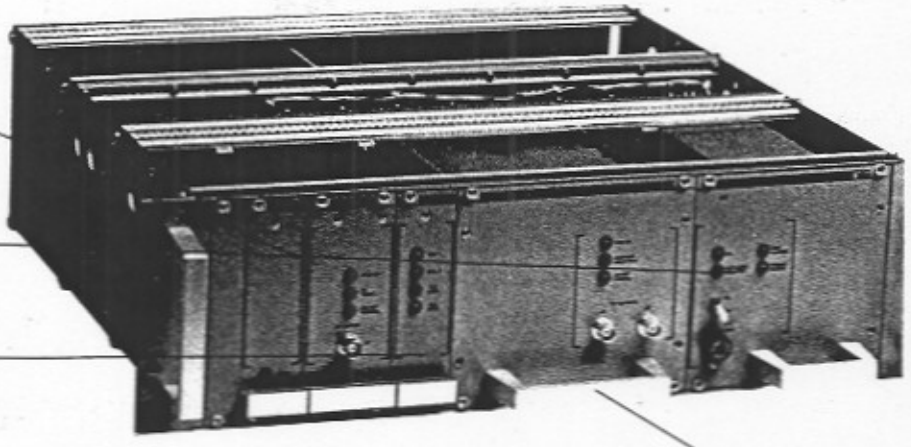
Efratom's Modular Frequency & Time Systems

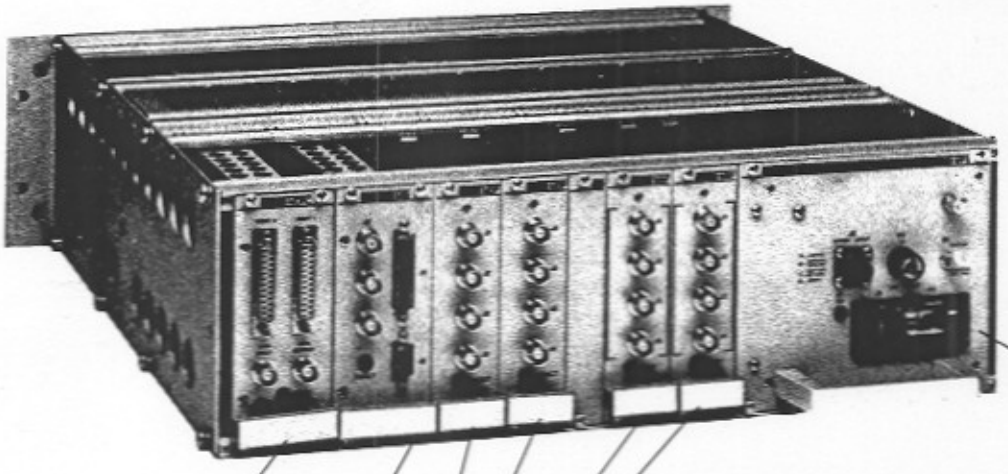


QUARTZ CRYSTAL OSCILLATOR (MXO)

BATTERY (MBU)

RUBIDIUM TO CRYSTAL OSCILLATOR FREQ. SYNCHRONIZER (MDC-RX)

RUBIDIUM OSCILLATOR (MRK)

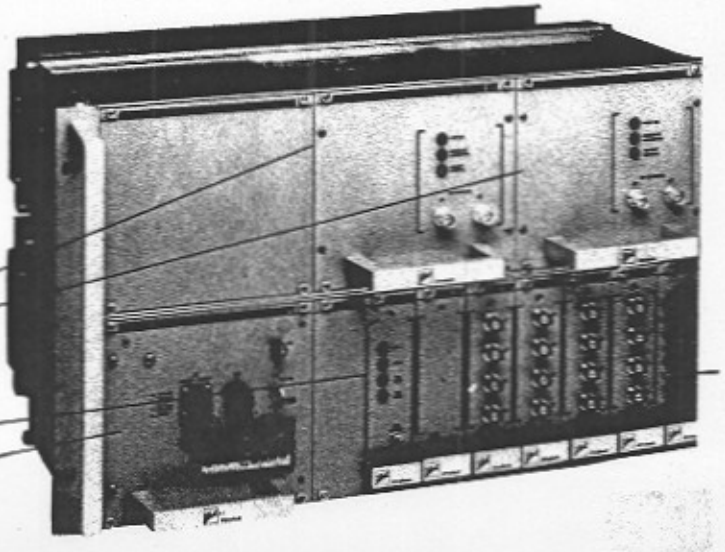


POWER SUPPLY (MPS)

DISCIPLINED Rb CONTROLLER FOR GPS (MDRC)

SYNTHESIZER AND INTERFACE (MSI) USED WITH TANS GPS RECEIVER

FREQUENCY DISTRIBUTION (MBF, MDP) 0.001, 0.01, 0.1, 1.0, 5.0, 10.0 MHz, 1-PPS



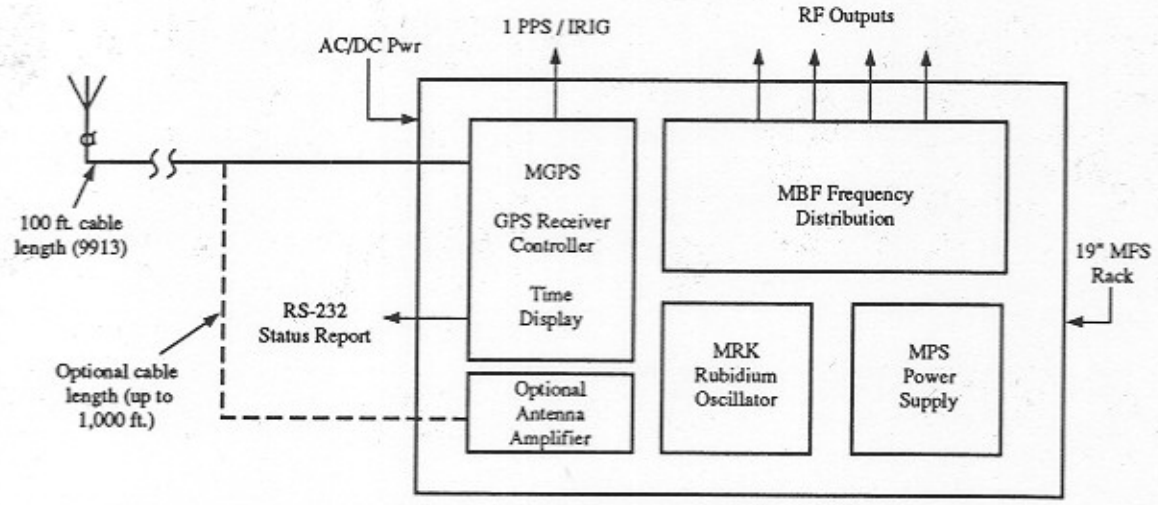
RUBIDIUM OSCILLATOR (MRK)

RUBIDIUM TO RUBIDIUM FREQ. SYNCHRONIZER (MDC-RR)

POWER SUPPLY (MPS)

