Brandywine’s Modular Master Clock System represents the next generation of modular timing systems. Built on the highly successful High Performance Timing System, the Modular Master Clock System is a leap forward in design.

**Features:**
- Redundant design with multiple signal paths built in for high-availability.
- 5 expansion slots (12 slots in 2U version).
- Industry-first GPS integrity checking
- Unique optical crosslink architecture for either Master-Slave hierarchical setups or Master-Master crosschecking and failover
- Operated by a detachable touch-screen interface, a first for any master clock system.
- Single or dual redundant configurations in a single 1U chassis
- Modules are hot-swappable from the front and minimize the need to disconnect cables.

At the center of the MMC system are Brandywine’s powerful Master Clock Modules (MCM). The MCM may be synchronized by a variety of reference sources and uses the selected reference to steer an embedded oscillator to provide stable and accurate time and frequency for the MMC. Multiple references can be prioritized with automatic failover. Uniquely, the MCM will also validate the GPS reference based upon the inherent stability of the MCM oscillator, providing hardening against possible GPS spoofing.

Available input reference selections include GPS (both C/A code and SAASM receivers are supported), IRIG-B, Have Quick/1PPS and external 10 MHz. In additional an MCM may be synchronized by up to 2 other MMC chassis using a fiber optic crosslink, this provides additional resiliency for the MMC time and frequency references.

The MMC supports multiple reference oscillator choices, including Rubidium (2U chassis only), Chip Scale Atomic Clock (CSAC) and Ovenized Oscillator (OCXO)

Up to two MCM modules may be installed in the 1U chassis, with automatic failover if the on-line module should fail.

The output signals for the Modular Master Clock System are generated by up to 5 hot-swappable Output Signal Modules (OSM), and are ideal for custom solutions or future expansion. Available modules include NTP, low-phase-noise frequency, IEEE-1588 PTP, time code modules such as IRIG A, B, G, H, and NASA 36, BCD, PPS, PPM, Have Quick as well as optical crosslink.

The MMC status and control is via an Ethernet port using SNMP, or a Brandywine provided application. An optional full color touch screen that allows control of the local chassis, as well as remote chassis that are connected via crosslink may be connected to the front panel via an umbilical cable. User controls for the MMC are protected via password with encrypted storage. Network protocols also fully support privacy and authentication.
Modular Master Clock (1U Version)

System Specifications

Signal Reference Inputs

**C/A code GPS Receiver (optional)**
- Receiver Type: GPS L1 C/A, SBAS L1 C/A
- GPS Reception: 14 channels (GPS, SBAS)
- Sensitivity:
  - Tracking: -159 dBm
  - Acquisition: -147 dBm
- Accuracy:
  - 15ns (1σ) (@ -130 dBm)
  - Hot Start: <5 sec (@ -130 dBm)
  - Warm Start: 70 sec (@ -130 dBm)
  - Cold Start: 70 sec (@ -130 dBm)

**SAASM GPS Receiver (optional)**
- Receiver Type: GB-GRAM Type II
- Keyfill cable: DAGR compatible DB15

**External 1PPS Input**
- Signal Format: Per ICD-GPS-060B
- Rate: 1 pulse per second
- Impedance: 50 ohm

**External GPS Have Quick T/C Input**
- Signal Format: Per ICD-GPS-060A, STANAG 4246 HQ2A
- Rate: 1 frame per second
- Impedance: 1k ohm
- Connector Type: DB15M

**External IRIG B Input**
- Signal Format: IRIG B Per IRIG 200-04
- Control Functions: Per IEEE1344
  - Modulation ratio: 2.5:1 to 3.3:1
  - Amplitude: 1 Vp-p to 5Vp-p
  - Impedance: >600 ohm
- Connector Type: SMA

Environmental

Power
- 2 power supply slots are available. Can be either AC input, DC input or a combination.
- AC Supply:
  - Voltage: 90-265 VAC 50/60 Hz.
  - Connector: IEC 320 C14 (standard)
- DC Supply:
  - Voltage: 21-32VDC
  - Connector: Barrier Terminal Block

Physical
- Length (depth): 20.00"
- Width: 17.00" Chassis
- Height: 19.00" Front Panel
- Weight: 1.72 1U chassis
- 25 lbs nominal (slides not included)

Temperature
- Air Temperature: -15 to 55degC
- Altitude Conditions: -1500 ft to +11,000 ft
- Airflow: 30 cfm front to rear.

