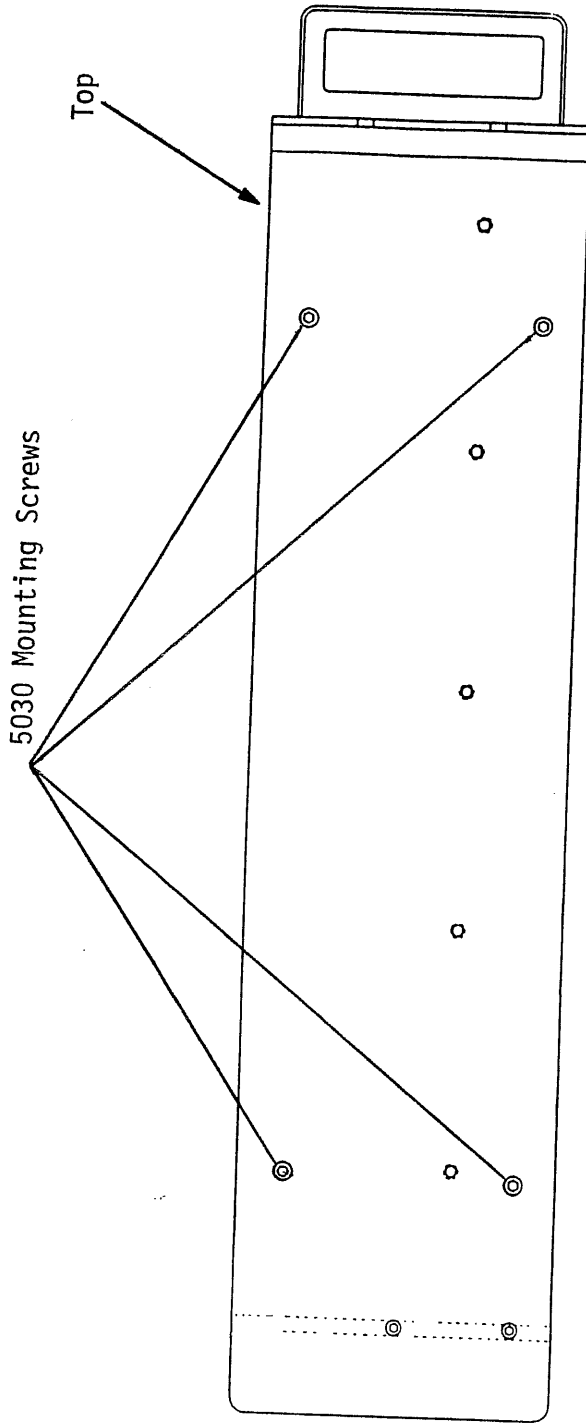
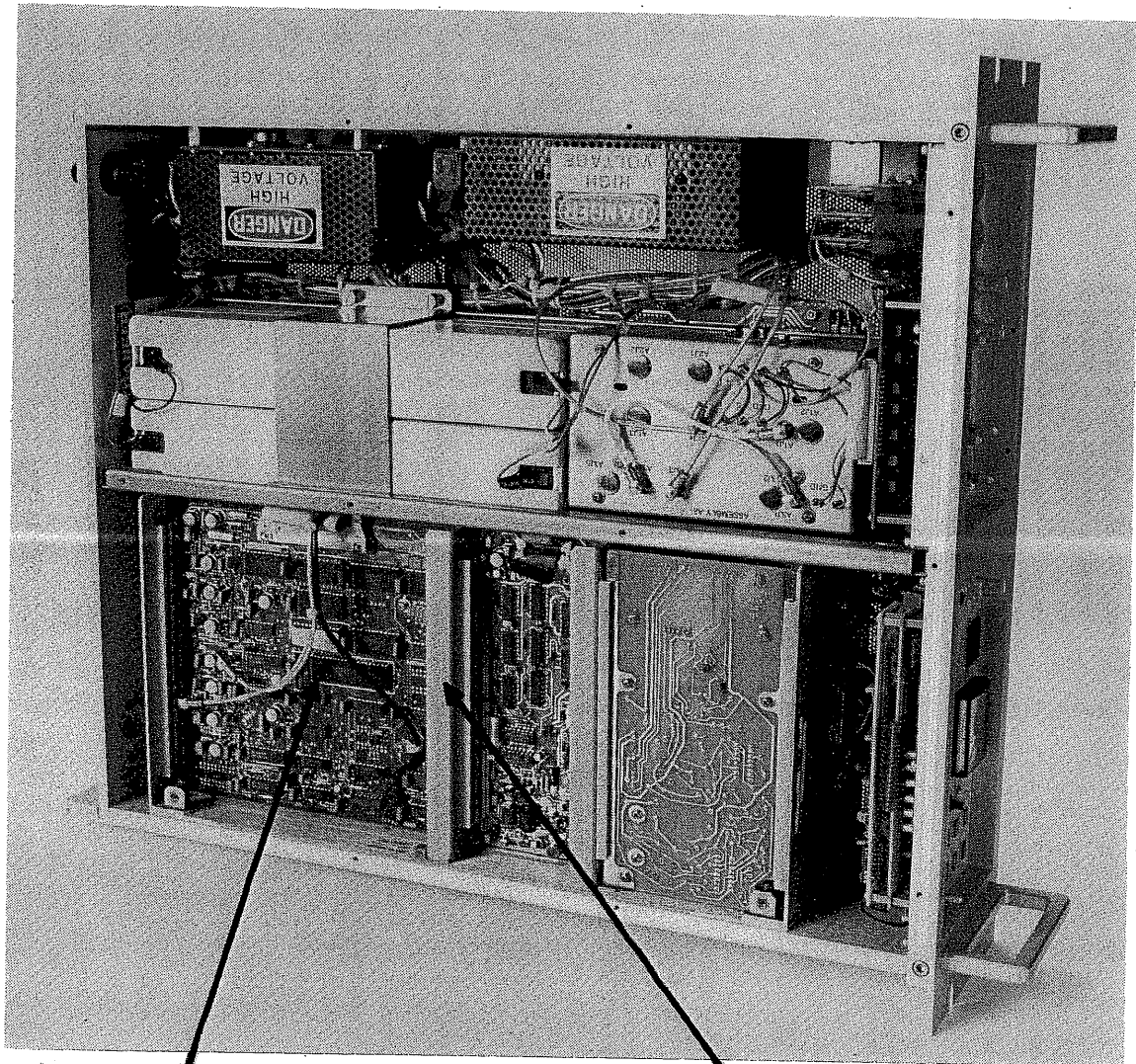