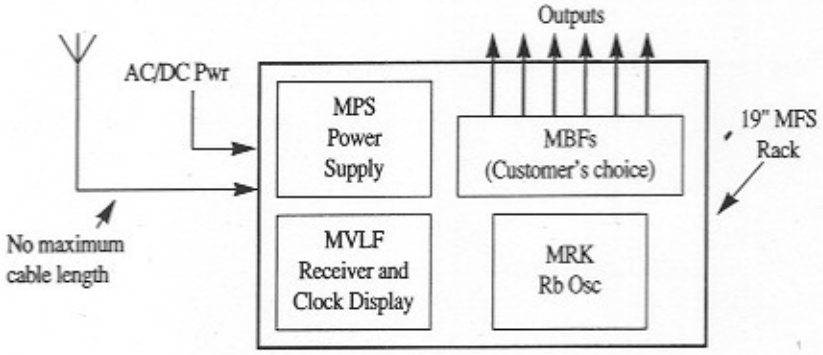
Example Modular Systems

Alternative to a Primary Standard- GPS-RR



1E-12 rms Frequency Accuracy, ±100 ns UTC Time Error, under SA

Alternative to a Primary Standard – MFS, VLF/LF option

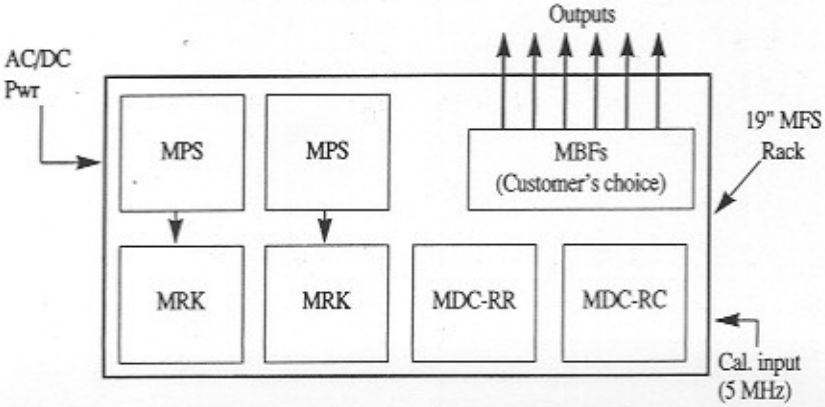


The MVLF uses nationally controlled/traceable low frequency transmitters (WWVB, MSF, DCF77, etc.) or the international Omega system to steer a Rb oscillator, providing an alternative to the GPS based system. (See MVLF module for details.)

1E-11 Frequency Accuracy, <1 µs UTC* Time Error with OMEGA

*UTC must first be set in MVLF

Redundant Frequency Generator, Calibrated by External Standard



This MFS System phase locks the secondary MRK to the Master MRK. At failure detection of Master, secondary MRK is switched into MFS by the MDC-RR. The MDC-RC allows the Master MRK to be calibrated to an external standard. (The second MRK is automatically calibrated because it is phase-locked.)

1E-11/Mo. Freq. Aging, Ext. Cal. Rb (MRK) to ±5E-12, (-) 155 dBc @ 100 Hz (MRK-LN option)

Modular Frequency and Time Systems (MFS)

The Modular Frequency and Time System (MFS) provides the time and frequency industry with an innovative way to use a host of standard modules to form a 19 inch rack system. The main theme is as follows:

- Generate precise frequency and time through use of Rubidium Atomic Oscillators, Crystal Oscillators, and VLF/LF/GPS Receiver signals.
- Buffer and distribute frequency and time with virtually unlimited number of outputs at various frequencies.
- Automatic calibration of Rubidium Oscillators through use of external standards or VLF/LF/GPS receiver modules.
- Redundant systems based on independent or phase-locked oscillators.
- Battery backup to protect against ac power failure.

MFS Concept

The Efratom MFS is conceived as follows: The customer defines system requirements and contacts Efratom. Efratom will assist the customer in providing a custom solution to specific requirements. The custom MFS is based on the standard modules described in this brochure. The modules plug into the front and rear of a standard 19" rack, 5¼" high and 17½" deep. This unique feature doubles the available panel space to 32 inches of modules within the 19 inch rack. Optional chassis slides are available to provide access to the rear modules.

The module size is based on the DIN Euroboard system. The width of each module is specified in increments (I) and space not used is covered by blank panels. Each increment is equal to 7/10". A panel of 7(I) would fit into a 1.40" wide space in the rack chassis. The total width of the Efratom chassis is 80(I) front and 80(I) rear for a total usable space of 160(I). An 84(I) wide rack (168 total) is also available, if chassis slides are not used.

All modules interface with the rack using Cannon connector G06M426 series body with 6 rf or HV plug inserts, except the MSS Module, which uses a 96 pin connector. The connector pins for pin functions are not listed here but are shown in the operating manual for each module. The Cannon G06M426 series connector features 42 pins. The RF connectors used on the dress panels are BNC jacks.

Module	Width	Weight	Basic Function
MRK	28(I)	5.7 lb.	Rubidium Oscillator
MXO	10(I)	1.5 lb.	Quartz Crystal Oscillator
MBF	7(I)	1.2 lb.	Frequency Distribution
MBFD	7(I)	1.2 lb.	Frequency Distribution
MBF-T	7(I)	1.2 lb.	Frequency Distribution
MBF-R	7(I)	1.2 lb.	Frequency Distribution
MSI	10(I)	1.5 lb.	Synthesizer & Interface
MDP	7(I)	1.5 lb.	1 PPS Generation
MDC-RC	7(I)	1.2 lb.	Rubidium Oscillator Calibrator
MGPS	49(I)+14(I)	4.4 lbs.	GPS Receiver Controller
MDRC	10(I)	1.5 lb.	Disciplined Rb Controller for GPS
MDC-RR	7(I)	1.5 lb.	Frequency Synchronizer RF switch
MDC-RX	7(I)	1.5 lb.	Frequency Synchronizer RF switch
MPC	7(I)+7(I)*	1.1 lb.	Phase Comparator
MPS	28(I)	9 lb.	Power Supply
MBU	24(I)	8 lb.	Battery
MVLF	42(I)+14(I)*	4.4 lb.	VLF/LF Frequency Receiver
MRTC	42(I)+7(I)*	4.4 lb.	Real Time Clock and IRIG Code Generator
MSS	10(I)	1.5 lb.	System Status

*Connector Panel

Example Modular Systems Block Diagrams

The MFS is designed, fabricated, and tested to standard commercial practices.

The environments for the MFS rack are as follows:

Operating Temperature:	-25°C to 50°C ambient (0 to 50°C for those modules noted)
Storage Temperature:	-40°C to 75°C ambient, (with MBU Battery Module installed: -40°C to 65°C)
Humidity:	95% Relative Humidity

The Standard Modules

Frequency Generators

- ***MRK - Rubidium Oscillator (Basic Model FRK family)***

  This module represents the basic ultra-stable frequency generator for the modular line of products at 5 or 10 MHz.

- ***MXO - Quartz Crystal Oscillator***

  The MXO is primarily intended as a temporary backup oscillator to an MRK.

Frequency Distributors

- ***MB* - Frequency Distribution***

  (MBF) 4 each 0.1, 1.0, 5.0, or 10 MHz outputs, individually adjustable for 0.5 to 1.5 Vrms.

  (MBFD) 5 outputs for internal distribution within the rack

  (MBF-T) 4 each TTL compatible 0.001, 0.01, 0.1, 1.0, or 5 MHz outputs

  (MBF-R) 4 each RS-422 compatible 0.001, 0.01, 0.1, 1.0, or 5 MHz outputs

- ***MSI - Synthesizer and Interface*** – Designed to serve as an interface between the MFS and the Trimble TANS receiver in a Rb/GPS disciplined system. The MSI accepts a 10 MHz reference frequency and generates octave multiples of 1.023 or 1.024 MHz, with a maximum multiplication factor of 16. Three outputs are available in either sine or TTL format.
- ***MDP - 1 PPS Generation*** – 1 output 1 PPS, 10 volts and 1 output RS-422 CMOS/TTL Compatible.

Frequency Calibrators

- ***MDC-RC - Rubidium Oscillator Calibrator*** – Automatically calibrates an MRK Rubidium Oscillator to a temporarily connected external high-performance cesium oscillator. With the proper external reference, a calibration of 5E-12 can be achieved.
- ***MGPS- GPS Receiver Controller*** – Automatically calibrates a Rb Oscillator to the GPS L1 C/A coded signal. Features *built-in GPS receiver*: provides precision time (±100nsec) and frequency (1E-12 rms) via independent control loops. User friendly LCD display.
- ***MDRC - Disciplined Rb Controller for GPS*** – Calibrates an MRK Rubidium Oscillator via an *externally supplied GPS receiver* to GPS satellite signals.

Frequency Synchronizers/RF Switches

- ***MDC-RR and MDC-RX*** - Rb to Rb and Rb to Crystal – Synchronization and/or RF switching of two oscillators to form a redundant, uninterruptible frequency source/time-base in the event of an oscillator failure. In such a case, the MDC switches-in the backup oscillator to drive the MFS.

Frequency/Phase Comparison

- ***MPC - Phase Comparator*** – The MPC measures phase difference between a unit under test and the 5 MHz or 10 MHz reference signal generated by the internal MRK or MXO. The unit under test can have an output frequency of 1, 2, 3, 4, 5, 6, 7, 8, 9, or 10 MHz.

