The MPFICQor Military Isolated PFC Module is a high power, high efficiency AC-DC converter. It operates from a universal AC input and generates an isolated output. Both regulated and semi-regulated (droop version) modules are available. Used in conjunction with a hold-up capacitor, and SynQor's MCOTS AC line filter, the MPFICQor will draw a nearly perfect sinusoidal current (PF>0.99) from a single phase AC input. The module is supplied completely encased to provide protection from the harsh environments seen in many military and aerospace environments.
**Typical Application**

**Input:** 85-264Vrms  
**Output:** 28Vdc  
**Current:** 11.5A

**SynQor MPFIC Module**

**Isolation**

**Example Parts:**
- **F1:** 5A / 250V Fuse
- **MOV1, TVS1:** Must prevent peak voltage from exceeding 575V during all transients. Must also not be acting for the desire operating range.
- **C_Hold-Up:** 50 - 500 μF (Dependent on Power Level and Line Frequency)
- **CY1-CY2:** See "EMI Considerations" in application notes

**Figure A:** Typical Application of the MPFICQor module to create an AC-DC Power Supply
# Technical Specification

## MPFIC-U-28-HT Electrical Characteristics

Operating conditions of 115Vrms, 60Hz input, 11.5A output, 200µF bulk capacitance, and baseplate temperature = 25°C unless otherwise noted; full operating baseplate temperature range is -55°C to +100°C with appropriate power derating. Specifications subject to change without notice.

### Parameter | Min. | Typ. | Max. | Units | Notes & Conditions
--- | --- | --- | --- | --- | ---
### ABSOLUTE MAXIMUM RATINGS
Input Voltage (L1 to L2/N) & 575 & Vpk & & & 
Isolation Voltage (Input to Output) & 4250 & Vdc & & See Note 3
Isolation Voltage (Input/Output to Baseplate) & 2150 & Vdc & & See Note 3
Operating Temperature & -55 & 100 & °C & Baseplate temperature
Storage Temperature & -65 & 125 & °C & &
Voltage at AC GOOD and pins & -0.3 & 16 & V & &
Voltage at DC GOOD and pins & -0.3 & 16 & V & &
Current drawn from AUX pin & 0 & 10 & mA & &
Voltage at PFC enable pin & -2 & 575 & V & &
### INPUT CHARACTERISTICS (L1 to L2/N)
Operating Input Voltage Range & 85 & 264 & Vrms & &
AC Input Continuous & & & & &
AC Input 100ms Transient & 30 & 440 & Vrms & >1s duration
Input Under-Voltage Lockout & & & & &
Input Over-Voltage Shutdown & & & & &
Operating Input Frequency & 47 & 63 & Hz & 50/60Hz range, for startup
 & 360 & 800 & Hz & 400Hz range, for startup
 & 45 & 800 & Hz & After startup, unit operates over wide frequencies
Power Factor of AC Input Current & 0.99 & 0.97 & % & &
Total Harmonic Distortion of AC Input Current & 3 & & % & &
Inrush of AC Input Current & & & & &
50/60Hz & 10 & 20 & Apk & &
400Hz & & & & &
Enabled AC Input Current (no load) & 100 & 180 & mArms & 115 Vrms input
Disabled AC Input Current & 30 & 50 & mArms & &
Maximum Input Power & & & & &
Maximum Input Current & & & & &
### OUTPUT CHARACTERISTICS
Output Voltage Set Point at Full Load & 27.6 & 28.0 & 28.4 & Vdc & See Figure 6 for V-I curve
- Standard Option & 26.3 & 27.0 & 27.3 & Vdc & Vin<250Vrms, for higher Vin see application notes
- D Option & & & & &
Total Output Voltage Range & 27.3 & 28.7 & Vdc & &
- Standard Option & & & & &
- D Option & 26.0 & 29.0 & Vdc & &
Standard Option Voltage Regulation & ±0.3 & 0.5 & % & Above half load
Over Line & & & & &
Over Load & -1.5 & 240 & mV & Vin<250Vrms, for higher Vin see application notes
Over Temperature & & & & &
Output Voltage Ripple and Noise & 3.0 & 1.2 & % & 60Hz, see Note 1
- Peak-to-Peak & & & & &
- RMS & & & & &
Operating Output Current Range & 0 & 11.5 & A & Unit continues to operate for 1s before shutdown
Output Current Limit & 115 Vrms & & 14.5 & A & &
230 Vrms & & & & &
Maximum Output Capacitance & 2,000 & µF & & At half resistive load
### HOLD-UP CHARACTERISTICS
Typical Hold-up Voltage & 400 & & Vdc & &
Hold-up Voltage Range & 385 & 415 & Vdc & Hold-up voltage varies with load
Hold-up Over-Voltage Protection Threshold & 440 & 460 & Vdc & &
Hold-up Under-Voltage Shutdown Threshold & 200 & & Vdc & &
Hold-up Capacitance & 50 & 500 & µF & See Note 2
External Common-Mode Capacitance & 20 & nF & & See "EMI Considerations" in application notes
### Efficiency
100% Load at 115Vrms & 90 & % & & See Figure 1 for efficiency curve
100% Load at 230Vrms & 92 & % & & See Figure 1 for efficiency curve

Note 1: 200µF electrolytic hold-up capacitor having a typical ESR of 0.5Ω. Ripple amplitude dependent on capacitance and ESR of hold-up capacitor.