Shock and Vibration
- Operating Shock: MIL-STD 810F 20g/11ms
- Bench Handling Shock: MIL-STD 810F
- Vibration: MIL-STD-167-1

EMC
- FCC Part 15, Class A
- IEC CISPR 22
- CE
Modular Master Clock (1U Version)

Master Clock Module (MCM)

The Master Clock Module is the clock at the heart of the MMC. The MMC may use either one (standard) or two (optional) hot-swappable Master Clock Modules for redundancy and high-availability operation. The MCM may be configured with one of three types of disciplined oscillators, depending upon price/performance desired. The MCM is accessed either via the (optional) detachable touch screen display, an external Ethernet port, or a front panel maintenance Ethernet port. All aspects of the MMC operation are available through the optional display. For MMC configurations where multiple chassis are connected via an optical fiber link, the status and configuration of a remote chassis can be accessed across this link.

The MCM provides a number of signal outputs without the need to install any Output Signal Modules.

Each MCM includes provision for Information Assurance. The touch display is password protected, and the password is stored in encrypted form. Password requirements and updates are implemented by means of warning screens. All Network connections use both authentication and privacy corresponding to the protocol in use. Only required ports and protocols are enabled.

### Oscillator Options

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Rbodium</th>
<th>CSAC</th>
<th>OCXO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time</td>
<td>Locked</td>
<td>5ns 2o</td>
<td>&lt;5ns 2o</td>
</tr>
<tr>
<td>Accuracy</td>
<td>Holdover</td>
<td>&lt;10µs</td>
<td>&lt;100µs</td>
</tr>
<tr>
<td>Temperature</td>
<td>-40°C to 50°C</td>
<td>&lt;1E-12</td>
<td>&lt;2E-12</td>
</tr>
<tr>
<td>Frequency</td>
<td>Locked</td>
<td>&lt;2E-11</td>
<td>&lt;2E-12</td>
</tr>
<tr>
<td>Accuracy</td>
<td>Holdover</td>
<td>&lt;9E-11</td>
<td>&lt;5E-11</td>
</tr>
<tr>
<td>Reference Error</td>
<td>&lt;1E-10</td>
<td>&lt;5E-10</td>
<td>&lt;1E-8</td>
</tr>
<tr>
<td>Detection Sensitivity</td>
<td>&lt;2E-10</td>
<td>&lt;5E-10</td>
<td>&lt;1E-8</td>
</tr>
</tbody>
</table>

### MCM Inputs

- Available Reference selection
  - GPS (optional)
  - IRIG B
  - IRIG B + 1PPS
  - Have Quick +1PPS
  - 1PPS
  - 10MHz
  - Crosslink A
  - Crosslink B

### MCM Outputs

- **Time and Frequency Outputs**
  - 1PPS
  - 10 MHz

- Propagation delay compensation
  - Input: ±1ns -100µs in 1ns steps all inputs
  - Outputs: ±0 – 1ms in 5ns steps

- Status and Control
  - 100BaseT Ethernet
  - SNMP v3, RFC 3411, 3418
  - NTP v4, RFC 5905
  - IP v4, IP v6

- Touch panel display
  - 4.1 inch WVGA (800 X 480) LED 350 NIT
  - Digital Landscape TFT LCD w/ Touch Screen

- Alarm Relay
  - Dry Contact Closure 100mA
  - Audible Buzzer Alarm

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1 2U chassis only
Modular Master Clock (1U Version)

Universal Output Signal Module

The Universal OSM provides the ultimate in flexibility. The Universal OSM has 4 outputs, each of which is user-programmable to a wide variety of time code or pulse outputs. This flexibility ensures that an MMC can be reconfigured as requirements change, and fewer modules are needed in comparison to designs where modules are single function. Time code outputs can be configured independently for local time. Passive rear transition modules are available for single ended BNC, or differential connectors. Each output is individually adjustable for propagation delay, ensuring that for high accuracy synchronization different cable lengths can be accommodated.