Power Supplies

- ***MPS - Power Supply*** – Using externally supplied ac or dc, the MPS supplies the required voltages to the MFS modules. The MPS is capable of supplying up to ~100W of dc power. This is sufficient power for 2 MRK, 2 MDC, and 5 MBF modules (example only).
- ***MBU - Battery*** – Supports the MFS modules in the event of a power failure (2.5 Ah).

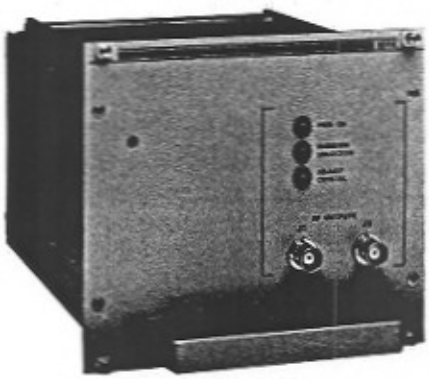
Frequency Receiver and Clock Display

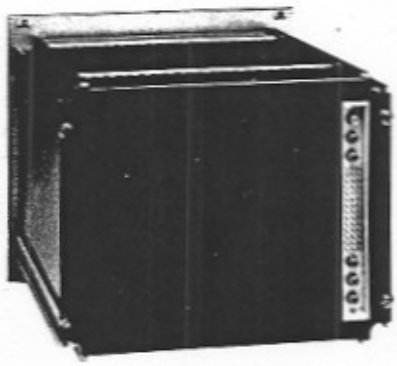
- ***MVLF - VLF/LF Frequency and Time Receiver*** – Contains a synchronization processor to discipline the MRK Rubidium Oscillator to an accuracy of 1E-11. This eliminates the long-term drift of the Rb oscillator. Time can be maintained to <1 µsec for VLF and <0.2 µsec for LF.
- ***MRTC - Real Time Clock and IRIG Code Generator*** – Although the MVLF includes the clock functions, the MRTC clock module/display is available without the VLF/LF receiver.

System Status

- ***MSS - System Status*** – Monitors status of individual modules within the rack.

Frequency Generators – MRK, Rubidium Oscillator

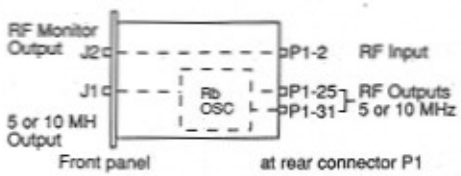




The Modular Rubidium Oscillator, Model MRK, is the primary frequency generating source of the Efratom MFS. It provides a 5 or 10 MHz sinusoidal output frequency of excellent short- and long-term stability over a wide range of environmental conditions. This superior stability is achieved by locking an internal crystal oscillator to the ground state hyperfine transition of ^{87}Rb. The module is designed to interface to all other MFS modules through the rear connector. The MRK contains the well proven, field tested Model FRK Rubidium Frequency Standard.

Model #	Output Characteristics
MRK-1AOC1	L, 10 MHz
MRK-2AOC1	H, 10 MHz Low Aging
MRK-3AOC2	LLN, 5 MHz Low Noise
MRK-4AOC2	HLN, 5 MHz Low Noise, Low Aging
MRK-3AOC1	LLN, 10 MHz Low Noise
MRK-4AOC1	HLN, 10 MHz Low Noise, Low Aging

RF Signal Diagram



The "Monitor" output is brought through the module from another rf source which is injected at P1-2. This rf signal may originate from an MBF module.

The MRK has 2 rf outputs at the rear connector and one rf output at the front dress panel which are 5 or 10 MHz depending upon model selected.

Electrical Specifications

RF Output 5 or 10 MHz sinewave
0.5 ± 0.1 Vrms into 50 ohms
Frequency set to within ± 5E -11 at shipment

Aging	L	4E-11/month
	H	1E-11/month
Short-Term Stability	L	3E-11 (τ^{-1}) for 1 sec < τ < 100 sec
	H	1E-11 (τ^{-1}) for 1 sec < τ < 100 sec
Temperature Coefficient	L	3E-10 over MFS temp range
	H	1E-10 over MFS temp range

Phase Noise, SSB (1 Hz BW), See Figure 1			
	Output	**Hz from carrier**	**-dBc / √Hz**
L	10 MHz	100	120
H		1000	145
LLN	5 MHz	100	155
HLN		1000	155
LLN	10 MHz	100	147
HLN		1000	147

Warm-Up 10 minutes to reach 2E-10 at 25°C ambient

Harmonic / Non-Harmonic -40 dBc down / -80 dBc down

Trim Range 2E-9

Retrace 2E-11 (after 1 hr pwr on @ 25°C and up to 48 hrs pwr off)

Magnetic Field 4E-13 / Am^{-1}, or 3E-11 / 0.1 militesla

Altitude 1E-13 / mbar from sea level to 40,000 ft.

Power Input Electronics 20.5 Vdc, 9 W
Heater 18.5 Vdc minimum, 30 W warm-up
5 W at 25°C
10 W at -25°C

LED Indicators on Front Panel

Pwr On	(Grn)	Normally ON
Rubidium Unlocked	(Red)	Normally OFF ON if Rubidium out of lock
Adjust Crystal	(Yel)	Normally OFF ON when calibration required

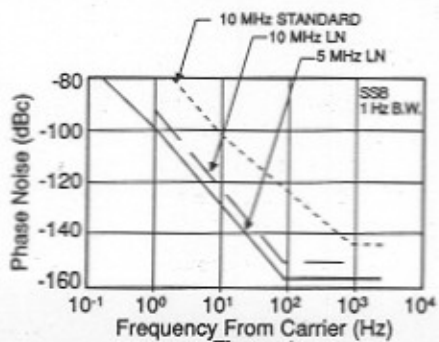
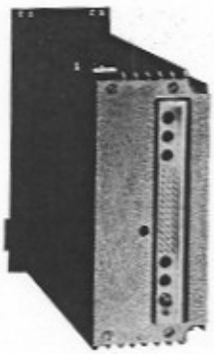


Figure 1

Frequency Generators, – MXO, Quartz Crystal Oscillator



The Modular Crystal Oscillator, Model MXO, is a highly stable 10 MHz Voltage Controlled Crystal Oscillator, and is based on a high quality, 3rd overtone, AT-cut quartz oscillator. To improve its stability over temperature, the crystal and the oscillator are thermostatically controlled. Its good performance and low cost make the MXO ideally suitable as a backup oscillator in a redundant MFS. As with any crystal oscillator, its aging characteristics will greatly improve if operated continuously.

Model Number	Description
MXO 0A0C1	10 MHz Sinewave

RF Signal Diagram

Electrical Specifications

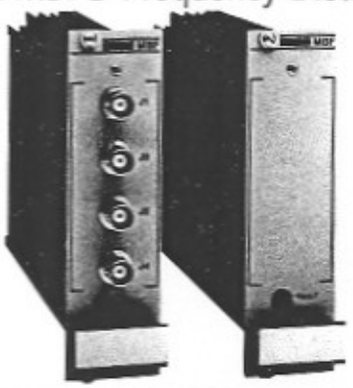
RF Output	10 MHz sinewave 0.5 ± 0.1 Vrms into 50 ohms One output at front dress panel One output at rear connector
Warm-Up	60 minutes to 2E-8 (as compared to frequency after 24 hrs) 15 minutes to 5E-7
Aging	1E-6/year
Short-Term Stability	1E-11 (1.0 second Allan Var.)½
Phase Noise (-dBc / √Hz) SSB (1 Hz BW)	-120 dBc at 100 Hz from carrier -135 dBc at 1 kHz from carrier
Harmonic/ Non-Harmonic	-30 dBc down / -100 dBc down
Trim Range	2E-6 typical
Load Dependence	± 2E-10 for 10% load change
Temp Coefficient	3E-8, -25° C to 50° C
Power Input	20.5 Vdc, 13 W warm-up 5 W at 25° C, 9W at -25° C

LED Indicators on Front Panel

PWR On	(Grn)	Normally ON
Rubidium Unlocked	(Red)	Normally OFF ON if Rubidium out of lock
Adjust Crystal	(Yel)	Normally OFF ON when calibration required

Frequency Distributors

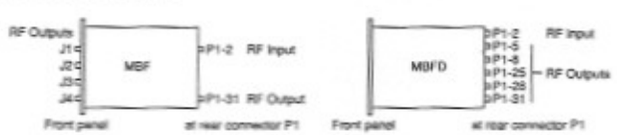
MBF and MBFD Frequency Distribution



The Modular Frequency Distribution unit, Model MBF, provides (4) outputs of 0.1, 1.0, 5.0, or 10 MHz derived from the primary RF Oscillator (MRK or MXO) within the MFS chassis. The MBFD has (5) outputs used to distribute rf within the 19" rack (consult factory for MBFD usage). Both the MBF and MBFD contain fault monitor circuits which will alert the user if one or more of its outputs fail or if the input signal drops below minimum drive levels.