Note 2: The MPFICQor is able to operate with a minimum of 50µF of hold-up capacitance, but SynQor recommends at least 330µF if the power system will be required to conform to lightning surge standards. This is because the MPFICQor relies on the hold-up capacitor to absorb the energy from a lightning surge.
MPFIC-U-28-HT Electrical Characteristics (continued)

Operating conditions of 115Vrms, 60Hz input, 11.5A output, 200µF bulk capacitance, and baseplate temperature = 25°C unless otherwise noted; full operating baseplate temperature range is -55 °C to +100 °C with appropriate power derating. Specifications subject to change without notice.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Min.</th>
<th>Typ.</th>
<th>Max.</th>
<th>Units</th>
<th>Notes &amp; Conditions</th>
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<td>Turn-On Time</td>
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<td></td>
<td>s</td>
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<tr>
<td>Output Voltage Overshoot</td>
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<td></td>
<td>%</td>
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<td>See Absolute Maximum Ratings, Note 3</td>
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<td>MΩ</td>
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<td>Isolation Capacitance</td>
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<td>pF</td>
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<td>Board Temperature</td>
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<td>Transformer Temperature</td>
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<td>°C</td>
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<td>Maximum Baseplate Temperature, T&lt;sub&gt;B&lt;/sub&gt;</td>
<td>100</td>
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<td>Hold-up Capacitor Precharge</td>
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<td>Precharge Current</td>
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<td>kHz</td>
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<td>PFC Enable (PFC ENA)</td>
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<td>On-State Voltage</td>
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<td>DC Good (DC GOOD)</td>
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<td></td>
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<td>Referenced to HU-</td>
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<td>Pull-down resistance</td>
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<td>Ω</td>
<td>Open collector</td>
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<td>Over-Temperature Trip Point</td>
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<td>°C</td>
<td>At internal PCB</td>
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<td>Auxiliary Bias Supply</td>
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<td>Voltage Range (≤3 mA Load)</td>
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<td>mA DC</td>
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<td>Calculated MTBF (MIL-217) MIL-HDBK-217F</td>
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<td>Ground Benign, T&lt;sub&gt;B&lt;/sub&gt; = 70°C</td>
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<td>Calculated MTBF (MIL-217) MIL-HDBK-217F</td>
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<td></td>
<td></td>
<td>kHrs</td>
<td>Ground Mobile, T&lt;sub&gt;B&lt;/sub&gt; = 70°C</td>
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</tbody>
</table>

Note 3: 1 minute for qualification test, and less than 1 minute in production.
Technical Specification

Figure 1: Efficiency at nominal output voltage vs. output current for 115Vrms and 230Vrms (60Hz) input voltage at Tb = 25°C.

Figure 2: Power dissipation at nominal output voltage vs. output current for 115Vrms and 230Vrms (60Hz) input voltage at Tb = 25°C.

Figure 3: Typical Input Voltage and Current waveforms at full load current (115Vrms, 60Hz) Top: Vin (200V/div), Bottom: Iin (5A/div), Timebase: (5ms/div).

Figure 4: Typical Input Voltage and Current waveforms at full load current (115Vrms, 400Hz). Top: Vin (200V/div), Bottom: Iin (5A/div), Timebase: (1ms/div).

Figure 5: Output current vs. leading power factor, MPFIC module only (no input filter).

Figure 6: Typical output voltage vs. output current for regulated and droop version outputs.
MPFIC-U-28-HT
Input: 85-264Vrms
Output: 28Vdc
Current: 11.5A

Technical Specification

Figure 7: Line drop out with 400μF hold-up capacitor at full load current (115Vrms, 60Hz) Top: Vin (200V/div), Mid: Iin (5A/div), Bottom: Vout (10V/div), Timebase: (50ms/div).

Figure 8: Output voltage response to step-change in load current with 200μF hold-up capacitor (50%–75%–50% of Iout(max)), 115Vrms, 60Hz Top: Vout (2V/div), Bottom: Iout (5A/div), Timebase: (100ms/div).

Figure 9: Typical startup waveform with 200μF hold-up capacitor (115Vrms, 60Hz) Top: Vin (200V/div), Ch2: Hold-up capacitor voltage (100V/div), Ch3: Vout (10V/div), Bottom: Iin (5A/div), Timebase: (200ms/div).