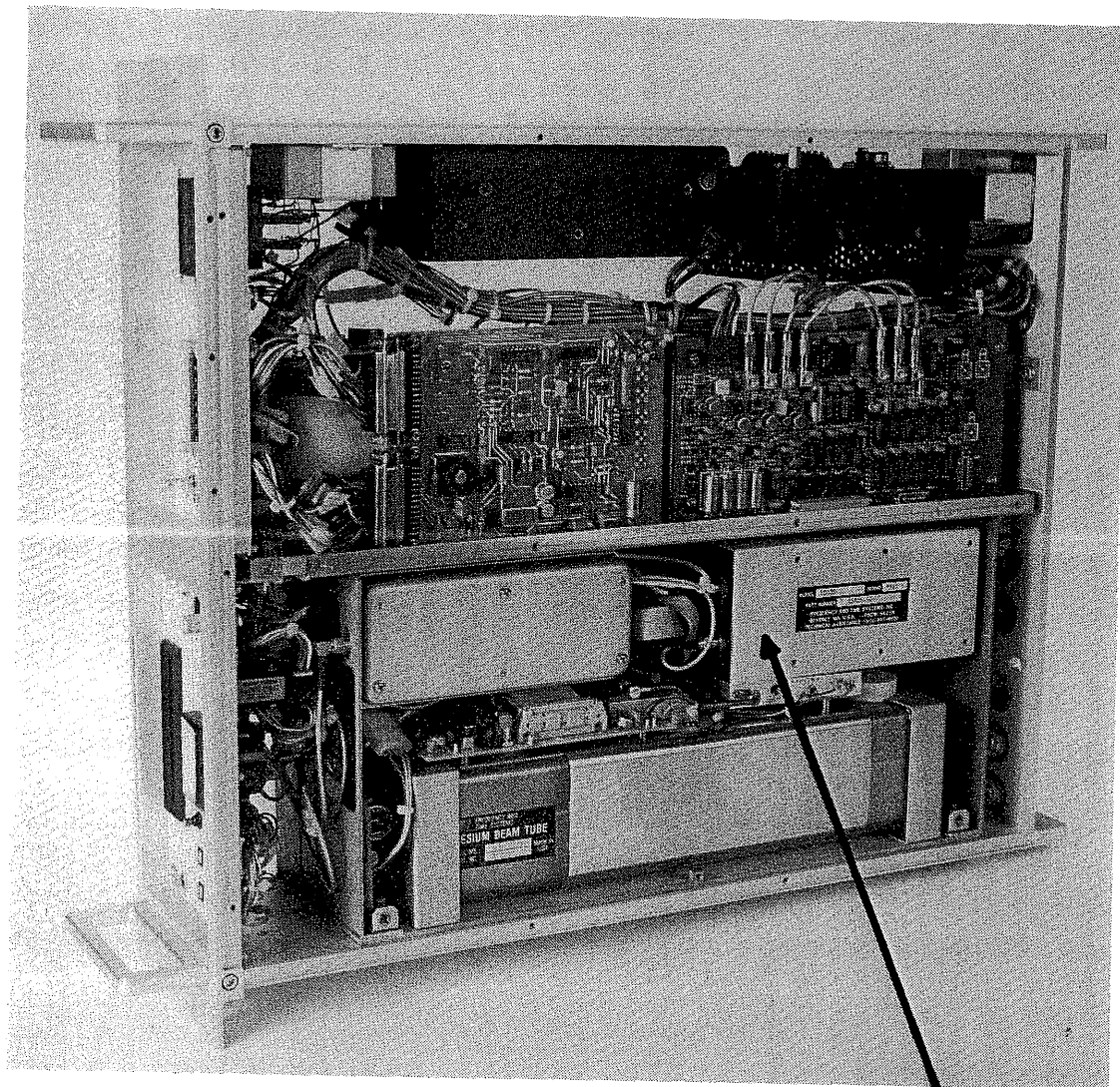
Figure A-1 FTS 4060, Left Side



**5030 Processor Board**