MBF Model	Input/Output	MBFD Model
MBF-OA1C1 MBF-8A1C1	10 MHz / 10 MHz	MBFD-OA1C1
MBF-OA1C2 ----------	10 MHz / 5 MHz	----------
MBF-OA1C3 ----------	10 MHz / 1 MHz	----------
MBF-OA1C4 ----------	10 MHz / 0.1 MHz	----------
MBF-OA2C1 ----------	5 MHz / 10 MHz	----------
MBF-OA2C2 MBF-8A2C1	5 MHz / 5 MHz	MBFD-OA2C1
MBF-OA2C3 ----------	5 MHz / 1 MHz	----------
MBF-OA2C4 ----------	15 MHz / 0.1 MHz	----------

RF Signal Diagram



Electrical Specifications

RF Input 5 or 10 MHz
- MBF-0XXXX 0.4 to 0.6 Vrms, 50 ohm input impedance
- MBF-8XXXX 0.4 to 0.6 Vrms, > 1k ohm input impedance
- MBFD-0XXXX 0.15 to 0.6 Vrms, 50 ohm input impedance

RF Output (4) each 0.1, 1.0, 5.0, or 10.0 MHz
- MBF 1 Vrms into 50 ohms, each adjustable from 0.5 to 1.5 Vrms
- MBFD 0.5 ± 0.1 Vrms into 50 ohms

Isolation -55 dBc between outputs, -90 dBc between modules -80 dBc between outputs – available

Harmonic -34 dBc

Phase Noise

MBF/MBFD	(-dBc / √Hz) at 100 Hz	(-dBc / √Hz) at 1000 Hz
MBX -XA1C1	-147 (LN MRK) -120 (STD MRK)	-147 (LN MRK) -145 (STD MRK)
MBX -XA2C1	+9 dBc above input	+9 dBc above input
MBX-XA2C2	-155	-155

When an MDC-RX or MDC-RR is used in the system, contact the factory for potential effects on the phase noise floor.

Short Circuit Proof Outputs

Power Input 20.5 Vdc, 3 W

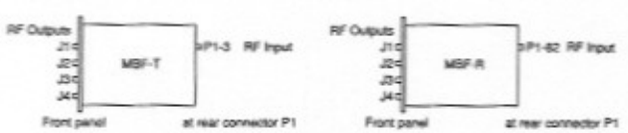
LED Indicators on Dress Panel Rf Fault (R)

MBF-T and MBF-R Frequency Distribution

The Modular Frequency Distribution units, Model MBF-T and Model MBF-R provide up to four (4) TTL (MBF-T) or EIA RS-422 (MBF-R) compatible outputs derived from a 10 MHz primary rf oscillator (MRK or MXO) within the MFS chassis. Standard output frequencies are 0.001, 0.01, 0.1, 1.0, or 5.0 MHz; however, combinations of these frequencies are available upon request. Each buffer module contains fault indicator circuitry which will alert the user if one or more of its outputs fail or if the input signal drops below minimum drive levels.

MBF-T Model	RF Input/Output	MBF-R Model
MBF-T-OA1C2	10 MHz in / 5 MHz out	MBF-R-OA1C2
MBF-T-OA1C3	10 MHz in / 1 MHz out	MBF-R-OA1C3
MBF-T-OA1C4	10 MHz in / .1 MHz out	MBF-R-OA1C4
MBF-T-OA1C5	10 MHz in / .01 MHz out	MBF-R-OA1C5
MBF-T-OA1C6	10 MHz in / .001 MHz out	MBF-R-OA1C6

RF Signal Diagram



Electrical Specifications

RF Input 10 MHz
0.4 to 0.6 Vrms; 50 ohm input impedance

RF Output (4) each 0.001, 0.01, 0.1, 1.0, or 5.0 MHz

MBT TTL compatible into 50 ohm load; 50% Duty Cycle; 20 nsec Max Rise Time and Fall Time.

MBR RS-422 compatible into 100 ohm load; 50% Duty Cycle; 20 nsec Max Rise Time and Fall Time.

Short Circuit Proof Outputs

Power Input 20.5 Vdc, 5.0 W

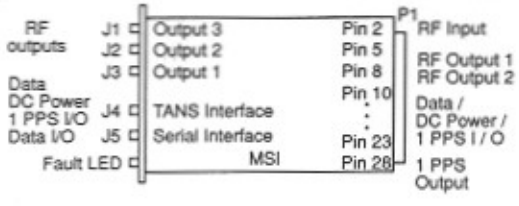
LED Indicators on Dress Panel Rf Fault (R)

Frequency Distributors – MSI, Synthesizer and Interface

The Modular Synthesizer and Interface, Model MSI, accepts a 10 MHz frequency reference and generates octave multiples of 1.023 MHz or 1.024 MHz, with a maximum multiplication factor of 16. Three outputs are available in sine or TTL format. The MSI module is designed primarily to serve as an interface between the MFS and the Trimble TANS GPS receiver as part of Efratom's GPS option to the MFS. In addition to providing the necessary RS-232 and 1 PPS interfaces, the module generates the rf (16.368 MHz) and dc inputs that are required by the TANS receiver. The MSI will output the time of day (ASCII format) information from the MDRC via the RS-422 interface port (J5). The excellent performance of the module, however, makes it suitable for use in other applications as a general-purpose frequency synthesizer. A LED indicator on the dress panel indicates module fault.

MSI Model	Input	Output 1	Output 2	Output 3
MSI-101	10 MHz	16.368 MHz	1.023 MHz TTL	2.046 MHz TTL
MSI-102	10 MHz	16.368 MHz	1.024 MHz TTL	2.048 MHz TTL
MSI-103	10 MHz	10.23 MHz TTL	10.23 MHz TTL	10.23 MHZ TTL

Signal Diagram



Electrical Specifications

RF Input 10 MHz, 0.5 ± 0.1 Vrms into 50 ohms

1 PPS Input
Signal Level: Differential 1 PPS, RS-422 spec compatible
Polarity: Negative
Pulse Width: 10 nsec minimum

RF Outputs* 1.023 MHz x N or 1.024 MHz x N (N=1, 2, 4, 8, 16)

Signal Level
Sine Wave: 1 Vrms into 50 ohms, minimum
TTL: TTL compatible into 50 ohms

Phase Noise dBc/√Hz, SSB (1HzBW): -70 dBc at 1 Hz; -110 dBc at 100 Hz; -130 dBc at 1000 Hz

Harmonic Distortion -40 dBc (sine wave only)

Non-Harmonic Distortion -70 dBc

1 PPS Outputs*
Signal Level TTL compatible into 50 ohms

Polarity Positive

Pulse Width Programmable, 1 µsec to 126 µsec, 0.5 µsec steps

Switching Characteristics (typical)
Rise Time < 25 nsec
Fall Time < 100 nsec

Input Power (dc output unloaded)
20.5 Vdc, 8 W at +25°C steady-state

RS-232 Interface (on board)
Inputs/Outputs: RS-232 compatible

RS-422 Interface (on board)
Inputs/Outputs: RS-422 compatible

LED Indicator on Front Panel
Module Fault: (Red) Normally OFF

Mechanical Specifications
Width: 10 units
Connectors: J1, J2, J3 BNC
Connector J4: DB-25S
Connector J5: DB-9S
Connector P1: Cannon G06M426P4BEBL

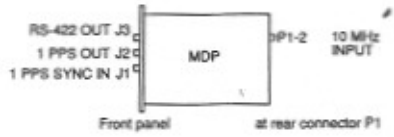
*Short circuit protected

Frequency Distributors
MDP, 1 PPS Generation

The Modular Digital Pulse, Model MDP provides multiple 1 PPS outputs (1 PPS at J2 and RS-422 at J3). When used in conjunction with an external 1 PPS signal, the MDP automatically synchronizes its 1 PPS outputs to within ±100 nanoseconds of the external signal. Synchronization is indicated by the "SYNC" LED which blinks until the external signal is removed. The internal 1 PPS is derived from the MFS primary oscillator.