Figure 10: Input voltage transient response with 200μF hold-up capacitor at full load current (115Vrms-230Vrms-115Vrms, 60Hz), Top: Vin (200V/div), Mid: Iin (5A/div), Bottom: Vout (2V/div), Timebase: (50ms/div).

Figure 11: Maximum output current vs. base plate temperature derating curve.

Figure 12: Maximum output current vs. input voltage, output turn-on threshold is 85Vrms.
### Mil-COTS Qualification

<table>
<thead>
<tr>
<th>Test Name</th>
<th>Details</th>
<th># Tested (# Failed)</th>
<th>Consistent with MIL-STD-883F Method</th>
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</thead>
<tbody>
<tr>
<td>Life Testing</td>
<td>Visual, mechanical and electrical testing before, during and after 1000 hour burn-in @ full load</td>
<td>15 (0)</td>
<td>Method 1005.8</td>
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<tr>
<td>Shock-Vibration</td>
<td>Visual, mechanical and electrical testing before, during and after shock and vibration tests</td>
<td>5 (0)</td>
<td>MIL-STD-202, Methods 201A &amp; 213B</td>
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<tr>
<td>Humidity</td>
<td>+85 °C, 95% RH, 1000 hours, 2 minutes on / 6 hours off</td>
<td>8 (0)</td>
<td>Method 1004.7</td>
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<tr>
<td>Temperature Cycling</td>
<td>500 cycles of -55 °C to +100 °C (30 minute dwell at each temperature)</td>
<td>10 (0)</td>
<td>Method 1010.8, Condition A</td>
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<tr>
<td>Solderability</td>
<td>15 pins</td>
<td>15 (0)</td>
<td>Method 2003</td>
</tr>
<tr>
<td>DMT</td>
<td>-65 °C to +110 °C across full line and load specifications in 5 °C steps</td>
<td>7 (0)</td>
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</tr>
<tr>
<td>Altitude</td>
<td>70,000 feet (21 km), see Note</td>
<td>2 (0)</td>
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</table>

Note: A conductive cooling design is generally needed for high altitude applications because of naturally poor convective cooling at rare atmospheres.

### Mil-COTS Converter and Filter Screening

<table>
<thead>
<tr>
<th>Screening</th>
<th>Process Description</th>
<th>S-Grade</th>
<th>M-Grade</th>
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<tbody>
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<td>Baseplate Operating Temperature</td>
<td>-55 °C to +100 °C</td>
<td>-55 °C to +100 °C</td>
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<tr>
<td>Storage Temperature</td>
<td>-65 °C to +135 °C</td>
<td>-65 °C to +135 °C</td>
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<tr>
<td>Pre-Cap Inspection</td>
<td>IPC-A-610, Class III</td>
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<td>●</td>
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<tr>
<td>Temperature Cycling</td>
<td>MIL-STD-883F, Method 1010, Condition B, 10 Cycles</td>
<td>●</td>
<td>●</td>
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<tr>
<td>Burn-In</td>
<td>100 °C Baseplate 12 Hours</td>
<td>12 Hours</td>
<td>96 Hours</td>
</tr>
<tr>
<td>Final Electrical Test</td>
<td>100%</td>
<td>25 °C</td>
<td>-55 °C, +25 °C, +100 °C</td>
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### Mil-COTS MIL-STD-810G Qualification Testing

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<th>MIL-STD-810G Test</th>
<th>Method</th>
<th>Description</th>
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<td>Fungus</td>
<td>508.6</td>
<td>Table 508.6-I</td>
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<td>Altitude</td>
<td>500.5</td>
<td>Procedure I, Storage: 70,000 ft / 2 hr duration</td>
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<td>500.5</td>
<td>Procedure II, Operating: 70,000 ft / 2 hr duration; Ambient Temperature</td>
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<td>Rapid Decompression</td>
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<td>Procedure III, Storage: 8,000 ft to 40,000 ft</td>
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<td>Acceleration</td>
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<td>Procedure II, Operating: 15 g</td>
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<td>Salt Fog</td>
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<td>Storage</td>
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<td>High Temperature</td>
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<td>501.5</td>
<td>Procedure II, Operating: 100 °C / 3 hrs</td>
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<tr>
<td>Low Temperature</td>
<td>502.5</td>
<td>Procedure I, Storage: -65 °C / 4 hrs</td>
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<td>502.5</td>
<td>Procedure II, Operating: -55 °C / 3 hrs</td>
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<td>Procedure I, Wind Blown Rain</td>
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<td>Immersion</td>
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<td>Procedure II, Aggravated cycle @ 95% RH (Figure 507.5-7 aggravated temp - humidity cycle, 15 cycles)</td>
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<td>Shock</td>
<td>516.6</td>
<td>Procedure I, 20 g peak, 11 ms, Functional Shock (Operating no load) (saw tooth)</td>
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<tr>
<td>Sinusoidal vibration</td>
<td>516.6</td>
<td>Procedure VI, Bench Handling Shock</td>
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<td></td>
<td>510.5</td>
<td>Procedure II, Blowing Sand</td>
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Application Section

Basic Operation & Features

The MPFICQor isolated power factor correction module is a high efficiency, high power AC-DC converter. It operates from a universal AC input to generate an isolated DC output voltage. Both regulated and semi-regulated (droop version) modules are available. As shown in Fig. A, a typical power supply would be comprised of a SynQor MCOTS AC Line Filter, a SynQor MPFICQor module and an energy storage hold-up capacitor. A fuse is needed to meet safety requirements.