Available output formats:
- 1 PPS and 1PPM
- HaveQuick
- IRIG A, B, E, G, H
- XR3
- 2137

Specifications:

**Pulse-per-second/minute**

<table>
<thead>
<tr>
<th>Signal Format</th>
<th>Pulse per second/minute</th>
</tr>
</thead>
<tbody>
<tr>
<td>1PPS Rate</td>
<td>1 pulse per second</td>
</tr>
<tr>
<td>1PPM Rate</td>
<td>1 pulse per minute</td>
</tr>
<tr>
<td>Rising Edge</td>
<td>On Time</td>
</tr>
<tr>
<td>Rise Time</td>
<td>&lt;20ns</td>
</tr>
<tr>
<td>Fall time</td>
<td>&lt;100ns</td>
</tr>
<tr>
<td>Pulse Width</td>
<td>20 µs ±5% default</td>
</tr>
<tr>
<td>Amplitude</td>
<td>10V ±10% into 50Ω</td>
</tr>
<tr>
<td>Output condition</td>
<td>when TFOM&lt;7 only</td>
</tr>
</tbody>
</table>

**Have Quick Time of Day Output**

<table>
<thead>
<tr>
<th>Signal Format</th>
<th>HaveQuick A and B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rising Edge</td>
<td>On Time</td>
</tr>
<tr>
<td>Rise Time</td>
<td>&lt;100ns</td>
</tr>
<tr>
<td>Fall time</td>
<td>&lt;100ns</td>
</tr>
<tr>
<td>1PPS coherence</td>
<td>&lt; 100ns of rising edge</td>
</tr>
<tr>
<td>Amplitude</td>
<td>5V ±5%</td>
</tr>
<tr>
<td>Output condition</td>
<td>when TFOM&lt;7 only</td>
</tr>
</tbody>
</table>

**BCD Time Code Output**

<table>
<thead>
<tr>
<th>Signal Format</th>
<th>BCD Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rate</td>
<td>50 bits/sec</td>
</tr>
<tr>
<td>1PPS coherence</td>
<td>&lt; 100ns of rising edge</td>
</tr>
<tr>
<td>Mark (logical 1)</td>
<td>+2.5V ±1V</td>
</tr>
<tr>
<td>Space (logical 0)</td>
<td>-2.5V ±1V</td>
</tr>
<tr>
<td>Output condition</td>
<td>when TFOM&lt;7 only</td>
</tr>
</tbody>
</table>

**IRIG B Time code Output**

<table>
<thead>
<tr>
<th>Signal Format</th>
<th>IRIG B Codes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rate</td>
<td>1kHz modulated</td>
</tr>
<tr>
<td>Modulation ratio</td>
<td>10:3 ±10%</td>
</tr>
<tr>
<td>Amplitude</td>
<td>5Vpp ±20%</td>
</tr>
<tr>
<td>Output condition</td>
<td>when TFOM&lt;7 only</td>
</tr>
</tbody>
</table>

**2137 Time code Output**

<table>
<thead>
<tr>
<th>Signal Format</th>
<th>2137</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carrier</td>
<td>1kHz modulated</td>
</tr>
<tr>
<td>Modulation ratio</td>
<td>10:3 ±10%</td>
</tr>
<tr>
<td>Amplitude</td>
<td>5Vpp ±20%</td>
</tr>
<tr>
<td>Output condition</td>
<td>when TFOM&lt;7 only</td>
</tr>
</tbody>
</table>