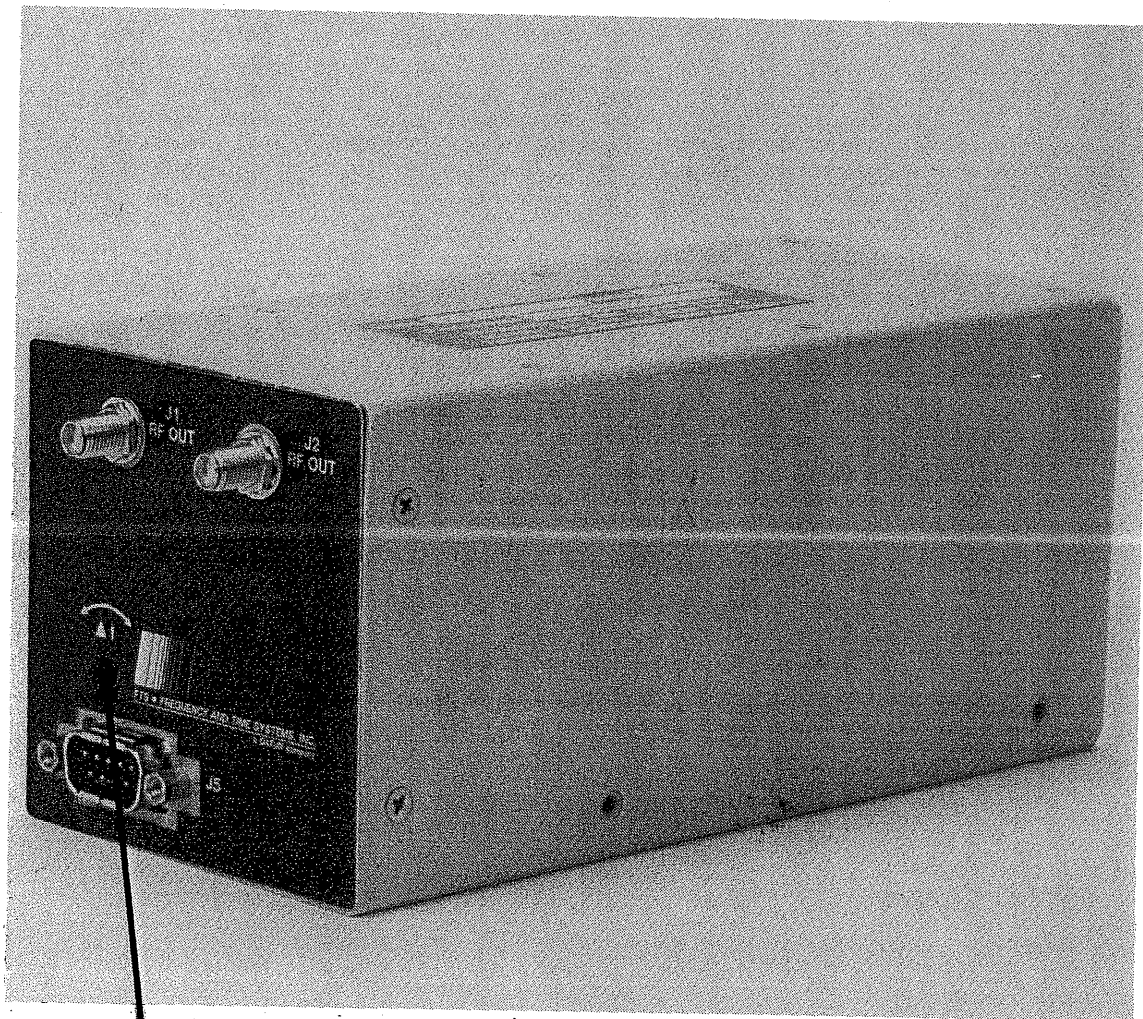
**FTS 5030 Cesium  
Beam Frequency Standard Module**