One of the primary purposes of the MPFICQor is to shape the input current that is drawn from a single-phase sinusoidal AC source into a nearly perfect sinusoidal waveform so that the AC-DC power supply will present a very high power factor load (PF > 0.99) to this source. In doing this wave-shaping, the MPFICQor ensures that the harmonic components of the AC current waveform are below the levels called for in military standards such as MIL-STD-1399 and MIL-STD-704. The total harmonic distortion of the AC current waveform is typically 3% at full load.

The MPFICQor accomplishes its wave-shaping task by first rectifying the filtered AC source voltage, and then processing the input power through a non-isolated, high-efficiency, high-frequency "boost converter" that both gives the input AC current its sinusoidal shape and provides a regulated DC voltage across the hold-up capacitor. This stage is then followed by a highly efficient, fixed duty cycle isolation stage, which provides the isolated output voltage. For regulated output modules, the output voltage is sensed and this information is sent to the primary side control circuitry through a digital isolator. The DC voltage across the hold-up capacitor is then adjusted to keep the output voltage regulated.

The hold-up capacitor handles the cyclic imbalance between the flow of energy drawn from the AC source and the flow of energy delivered to the load. This energy imbalance has a cyclic frequency twice that of the AC source voltage (e.g. 120Hz for a 60Hz input). This relatively low frequency makes the hold-up capacitor relatively large. Another purpose of the hold-up capacitor is to be a source of energy so that the output can continue to deliver load power during a temporary brownout or dropout of the AC source. A typical power supply will have sufficient hold-up capacitor to give a "hold-up time" in the 20ms range, but longer times can be achieved with yet more hold-up capacitance.

Besides shaping the AC current waveform, the MPFICQor performs several other important functions. At start-up it controls the level of inrush current drawn from the AC source to charge the hold-up capacitor. It limits the DC current that can be drawn from the hold-up terminals and it will shut-down if a short circuit appears across the hold-up terminals. It will also shut-down if the AC input voltage is out of its range (either too high or too low) for too long, or if the temperature of the module is too high.

In addition, the MPFICQor has several input control signals that include PFC_ENABLE, AC_GOOD, and DC_GOOD. All of these signals are described in more detail below. There is also an auxiliary bias supply that can be used to power a low power control circuit. All control signals and AUX are referenced to HU-.

Start-Up Sequence

When the AC source voltage is first applied, regardless of whether the MPFICQor is enabled or disabled through its PFC_ENABLE pin, the MPFICQor will pre-charge the output hold-up capacitor with a current limited to approximately 50mA. This pre-charging continues until the hold-up voltage is within approximately 10V of the peak voltage of the AC source. If, at this time, the PFC_ENABLE input is logically high, and the MPFICQor is therefore disabled, the MPFICQor will remain in this pre-charged state indefinitely. The output voltage will remain at 0V.

When the PFC_ENABLE input pin is pulled low, and after the pre-charging is completed if it is not already, the boost converter within the MPFICQor will start operating and the MPFICQor’s hold-up voltage will be increased to its nominal regulated value. After this regulated voltage level is achieved, the isolation stage within the MPFICQor will then start operating. The converter’s output voltage will rise to its nominal value.

If the PFC_ENABLE input is de-asserted (pulled high or allowed to float), the boost converter, as well as the isolation stage, in the MPFICQor will shut down.

NOTE: The voltage across the hold-up capacitor will remain in a charged state after the MPFICQor is disabled as long as the AC source voltage is present.

Brownout/Dropout Sequence

If the AC source voltage is present but it is below its continuous minimum input voltage limit, the MPFICQor will still draw whatever power it can (within its current limit) from the AC source. This power may not be enough for the total load power, in which case the hold-up capacitor will provide the balance of the power. The voltage across the hold-up capacitor and output voltage will therefore drop as hold-up capacitor discharges.

If the AC source voltage drops below its specified transient minimum input voltage limit, the MPFICQor’s boost converter
will shut down and no longer deliver power to the output. Under this condition, all of the load power will be drawn from the hold-up capacitor.

If and when the voltage across the hold-up capacitor drops below its specified minimum limit, the isolation stage will stop operating and output will be turned off. This condition will cause the MPFICQor to return to the beginning of the startup sequence described above.

**NOTE:** Regardless of what happens to the MPFICQor’s hold-up voltage under a brownout or dropout condition, if the AC source voltage drops below its rated under-voltage value for 1 second or more, the MPFICQor will shut down.