Model Number	1 PPS Characteristics J2
MDP-OA1CO	Amplitude: 10 Volts ±10% peak into 50 ohms

Signal Diagram



Electrical Specifications

Inputs *
10 MHz sinewave
0.5±0.1 Vrms (REF input from MRK or MBF)
1 PPS SYNC (input J1)
3.5 to 11 Volts peak
Width ≥ 2.0 µsec
Rise Time ≤ 20 nsec

Outputs

(1 PPS	J2, J3)
Width	20 ± 2 µsec
Rise Time	≤ 20 nsec
Fall Time	≤ 100 nsec
Jitter	≤ 10 nsec

RS-422 balanced driver output (J3)
EIA RS-422 compatible

Power Input 20.5 Vdc, 3 W

LED Indicators on Front Panel

SYNC (green) Synchronization

Connectors on Front Panel

J1 & J2 BNC Jack
J3 M24308 / 3-1 or equiv.

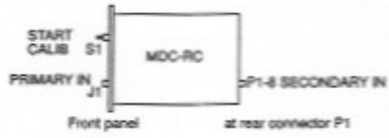
* 50 ohm input impedance

Frequency Calibrators
MDC-RC, Rubidium Osc. Calibrator

The Modular Rubidium Oscillator Calibrator, Model MDC-RC, calibrates the MRK Rubidium Oscillator via a temporarily connected 5 MHz Cesium Frequency Standard. The Primary Standard is connected to the MDC-RC connector (J1), The "START CALIB" button is pressed, and the Secondary Standard (the MRK) is syntonized to ±5E -12 of the Primary Cesium reference. When calibration is complete, (approximately 90 minutes) the C-field control voltage signal is held in memory until the next calibration cycle. The external reference Standard must be equal to or better in noise characteristics than the MRK; Option 004 Cesium Standard is recommended.

Model Number	Primary Input / Secondary Input
MDC-RC-A1CO	5 MHz Cs / 10 MHz Rb
MDC-RC-A2CO	5 MHz Cs / 5 MHz Rb

Signal Diagram



Electrical Specifications

Primary RF Input (J1 Front Panel Input)
Cesium Standard 5 MHz sinewave
0.4 to 1.0 Vrms, 50 ohm input impedance

Secondary RF Input (Internal MFS connection to MRK)
Rubidium Standard 5 or 10 MHz sinewave
0.5 ± 0.1 Vrms, 50 ohm input impedance

Calibration (MRK)

Calibration Accuracy	± 5E -12
Calibration Time	Approximately 90 minutes
Trim Range	2E -9
Resolution	Approximately 5E -13 (LSB)

Power Input 20.5 Vdc, 3 W

LED Indicators on Front Panel

Cal In Progress	(Grn)	ON during calibration
Cal Fault	(Red)	ON during warm-up until MRK locks; also if external std is outside the track-and-hold range
Pri Std	(Grn)	ON when external std is connected
Sec Std	(Grn)	ON when secondary std is connected

Frequency Calibrators – MDRC, Disciplined Rb Controller for GPS

- Frequency Accuracy: ≤ 1E-11 under SA
- Timing Accuracy: 500 nsec under SA
- Cesium Performance
- Directly Traceable to NIST
- Used With An External GPS Receiver(1)

(1) Note: Model MDRC differs from Model MGPS in that the MDRC is a controller only and must use an external RCVR. Model MGPS is a RCVR/Controller combination.

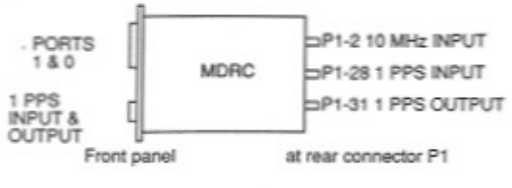
The Modular Disciplined Rb Controller for GPS, Model MDRC, has standard firmware to interface with a Trimble GPS Receiver (TANS) or to operate with the corrected 1 pps signal from any GPS receiver. When the Trimble TANS receiver is used, the synthesizer Model MSI must be used as an interface between the MFS rack and the TANS GPS receiver.

For a basic description of the GPS signal, refer to the MGPS on the preceding page. The main difference between the MDRC and the MGPS is that the former uses a receiver outside the 19" chassis and has no built-in display. *The receiver is located within 50 ft. of the antenna and up to 1000 ft. of cable connect the receiver and the modular system.* The monitoring of the system performance will typically be done through the RS-232 interface and a customer-supplied personal computer or VT100 terminal.

When the MDRC is installed with a power supply (MPS), a Rubidium Oscillator (MRK), and a GPS receiver, the user is provided with very precise time and frequency traceable to UTC (USNO / NIST).

The MDRC provides a standard 1 pps output (BNC connector) and two RS-232 ports (25 pin, D-sub) all on the front panel. Port 0 is used to interface with the receiver and Port 1 may be used to report MDRC / MRK / Receiver status via any DEC VT-100 compatible display terminal. Time of day information, day of week: hrs: min: sec, is available over the RS-232 port 1 in an ASCII format.

Signal Diagram



Electrical Specifications

1 PPS Output	CMOS/TTL Compatible Positive edge synchronous into 50 Ω Width (16 ± 1) µs Rise Time < 25 nsec Fall Time < 100 nsec Jitter < 2 nsec rms
1 PPS Input	CMOS/TTL Compatible 2-10 Volts peak, 50Ω Positive edge sensitive Dynamic range 4µsec/sec max drift rate
10 MHz Input	10 MHz, 0.5±0.1 Vrms to 2.0 Vrms
Analog Output (C-Field Control)	0 to 5 volts (12-bit DAC)
Data Input/Output	Two RS-232 ports, 9600 baud for Port 1, 1200 baud for Port 0
Status Outputs	8 CMOS outputs for MDRC status Sync LED on front panel
Power	20.5 Vdc, 4.5 W
Connectors (front panel)	1 PPS signals - BNC (amphenol 31-2221) RS-232 signals - D-sub, 25-pin

Time & Frequency Performance*

	4 hours	4 days
Frequency accuracy	≤ 1E-11	≤ 5E-12
1PPS accuracy	≤ 500 nsec	≤ 500 nsec

Options

MDRC-A1C3-XXX	Cannon Connector
MDRC-A1D3-XXX	DIN Connector
Trimble TANS Receiver Firmware	-011
1PPS Mode Firmware	-010

*Includes SA as described in the Technical Characteristics of the NAVSTAR GPS document published in June 1991 by the NAVSTAR GPS Technical Support Group. Assumes 24h continuous operation in a fixed stationary position with temperature changes of less than <±2°C/day. Subject to sufficient satellite availability.

Frequency Synchronizers / RF Switches

MDC-RR, Rubidium to Rubidium

The Modular Rubidium to Rubidium sync/RF Switch, Model MDC-RR, functions as an RF switch or as a Phase Lock Loop (PLL), capable of locking two MRK frequency sources. In the RF switch mode, the MFS becomes a redundant system based on two fully independent frequency sources. In this mode however, up to .2 microsec time error can occur at the time of the switch-over. In the PLL mode the error is reduced to less than 10 nanosec; however, the STD 2 MRK is not fully independent of the STD 1 MRK.

The tradeoff between the two basic configurations depends on the system specification. Efratom is pleased to assist potential customers in their system evaluations.

In either case, the MDC-RR will, during initial turn-on, select the first locking MRK as the primary standard (driving the system). A front panel pushbutton allows the operator to select either MRK as the primary standard (STD 1 or STD 2). The system will always select the alternate standard if the standard selected has an anomaly indicated by the oscillator's BITE signal.