**XR3 Time code Output**

<table>
<thead>
<tr>
<th>Signal Format</th>
<th>XR3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rising Edge</td>
<td>On Time</td>
</tr>
<tr>
<td>Rise Time</td>
<td>&lt;100ns</td>
</tr>
<tr>
<td>1PPS coherence</td>
<td>&lt; 100ns of rising edge</td>
</tr>
<tr>
<td>Amplitude</td>
<td>5V ±5%</td>
</tr>
<tr>
<td>Output condition</td>
<td>when TFOM&lt;7 only</td>
</tr>
</tbody>
</table>

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Modular Master Clock (1U Version)

Low Phase Noise Analog
The Analog Low Phase Noise Module provides 4 low phase noise reference frequency outputs at 1, 5, or 10MHz.

Specifications:
<table>
<thead>
<tr>
<th>Waveform</th>
<th>Amplitude</th>
<th>Harmonic Distortion</th>
<th>Non Harmonic</th>
<th>Connector Type</th>
<th>Accuracy</th>
<th>MCM Switching</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sinusoid</td>
<td>13dBm/1Vrms</td>
<td>-60dBc</td>
<td>&lt;-80dBc 10kHz - 500MHz</td>
<td>Coaxial, BNC</td>
<td>Locked to MCM oscillator</td>
<td>Hitless switch</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Phase Noise 10MHz</th>
<th>5MHz</th>
<th>1MHz</th>
</tr>
</thead>
<tbody>
<tr>
<td>1Hz</td>
<td>-90dBc</td>
<td>-96dBc</td>
</tr>
<tr>
<td>10Hz</td>
<td>-120dBc</td>
<td>-130dBc</td>
</tr>
<tr>
<td>100Hz</td>
<td>-142dBc</td>
<td>-142dBc</td>
</tr>
<tr>
<td>1KHz</td>
<td>-155dBc</td>
<td>-155dBc</td>
</tr>
<tr>
<td>10kHz</td>
<td>-158dBc</td>
<td>-158dBc</td>
</tr>
</tbody>
</table>

Synthesizer Module
The Synthesizer Module provides 4 programmable output frequencies on the range 250Hz to 33MHz. The frequency scheme ensures that telecom frequencies on multiples of 8kHz are exact.

Specifications:
- Waveforms: Sinusoid, Square, Differential
- Connector Type: BNC, RS-422
- Accuracy: Locked to MCM oscillator
- MCM Switching: Hitless switch

NTP Server
The NTP Server module enables the Modular Master Clock to act as an NTP server over an Ethernet network. Designed with security in mind, the NTP server module uses a custom network stack that enables it to ONLY act as an NTP server, and prevent it from being used as a gateway to compromise the entire system.

Specifications:
- Signal Format: Ethernet 100BaseT
- Protocols supported: NTPv3 RFC1305, NTPv4 RFC 5905
- Authentication: MD5, SHA-1
- Connector Type: RJ45
- No of Outputs: 2

Optical Crosslink Module
The Optical Crosslink Module is a unique feature of the MMC. When installed, it allows a second MMC to be synchronized as a slave chassis. If both chassis have a primary reference installed (e.g. GPS) then the two MCM’s operate as peers. Peering provides additional redundancy, as well as providing additional references to detect failures. When a duplex cable is provided, the optical link provides seamless and automatic propagation delay compensation. A security mode allows the optical link to be operated in a single direction form Master to Slave over a single fiber.

Specifications:
- Connector Type: LC
- No of Outputs: 2 bi-directional per OSM
- Synchronization Accuracy: 1ns
- End to End Accuracy: <5ns synchronization
- Optical Wavelength: Single Mode 1300nm
- Class 1 CDRH/IEC 825
- Safety Range: 2000m 9/125um cable

3 Consult Factory for longer range or multimode