If, however, the voltage across the hold-up capacitor does not drop below its specified minimum limit before the AC source voltage returns to within its continuous operating range (and it hasn’t been absent for more than 1 second), the MPFICQor will automatically re-establish its power flow. The hold-up capacitor will be recharged immediately to the peak of the AC source voltage (if it has fallen below this value) and to its nominal regulated voltage level within a few cycles of the AC source waveform.

**NOTE:** During the first phase where the hold-up capacitor is recharged (if this phase exists) there will be an inrush current drawn from the AC source that depends on the details of how quickly the AC source voltage returns to its normal operating condition.

## Control Features

### Auxiliary Power Supply (AUX):

The circuit shown below is an effective model for the AUX bias power supply:

![Auxiliary Power Supply Circuit](image)

The purpose of the AUX power supply is to provide a low level of power to primary control circuitry, referenced to HU-.

The AUX power supply is present and regulated whenever the MPFICQor’s hold-up voltage is greater than approximately 75V. The AUX bias power supply is unspecified when MPFICQor’s hold-up voltage is less than about 75V (it may, for instance, come and go as the hold-up voltage rises on its way to 75V).

---

**PFC_ENABLE:**

The MPFICQor uses the following circuit for this input logic signal:

![PFC_ENABLE Circuit](image)

- If this input is floating or tied high the MPFICQor’s boost converter and its isolation stage are disabled.
- If this input is pulled low the MPFICQor’s boost is enabled after the pre-charger has charged the voltage across the hold-up capacitor to within approximately 10 volts of the peak of the AC source voltage. Isolation stage is turned on after hold-up voltage reaches regulation.

**AC_GOOD:**

The MPFICQor uses this circuit for this output logic signal:

![AC_GOOD Circuit](image)

- The AC_GOOD signal is internally pulled low whenever the AC source voltage is within the MPFICQor’s continuous operating range for at least one cycle of the source waveform, regardless of whether the MPFICQor is enabled or disabled.
- When the peak of the AC source voltage is outside this continuous operating range (either too high or too low), the AC_GOOD pin will float.
- The AC_GOOD signal is typically used with a pull-up resistor and an opto-coupler (as shown in Fig. A) to provide an isolated signal to the load that the AC source voltage is no longer within the specified continuous operating range. If this condition persists, the load power can only be delivered for the “hold-up time”, and it may therefore be desirable to have the load gracefully shut down. The AC_GOOD signal provides a warning for this action to be
Application Section

DC_GOOD:
The MPFICQor uses this circuit for this output logic signal:

- The DC_GOOD signal is internally pulled low whenever the output voltage has reached regulation. The DC_GOOD signal is typically used with a pull-up resistor and an opto-coupler (as shown in Fig. A) to provide an isolated signal to the load.
- When multiple droop version units are used in parallel for higher power applications, the load should not exceed the rating of a single module until all of the individual DC_GOOD outputs have been asserted low.

Protection Features

Input Over- and Under-Voltage:
If the AC source voltage exceeds the maximum peak voltage rating defined in the electrical specifications, the MPFICQor will shut down. However, under this condition the MPFICQor’s pre-charge circuit will continue to deliver 50mA of current to the hold-up capacitor whenever the AC source voltage is higher than the hold-up voltage. Care must be taken to insure this condition does not allow the hold-up voltage to rise high enough to damage the MPFICQor.

If a brownout or dropout of the AC source voltage occurs, and if it lasts long enough for the MPFICQor’s hold-up voltage to drop below its specified minimum limit, the MPFICQor will shut down. Furthermore, regardless of what happens to the MPFICQor’s hold-up voltage, if the AC source voltage drops below its rated under-voltage value for 1 second or more, the MPFICQor will shut down.

After any shutdown, the MPFICQor will automatically return to the beginning of the startup sequence described above.

Hold-up Over-Voltage:
If the hold-up voltage exceeds its specified maximum limit, the MPFICQor will remain active, but will stop delivering power through its main boost stage until the hold-up voltage falls below the over-voltage threshold. Under this condition, the isolation stage will remain active and provide output voltage.

The MPFICQor’s pre-charge circuit will continue to deliver 50mA of current to the hold-up whenever the AC source voltage is higher than the hold-up voltage. Care must be taken to ensure this condition does not allow the hold-up voltage to rise high enough to damage the MPFICQor.

Output Current Limit and Short-Circuit Shutdown:
If the MPFICQor’s output is overloaded such that its output current limit becomes activated, the output voltage will fall as the excess load current discharges the hold-up capacitor. The MPFICQor will continue to deliver power into this overload condition for 1s, after which the unit will shut down and automatically return to the beginning of the startup sequence described above. In above situations, both boost and isolation stage will turn off.

The MPFICQor responds to a short-circuit event by turning the isolation stage off. The output voltage of the MPFICQor will drop to zero. During the short circuit event, the boost converter will continue to run and the hold-up capacitor will remain charged. The module then enters a hiccup mode where it repeatedly turns on and off until the short-circuit condition is removed. This prevents excessive heating of the converter.