Model Number	Description
MDC-RR-A1C1	10 MHz Rb / 10 MHz Rb
MDC-RR-A2C2	5 MHz Rb / 5 MHz Rb

Signal Diagram

Electrical Specifications

RF Input 5 or 10 MHz sinewave
0.5 ± 0.1 Vrms, 50 ohms input impedance
STD 1 and STD 2 must be same frequency, isolation > 80 dBc

RF Input 5 or 10 MHz (same as input frequency)
-8.5 dBc nominal loss

Short-Term Stability and Phase Noise
Determined by the primary oscillator driving the MDC, except the MRK Low Noise Option, 140 dBc @ 100 Hz,150 dBc @ 1 kHz from the carrier

Phase Error at Switchover

PRIME to BACKUP < 10 nanoseconds, PLL mode
BACKUP to PRIME < .2 microsecond

Syntonization Error < 5E-12

Power 20.5 Vdc, 2W

LED Indicators on Front Panel

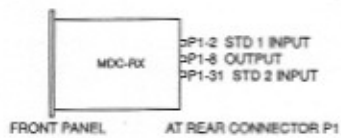
Std 1 (Grn) PLL Lock (Grn)
Std2 (Grn) Dac Lock (Grn)

MDC-RX, Rubidium to Crystal

The Modular Rubidium to Quartz osc. sync/RF Switch, Model MDC-RX functions as an RF switch or as a Phase Lock Loop (PLL) synchronizer of a Rubidium Frequency Standard (MRK) and an MXO Crystal Oscillator for a redundant system. Since the MRK is an atomic oscillator, the system will always use the MRK as the primary and the MXO as the backup. The MXO is syntonized to the MRK via the MXO xtal control voltage. Phase lock of the two oscillators occurs within 2 minutes after atomic lock is achieved on the MRK (typically 6-8 min after turn-on). When an MRK fails, the MDC-RX automatically switches to the MXO with a time error of < 10 nanoseconds. The system will not continue in an MRK spec manner, but will assume the MXO spec. The MXO provides an excellent lower cost backup oscillator to support the system until the MRK can be replaced. A failed unit can be removed without affecting the system operation. When the repaired MRK is reinserted, the MDC-RX will automatically switch from the backup MXO mode to the newly calibrated MRK.

Model Number	Primary Input / Secondary Input
MDC-RX-A1C1	10 MHz rb / 10 MHz XTAL

Signal Diagram



Electrical Specifications

RF Input 10 MHz sinewave
0.5 ± 0.1 Vrms, 50 ohms input impedance
STD 1 and STD 2 must be same frequency, isolation > 80 dBc

RF Input 10 MHz (same as input frequency)
-8.5 dBc nominal loss

Short-Term Stability and Phase Noise
Determined by the primary oscillator driving the MDC, except the MRK Low Noise Option, > 140 dB @ 100 Hz, >150 dB @ 1 kHz from the carrier

Phase Error at Switchover

PRIME to BACKUP < 10 nanoseconds

Syntonization Error < 5E-10

Power 20.5 Vdc, 2 W

LED Indicators on Front Panel

Std 1 (Grn) PLL Lock (Grn)
Std2 (Grn) Dac Lock (Grn)

Frequency / Phase Comparison – MPC, Phase Comparator

MPC
MODULE

MPC
SEPARATE
CONNECTOR
PANEL

The Modular Phase Comparator, Model MPC, accepts as a reference signal a 5 or 10 MHz signal generated by the MRK or MXO. The input to the MPC comes from the unit under test (UUT) which can be 1, 2, 3, 4, 5, 6, 7, 8, 9, or 10 MHz. The resultant phase comparison of the reference and the UUT is displayed on the MPC front panel meter. The phase comparison can also be displayed on an external recorder through a 0 to 10 Vdc output. Both the UUT input connector and the recorder output connector are located on a separate connector panel, usually located next to the MPC module.

Model Number	Description
MPC-OA1CO	10 MHz Reference
MPC-OA2CO	5 MHz Reference

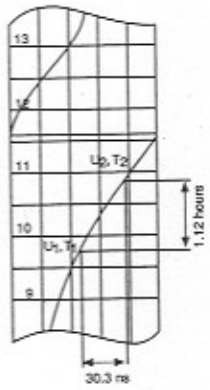
Electrical Specifications

Outputs

Front Panel Meter	0-10 Incremented scale with zero phase error, the pointer is at 5 (mid-scale) Meter accuracy ± 5% at full scale deflection
Deflection Yields	-100 to +100 nsec (5 MHz REF) -50 to +50 nsec (10 MHz REF)
Connector Panel Recorder Output	0 to 10 Vdc Full-scale
Alarm Output	TTL / CMOS compatible
Inputs	
REF Input	5 MHz; 10 MHz 0.5 ± 0.1 Vrms 50 ohm Input Impedance
UUT Input	1, 2, 3, 4, 5, 6, 7, 8, 9, or 10 MHz 0.4 to 1.5 Vrms 50 ohm Input Impedance
PWR Input	20.5 Vdc Regulated to ± 5%, 1.5 W

Application Note:

The measurement of extremely small frequency differences encountered when using high precision quartz and atomic oscillators is most commonly done by comparing the phase between two sources. The frequency difference may then be calculated as the first derivate of phase-over time. In practice this is done by watching the phase meter for some period of time and determining the associated phase change or by determining the time interval for a particular phase change using a stop watch. A more convenient way, particularly if very small frequency differences are to be expected, is to record the phase on a strip chart recorder. The figure shows a typical record and gives an example of how to interpret it.



U	Recorder Voltage
φ_{REF}	Reference Phase
φ_{UUT}	Unit Under Test Phase
f_{REF}	Reference Frequency
y	Normalized Frequency Departure of UUT
T	Measurement Time Interval

$\varphi = \varphi_{UUT} - \varphi_{REF}$

$U = 10\ V \cdot \varphi / (2 \cdot \pi \cdot f_{REF}) + 5\ V$

$Y = (\varphi_2 - \varphi_1) / (T_2 - T_1) / (2 \cdot \pi \cdot f_{REF})$

$Y = (U_2 - U_1) / (10\ V \cdot f_{REF}) / (T_2 - T_1)$

Example

$U_1 = 4.67\ V$

$U_2 = 7.70\ V$

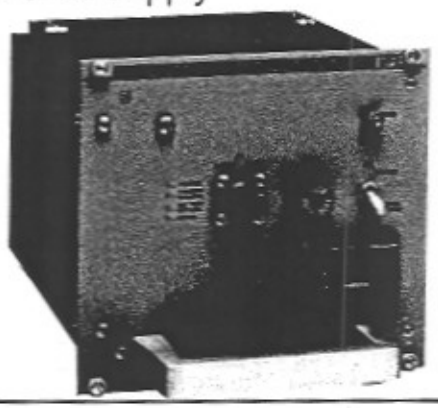
$T_2 - T_1 = 1.12\ h = 4032\ sec$

$y = (7.70\ V - 4.67\ V) / (10\ V \cdot 10\ MHz) / 4032\ sec$

$y = 30.3\ nsec / 4032\ sec = 7.5E\text{-}12$

Power Supplies

MPS, Power Supply



The Modular Power Supply, model MPS, is designed for use in the Efratom modular system. The unit will operate from an AC or DC input and supplies power to the other units within the rack assembly. "Priority switching" is employed in the MPS module. When AC, DC, and Modular Battery Unit model MBU inputs are present, the MPS selects AC as long as the AC input voltage requirements are met. The DC input will power the MPS when the AC fails to meet the requirements or is disconnected. The MBU input will be selected when both AC and DC inputs fail to meet the requirements.

The MPS provides filtering, rectification, and regulation of the input and supplies 20.5 Vdc regulated and 23-33 Vdc unregulated power for the MFS electronics. The MPS also supplies heater power to the Rubidium Oscillator (MRK) and low voltage AC power to the MBU module for battery charging.

The MPS can be used in conjunction with an MBU module, to provide full system performance during an AC power failure. A manual switch minimizes power drain during transport by powering down non-essential modules.