**Figure A-2 FTS 4060 TOP, CHASSIS VIEW**



5030 Quartz Oscillator

Figure A-3 FTS 4060 BOTTOM, CHASSIS VIEW

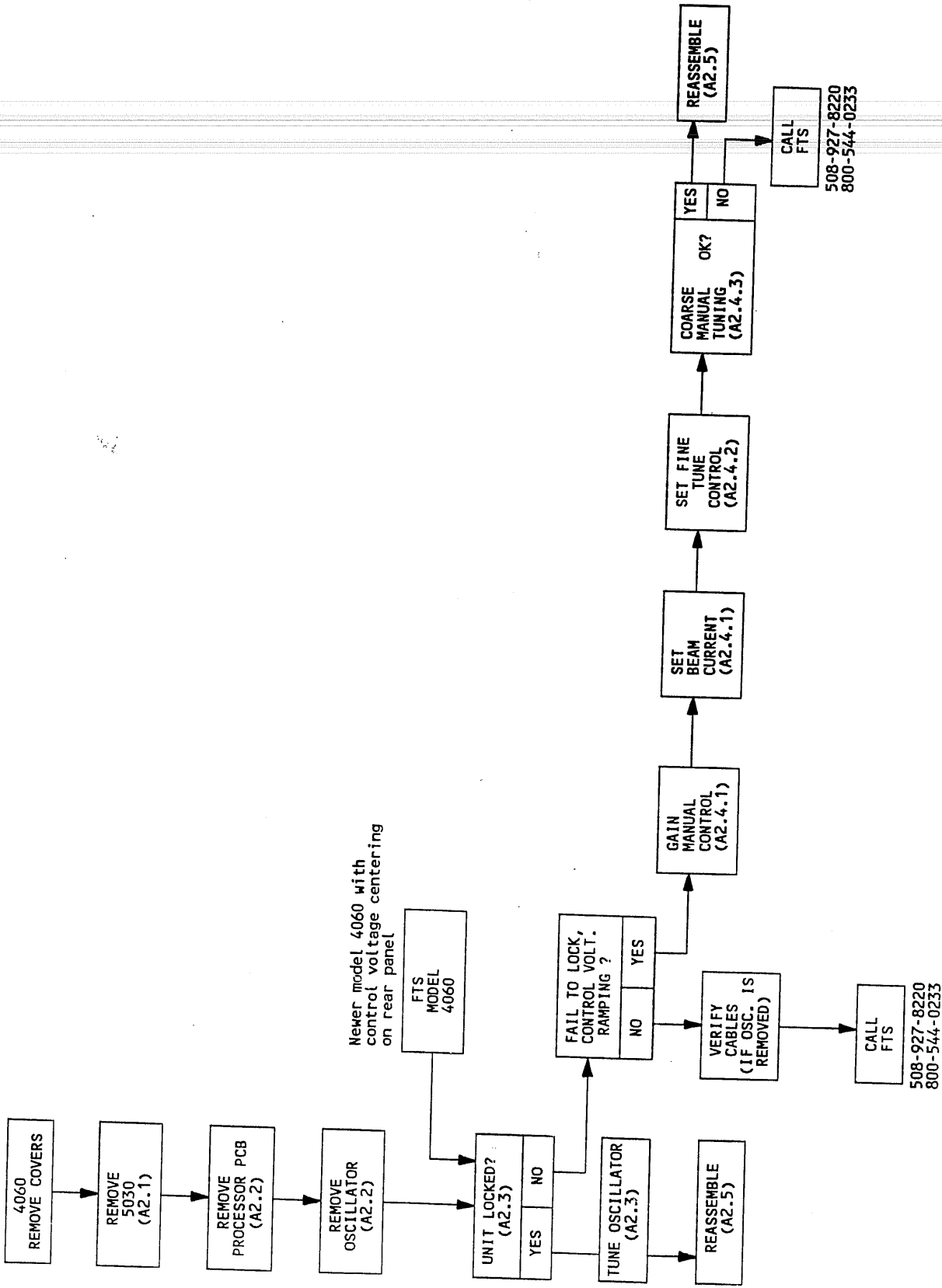


**Oscillator Coarse  
Frequency Control  
Potentiometer for older 4060 units.  
For newer 4060 units, the Oscillator  
Coarse Manual Tuning Control can be  
found on the 4060 rear panel marked  
"Osc Coarse Adj".**

**Figure A-4 Oscillator Tuning Potentiometer**

Older Model 4060 with control voltage centering within oscillator.

Newer model 4060 with control voltage centering on rear panel



(A\*\*.) Are References To Appendix A Paragraphs

Figure A-5 Control Voltage Centering Adjustment Flowchart