The off time during a short-circuit event is a function of input frequency. For 50/60Hz input, off time equals 25 line cycles. For example, at 60Hz, off time is:

\[ T_{off(60Hz)} = \frac{25}{60} = 417ms \]

For 400Hz input, off time is 200 line cycles:

\[ T_{off(400Hz)} = \frac{200}{400} = 500ms \]
Over Temperature:

If the internal temperature of the MPFICQor reaches 130°C, the MPFICQor will turn off its boost converter and isolation stage. When the internal temperature falls below 110°C, the MPFICQor will return to the beginning of the startup sequence described above.

Energy Storage Hold-Up Capacitor

The hold-up capacitor performs two functions:

- It handles the cyclic imbalance between the flow of energy drawn from the AC source and the flow of energy delivered to the load. In doing so, the voltage across the hold-up capacitor has a ripple at a frequency twice that of the AC source voltage (e.g., 120Hz for a 60Hz input). The larger the hold-up capacitor, or the higher the frequency of the AC source, the smaller this ripple will be.

- It provides a source of energy so that the MPFICQor can continue to deliver load power during a temporary brownout or dropout of the AC source. The larger the hold-up capacitor the longer it can provide this energy. Often it will be made large enough to allow the load to be gracefully shutdown after the AC source has been outside of its normal range for a set amount of time. A typical “hold-up time” would be in the 20 ms range for a 50/60 Hz system.

The total energy stored in a hold-up capacitor having capacitance C at any given voltage V is:

\[ E = \frac{1}{2}CV^2 \]

The amount of energy, \( \Delta E \), which can be drawn from this capacitor depends on the capacitor’s initial voltage, \( V_i \), and its final voltage, \( V_f \). This energy equals the amount of power, P, which the load draws through the isolation stage from the hold-up capacitor times the length of time, \( \Delta t \), which it takes for the hold-up capacitor’s voltage to drop from \( V_i \) to \( V_f \). This energy can be equated to the hold-up capacitance according to the following formula:

\[ \Delta E = \frac{P}{\eta_{ISO}} \Delta t = \frac{1}{2}C(V_i^2 - V_f^2) \]

In this formula, P is the load power and \( \eta_{ISO} = 96\% \) is the isolation stage efficiency. This formula can be rearranged to find the minimum required value for C to provide the hold-up time desired for a given power level.

\[ C_{min} = 2 \frac{P}{\eta_{ISO}} \Delta t / (V_i^2 - V_f^2) \]

For example, if we assume \( P = 300W \), \( \Delta t = 20ms \), \( V_i = 400V \), \( V_f = 300V \), and \( \eta_{ISO} = 96\% \), then we would want a hold-up capacitance of at least 180\( \mu F \).

NOTE: In the above example, the hold-up voltage drops by 25\% at the end of brownout period. This also means the output voltage will drop by 25\%. More hold-up capacitance is recommended if the secondary output voltage needs to be maintained at a higher level.

NOTE: The MPFICQor is able to operate with a minimum of 50\( \mu F \) of hold-up capacitance, but SynQor recommends at least 330\( \mu F \) if the power system will be required to conform to lightning surge standards. This is because the MPFICQor relies on the hold-up capacitor to absorb most of the energy from a lightning surge.

NOTE: Even though the MPFICQor limits the inrush current drawn from the AC source during its startup sequence, it will not necessarily limit this current at the end of a temporary brownout or dropout of the AC source when the hold-up capacitor’s voltage has not dropped below its minimum hold-up voltage limit. In such a condition the MPFICQor will not re-initiate a startup sequence and it will therefore not limit the current flowing through it. If the peak of the AC source voltage is greater than the hold-up capacitor’s voltage at the end of the brownout/dropout period, there will be a large inrush current for one half-cycle as the hold-up capacitor’s voltage is charged up to the peak of the AC source voltage. The larger the hold-up capacitor, the larger this inrush current will be. To limit inrush current during this event, limit the charging current of additional hold-up capacitance with a resistor and diode as shown below.

If it is desired to have a hold-up time longer than can be achieved with the maximum specified hold-up capacitance, then the circuit shown below can be used.

\[ \text{In this circuit the total hold-up capacitance is } (C1 + C2), \text{ and it can be made as large as desired as long as } C1 \text{ does not exceed the maximum capacitance specified in the Technical Specifications table. The resistor, } R_c, \text{ in series with } C2 \text{ is present to limit the current that will charge this capacitor after a temporary brownout/dropout event. Its resistance should be large enough to limit the charging current. The diode in parallel with the resistor permits the load converters to draw whatever energy they need from } C2 \text{ without being hindered by the resistor.} \]
Output Ripple Considerations:

The hold-up capacitor must have a ripple current rating high enough to withstand the ripple current generated on the hold-up capacitor of the MPFICQor. Ripple current amplitude is dependent only upon the total MPFICQor output power, $P_{DC}$, isolation stage efficiency $\eta_{ISO} = 96\%$, and the operating hold-up voltage $V_{HU} = 400\text{V}$. It can be calculated using the following formula:

$$I_{Crms} = \frac{P_{DC}}{\sqrt{2} \cdot \eta_{ISO} \cdot V_{HU}} = \frac{P_{DC}}{543}$$

The AC line frequency, $f_{ac}$, bulk capacitance, $C$, operating hold-up voltage, and output power will determine the amplitude of the voltage ripple present on the output of the MPFICQor. It can be calculated with:

$$V_{pk-pk} = \frac{P_{DC}}{2 \pi \cdot \eta_{ISO} \cdot f_{ac} \cdot C \cdot V_{HU}}$$

At 60 Hz: $V_{pk-pk} = \frac{P_{DC}}{1.47 \cdot 10^5 \cdot C}$

For example, to calculate the hold-up capacitor’s voltage and current ripple for a MPFICQor with a 300W output, 250µF hold-up capacitor, and a 60Hz fundamental AC line frequency:

$$I_{Crms} = \frac{300W}{543} = 0.55A_{rms}$$

$$V_{pk-pk} = \frac{300W}{2 \pi \cdot 0.96 \cdot 60 \cdot 250 \cdot 10^{-6} \cdot 400V} = 8.3V_{pk-pk}$$

In this case, the hold-up capacitor would require a minimum ripple current rating of 0.55$A_{rms}$, and the hold-up voltage would have a pk-pk ripple voltage of 8.3V, or 2%. Since the isolation stage is fixed duty cycle, the secondary output voltage will also have a 2% ripple at 2x the line frequency.

Safety Notes

The output of the MPFICQor is isolated from the AC source. But the hold-up voltage and the control signals are primary-side referenced and are therefore hazardous voltages. Care must be taken to avoid contact with primary-side voltages, as well as with the AC source voltage.

The MPFICQor must have a fuse in series with its AC source. The rating for this fuse is given in the Technical Specification table.

Thermal Consideration

The maximum operating base-plate temperature, $T_b$, is 100ºC. Refer to the thermal derating curves to see the allowable power output for a given baseplate temperature and input voltage. A power derating curve can be calculated for any heatsink that is attached to the base-plate of the converter. It is only necessary to determine the thermal resistance, $R_{Ths}$, of the chosen heatsink between the base-plate and the ambient air for a given airflow rate. The following formula can then be used to determine the maximum power the converter can dissipate for a given thermal condition:

$$P_{max\_diss} = \frac{T_B - T_A}{R_{Ths}}$$

This value of power dissipation can then be used in conjunction with the data shown in the figures to determine the maximum load power that the converter can deliver in the given thermal condition.

MIL-STD-704 Power Level & Power Factor

All versions of MIL-STD-704 state that single-phase loads must draw less than 500VA of AC power. The MPFIC’s maximum output power complies with this requirement.

Section 5.4.3 of MIL-STD-704F states that AC equipment drawing greater than 100VA shall have no leading power factor. Most electronic loads, including the SynQor MPFIC, contain a small amount of differential filter capacitance across the AC input, which draws a small amount of leading reactive power. This has a negligible effect on the power factor of the MPFIC when it is drawing significant real power. Nevertheless, a small amount of leading power factor exists, and an exception to MIL-STD-704F section 5.4.3 must be taken or a compensating parallel inductor must be included. Use Figures 5 to determine the amount of leading power factor and ensure compatibility with the target AC power system.


EMI Considerations
To meet various conducted line emission standards, additional Y-capacitors may be needed to attenuate common-mode noise. SynQor recommends that safter-rated ceramic capacitors be placed from HU- to Vout- and Vout- to ground. However, the total capacitance from the MPFIC HU- leads to earth ground should not be more than 20nF if one of the MPFIC input leads is connected to earth ground. See “Typical Application of the MPFIC Module” (Figure A) for a diagram and suggested parts.

Paralleling Multiple MPFICQors
In higher power applications, multiple droop version units can be used in parallel.
- Only droop version units can be used in parallel. Current share is accomplished by passive droop sharing method.
- On startup, total load should not exceed the rating of a single module until all of the individual DC_GOOD outputs have been asserted low.

Operation at High Input Voltages
If the AC input voltage exceeds about 250 Vrms, both the hold-up voltage and output voltage will be raised up in order to maintain proper input current power factor correction. Output voltage can increase by up to 15% from the nominal output set point as input voltage increases from 250 Vrms to 264 Vrms.