Model Number	Description
MPS-0A0C0	Standard Power Supply

Electrical Specifications

Power Input	100, 120, 220, 240 VAC Voltage selector and fused connector at J1 Line V +10% / -15%, 48-440 Hz, 200 W max. 22.5 to 32 Vdc, 6 A at J2 23 to 29 Vdc at P1-25, MBU input
Power Output	Supplied to MFS rack assembly at P1 Regulated 20.5 Vdc, 55 W, 3.5 m Vrms Ripple Unregulated 23-33 Vdc -12V @ 0.5 W, +5V @ 2.5 W Max total current for outputs is 5.0 A (6.0 at warm-up)
Heater Power (2 outputs)	Supplied to MRK 18.5 to 31 Vdc 40 W max for 10 minutes (warm-up), 20 W steady state 5 m Vrms max ripple when regulated mode (after warm-up)

Outputs are short circuit protected.
DC Input protected against reversed polarity.
AC and DC inputs are fused.

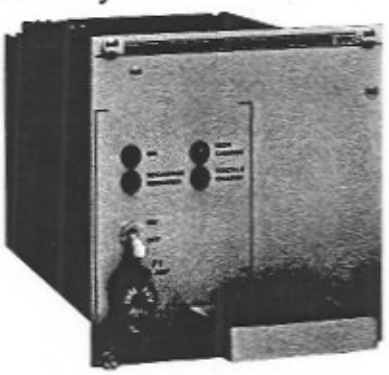
Power Connectors

DC input at J2	Cannon KPTO2E*-4P
AC Input at J1	IEC Connector (Cable supplied)

LED Indicators on Front Panel

AC On	(Red)	On with AC PWR on

MBU, Battery



The Modular Battery Unit, model MBU, is a standby power source designed to complement the MPS and provide uninterrupted DC power to modules in the MFS in the event of an AC power failure. The MBU provides a nominal 24 Vdc (2.5 Ah) via a rechargeable battery pack. The MPS provides low voltage AC power to the MBU as long as AC power is applied and switches the MBU's output on-line when an AC power failure occurs. For most system configurations an hour of backup power will be realized.

Model Number	Description
MBU-0A0C0	Standard Battery Module

Electrical Specifications

Power Input	35 Vac, 0.4 Amp, from Modular Power Supply (MPS)
Power Output	24 Vdc nominal, 45 Watt hours nominal
Battery Pack	The battery pack consists of twelve, 2 Vdc, 2.5 Ah batteries wired in series. GATES #0810-0004 (sealed lead acid)
Electrical Protection	Ac input and dc output fused.
Recharge Times	10 hours for 90% capacity 15 hours for 95% capacity

CAUTION

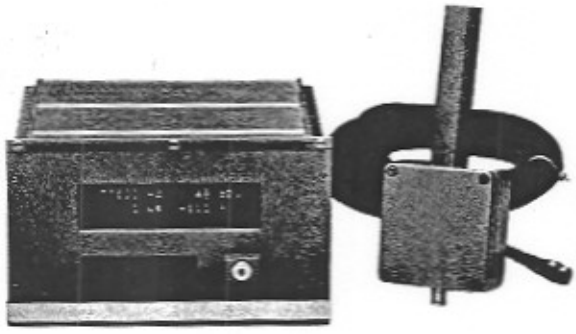
WHEN AN MBU IS INSTALLED IN THE MFS THE UPPER STORAGE TEMPERATURE IS 65°C INSTEAD OF THE USUAL 75°C.

Low Voltage Cut Off	When the batteries' voltage drops below the required voltage to operate the system, the MPS automatically turns off the MFS. This prevents the batteries from going into a "deep charge" condition.

LED Indicators on Front Panel

On	(Grn)	Indicates MBU is discharging
Recharge Required	(Red)	ON if MBU requires charging
High Charge	(Amber)	ON if MBU is receiving full charge
Trickle Charge	(Grn)	ON if MBU is receiving trickle charge

Frequency Receiver and Clock Display – MVLF, VLF/LF Frequency and Time Receiver



The Modular Frequency Receiver, Model MVLF, receives signals from the standard time and frequency transmitters in the VLF and LF bands. It phase-locks the MRK Rubidium Frequency Standard to the received signal. An appropriate time constant is selected to retain excellent short-term stability and phase noise characteristics, while simultaneously eliminating the aging experienced by a stand-alone Rb oscillator. An active E-field antenna (mounted separately) is supplied with the MVLF.

The MVLF includes a clock with display, providing the user with time-of-day (hour, minute, second), date (year, month, day), day-of-year and modified Julian Date information. It features 1 PPS phase shifting capability in decade steps of 100 nanoseconds to 1 sec. Leap seconds may be inserted automatically at the proper time as announced by the BIH (Bureau Internationale de l'Heure). The user may program the event at any time by specifying year, month, day, hour and minute. The clock is manually set to the nearest second of UTC via whatever means available (i.e., telephone). The MVLF determines the delay of the received amplitude modulated 1 PPS available from OMA, MSF, WWVB, HBG or DCF77. Due to limited bandwidth of the transmitting antenna and the atmospheric background noise, the accuracy is limited to approximately one millisecond. If, however, time can be transferred to the MVLF by any other more accurate means, it can be maintained to approximately 200 nsec by tracking the carrier phase of the received signal.

Model Number	Description
MVLF-0A1CO	11.8 - 77.5 kHz
MVLF-1A1CO	50.0 - 162 kHz

Electrical Specifications

Frequency Tuning Range

Omega-Hawaii	11800 Hz	MSF-Great Britain	60000 Hz
Omega-Liberia	12000 Hz	WWVB-USA	60000 Hz
Omega-Norway	12100 Hz	HBG-Switzerland	75000 Hz
Omega-Reunion	12300 Hz	DCF77-W. Germany	77500 Hz
Omega-Japan	12800 Hz		
Omega-Argentina	12900 Hz	**Optional Tuning Range**	
Omega-Australia	13000 Hz	Deutschlandfunk	153 kHz
Omega-N. Dakota	13100 Hz	France Inter. France	162 kHz
OMA-Czechoslovakia	50000 Hz		

Receiver Bandwidth (-3 dB) 200 Hz
(-60 dB) 1.5 kHz

Receiver Sensitivity 1 microvolt

S/N Ratio Required for Phase Tracking -30 dBc/100 Hz BW

Phase Tracking Accuracy 0.01 cycles (typ)

Time Accuracy

Can maintain time transferred to the MVLF to within:

< 1 microsec. For VLF, 11.8 to 13.1 kHz
< 0.2 microsec. for LF, 50 to 77.5 kHz

Note: The above are typical values for distances up to 5000 km from the transmitter for VLF and 500 km for LF

Clock Functions
- Automatic leap year correction
- Automatic leap second correction at pre-programmed time up to 100 years in advance
- Synchronization to external 1 PPS (± 150 nsec)
- Push button operated phase shifting in decade steps 100 nsec. to 1 sec.
- Push button operated clock and calendar setting

Outputs

Display: Vacuum fluorescence, 40 ASCII character, in (2) lines; frequency, phase, field strength, last update, time of last update, time of day, date, day of year, modified Julian date.

1 PPS: 10 microsec. nom. pulse width
10 nsec max rise time
10 nsec max jitter
5 volts nominal into 50 ohms (adjustable 3 to 11 volts)

Control: 0 to 5 Vdc (14 bit DAC for MRK C-Field Control)

Recorder: Phase: 0 to 10 Vdc for ± 0.5 cycles
Field Strength: 0 to 10 Vdc for 0 to +100 dB microvolt

Inputs: 10 MHz from MRK Rb oscillator
0.5 to 1.5 Vrms into 50 ohms
1 PPS sync
50 nsec minimum pulse width
100 nsec. maximum rise time
3 to 11 volts into 50 ohms

Power: 20.5 Vdc, ~12 W

CAUTION
WHEN AN MVLF/MRTC IS INSTALLED IN THE MFS, THE LOWER OPERATION TEMPERATURE IS 0°C INSTEAD OF THE USUAL -25°C.

MRTC Realtime Clock and IRIG Code Generator

When only the clock functions are desired, without the MVLF receiver, an MRTC can be requested. This unit is housed in the same configuration as the MVLF. Therefore, the environmental and physical characteristics described earlier apply to the MRTC. The power requirements for the MRTC are fulfilled by the MPS (20.5 Vdc), approx. 12 watts.

Model Number	Description
MRTC-OA1CO	No IRIG Output
MRTC-1A1CO	IRIG Outputs

IRIG Code Generator (option for MRTC only)

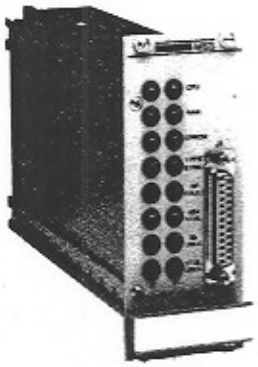
4 standard IRIG formats are programmable from front panel buttons.

Electrical Specifications

Rate Designation	A) 1000 PPS B) 100 PPS E) 10 PPS G) 10000 PPS
Form Designation Modulated	1) Sine wave, Amplitude
Carrier Frequency / Resolution	1) 100 Hz / 10 ms 2) 1 kHz / 1 ms 3) 10 kHz / 0.1 ms 4) 100 kHz / 0.01 ms
Coded Expressions	2) BCD 3) BCD, SBS
Open Loop Output Level	Adjustable, 0 ... > 2 Vrms
Source Impedance	600 ohms
Modulation	Adjustable, 0 ... 100%
Rate Epoch Error*	< 200 nsec
Carrier Epoch Error*	< 5% of resolution *referred to MRTC 1 PPS output
Rate, Carrier, Code Selection	Via MRTC Display menu
Software Requirement	Version 0300 or higher

System Status

MSS, System Status



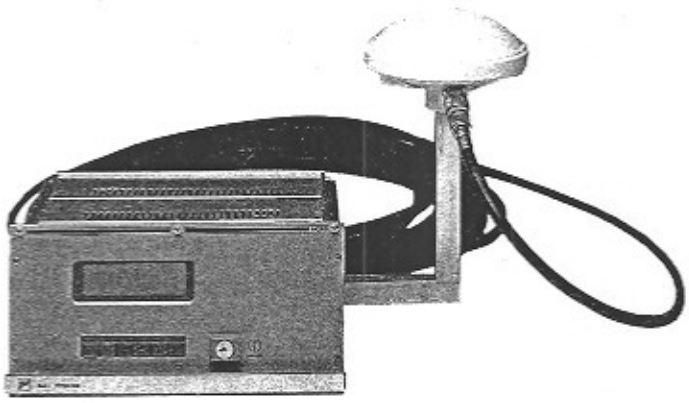
The Modular System Status, Model MSS, provides monitoring of CMOS / TTL compatible signal from a Modular Frequency System (MFS). If two sub-systems reside in the same MFS enclosure (typically, each sub-system contains an MPS, MRK, and MBF module as a minimum) half of the status module is dedicated to one sub-system while the other half of the status module is dedicated to the other sub-system. Panel mounted LEDs provide visual parameter status and a front panel mounted connector provides remote status monitoring capability. This remote status connector provides CMOS / TTL compatible output status signals for all signals being monitored. The module also contains dual relays (one per sub-system) for relay closure type monitoring. Up to eight signals can be monitored by each relay and normally open or normally closed fault indication may be specified. The module also provides for one pulsed status input signal (the presence of a repetitive pulse means the parameter monitored is okay) for each sub-system. The signals to be monitored must be specified at the system level and are hard-wired in the mainframe. The front panel LEDs and labeling are dependent on signals chosen for monitoring.

MSS Model	Description
MSS-OAOCO	Standard Status Module

Electrical Specifications

Inputs	Up to six (twelve) individually statused CMOS / TTL compatible signals per sub-system (system). Up to eight (sixteen) group statused CMOS / TTL compatible signals per sub-system (system). One (two) pulsed CMOS / TTL compatible signal(s) per sub-system (system).
Outputs	Eight (sixteen) CMOS/TTL compatible signals per sub-system (system) on status port. One (two) relay closure(s) per sub-system (system) on status port. Eight (sixteen) LED status indicators per sub-system (system).
Input Power	20.5 Vdc, 4.0 W (system)

MGPS, GPS-Receiver-Controller



- Frequency Accuracy: ±1E-12 rms under SA
- Timing Accuracy: 100 ns under SA
- Cesium Performance
- Directly Traceable to NIST
- Built-in GPS Receiver(1)

(1) Note: Model MGPS differs from Model MDRC in that the MGPS is a RCVR/Controller combination and Model MDRC is only a controller which must use an external RCVR.

The Global Positioning Satellite System

The Global Positioning Satellite System (GPS) is a satellite-based navigation and positioning system being deployed by the U.S. Department of Defense. In addition to providing precise position in three dimensions, the system also supplies precise time with an accuracy other systems cannot achieve.

When fully operational, the system will consist of 21 satellites in six orbit planes. The orbit altitude is chosen for a 12 (sidereal) hour period so that each satellite will repeat its ground track daily. With the satellite configuration currently available, 3-dimensional positioning is possible several hours per day virtually worldwide. Once the exact position has been determined, only one satellite is necessary to determine and maintain precise timing.

Each satellite transmits uniquely coded signals derived from a precision on-board clock which enable the receiver to determine the distance to the satellite by measuring the signal time of arrival. Since the satellite broadcasts its own position data, the three position dimensions and the receiver clock bias can be solved by simultaneously tracking four satellites.

GPS-Receiver-Controller Module Model MGPS

This module is part of Ball Efratom's Modular System line. It is designed to receive the L1, C/A coded signals from the GPS satellites. Using the reference frequency from the Rubidium Oscillator Module, it generates and maintains its own time scale. When timing information from GPS is available it automatically locks its time scale to GPS. During periods of no reception, the Rubidium Oscillator provides the necessary "flywheel" to maintain a high degree of accuracy.

In addition to providing precise time, the receiver/controller determines the Rubidium Oscillator frequency offset. This information is used to discipline the oscillator frequency thus providing an automatic on-line calibration feature. The frequency and time lock loops are independent of each other and can therefore be individually optimized.

Particular attention has been paid to user friendliness of the Receiver Controller Module. Depending on the availability of GPS system data (almanac, ephemeris) and satellite visibility, the receiver will acquire satellites and calculate position, time and frequency offset automatically within 2 to 15 minutes after turn-on.

MGPS-GPS-Receiver-Controller (continued)

Antenna / Preamplifier

(supplied with module)

Frequency	1565 - 1585 MHz
Polarization	Right-hand Circular
Gain	42...50 dB
Output VSWR	< 2:1
Connector	N type female
Dimensions	120 x 120 x 130 mm 4.80 x 4.80 x 5.20 in.
Operating Temperature	-55°C to +85°C

Antenna Cable

(supplied with module)

Type	RG 213/U
Length	25m*
Loss	< 10 dB
Connector	N type male (both ends)

Direct current is carried up to the antenna-preamplifier on the center conductor of the cable and GPS signals are carried from the antenna to the receiver controller.

*Contact factory for longer cable.

Receiver / Controller Module

Receiver Input	1575.42 MHz (L1) C/A Code
Timing Accuracy	±100 ns**
Frequency Accuracy	1E-12 rms**
Position Acc.	25 m rms**

**Includes SA as described in the Technical Characteristics of the NAVSTAR GPS document published in June 1991 by the NAVSTAR GPS Technical Support Group. Assumes 24h continuous operation in a fixed stationary position with temperature changes of less than ± 2° C/day. Subject to sufficient satellite availability.

Display	LCD type, 4 lines, 20 characters per line displays UTC time of day, day of year and calendar date, modified Julian Date, latitude, longitude, height (WGS84), frequency offset, control voltage, etc.
Keypad	6 pushbuttons and keylock switch
1 PPS Output	10 µs pulse width, 10 ns rise time, 5 V into 50 Ω (adjustable 3 to 11V)
RS 232 Interface	300 - 19200 Bd
Connectors	N-type, female (antenna) BNC, (1 PPS in, 1 PPS out) D9S (RS232), all via separate connector panel
Operating Temperature	0°C to +50°C
Size	49 Increments (I) receiver controller module, 14 I connector panel
Options	IRIG code output see MRTC data sheet for details). Have-Quick code output also available
Event Counter	Allows time tagging of events, 1 ns resolution. Front panel indication and/or RS 232 port output.