MCOTS AC Line Filter
An AC line filter is needed to attenuate the differential- and common-mode voltage and current ripples created by the MPFICQor and the load, such that the system will comply with EMI requirements. The filter also provides protection for the MPFICQor from high frequency transients in the AC source voltage. SynQor has a family of AC line filters that will provide these functions. It is recommended that a metal-oxide varistor (MOV) be placed from line-to-line on the input of the filter, and a TVS diode be placed from line-to-line on the output of the filter in order to keep the MPFICQor input voltage from exceeding 450V during all transients, except when the PFC is disabled, when the input can tolerate 575V transients for up to 100ms. See Figure A for example parts. If a non-SynQor AC line filter is used, the use of an MOV on the input and a TVS diode on the output of the filter is still recommended.
**NOTES**

1) Applied torque per M3 screw should not exceed 6in-lb (0.7 Nm).
2) Baseplate flatness tolerance is 0.004” (.10 mm) TIR for surface.
3) Pins 1 and 2 are 0.062” (1.57mm) diameter with 0.100” (2.54mm) diameter standoff shoulders.
4) Pins 3-10 are 0.040” (1.02mm) diameter, with 0.080” (2.03mm) diameter standoff shoulders.
5) All Pins: Material - Copper Alloy; Finish - Matte Tin over Nickel plate
6) Undimensioned components are shown for visual reference only.
7) Weight: 4.8 oz (136 g)
8) Threaded and Non-Threaded options available
9) All dimensions in inches (mm).

Tolerances:
- x.xx +/-0.02 in. (x.x +/-0.5mm)
- x.xxx +/-0.010 in. (x.xx +/-0.25mm)

unless otherwise noted.

10) Workmanship: Meets or exceeds IPC-A-610C Class II

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**PIN DESIGNATIONS**

<table>
<thead>
<tr>
<th>Pin</th>
<th>Name</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>VOUT+</td>
<td>Positive Output Voltage</td>
</tr>
<tr>
<td>2</td>
<td>VOUT-</td>
<td>Negative Output Voltage</td>
</tr>
<tr>
<td>3</td>
<td>L1</td>
<td>AC Line 1</td>
</tr>
<tr>
<td>4</td>
<td>PFC ENA</td>
<td>Negative Logic PFC Enable, Referenced to HU-</td>
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<tr>
<td>5</td>
<td>L2/N</td>
<td>AC Line 2 / Neutral</td>
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<tr>
<td>6</td>
<td>AC GOOD</td>
<td>Negative Logic AC Good Signal, Referenced to HU-</td>
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<tr>
<td>7</td>
<td>DC GOOD</td>
<td>Negative Logic DC Good Signal, Referenced to HU-</td>
</tr>
<tr>
<td>8</td>
<td>AUX</td>
<td>Auxiliary Bias Power Supply, Referenced to HU-</td>
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<tr>
<td>9</td>
<td>HU-</td>
<td>Negative Hold-up Voltage</td>
</tr>
<tr>
<td>10</td>
<td>HU+</td>
<td>Positive Hold-up Voltage</td>
</tr>
</tbody>
</table>
NOTES
1) Applied torque per M3 or 4-40 screw should not exceed 6 in-lb. (0.7 Nm).
2) Baseplate flatness tolerance is 0.010" (2.2mm) TIR for surface.
3) Pins 1 and 2 are 0.062" (1.57mm) diameter with 0.100" (2.54mm) diameter standoff shoulder.
4) Pins 3-10 are 0.040" (1.02mm) diameter, with 0.080" (2.03mm) diameter standoff shoulders.
5) All Pins: Material - Copper Alloy; Finish - Matte Tin over Nickel plate.
6) Undimensioned components are shown for visual reference only.
7) Weight: 5.0 oz (142 g).
8) All dimensions in inches (mm).
   Tolerances:
   x.xx  +/-0.02 in.  (x.x  +/-0.5mm)
   x.xxx  +/-0.010 in.  (x.xx  +/-0.25mm)
   unless otherwise noted.
9) Workmanship: Meets or exceeds IPC-A-610C Class II.
Ordering Information

Ordering Information / Part Numbering Scheme

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<tr>
<th>Family</th>
<th>Input Voltage</th>
<th>Output Voltage</th>
<th>Package Size</th>
<th>Thermal Design</th>
<th>Screening Level</th>
<th>Option</th>
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<td></td>
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<td>HT: Half-brick Tera</td>
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<td>N: Encased</td>
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<td></td>
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<td></td>
<td>D: Encased with Non-threaded Baseplate</td>
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<td></td>
<td>M: M-Grade</td>
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<td>D: Droop</td>
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</tbody>
</table>

Example: MPFIC-U-28-HT-N-M

PART NUMBERING SYSTEM

The part numbering system for SynQor’s ac-dc converters follows the format shown in the example.

APPLICATION NOTES

A variety of application notes and technical white papers can be downloaded in pdf format from our website.

STANDARDS COMPLIANCE

Input to output isolation 4250Vdc
Input/Output to baseplate isolation 2150Vdc
CE Marked

Reinforced Insulation
Basic Insulation to Baseplate

Note: An external input fuse must always be used to meet these safety requirements.

Contact SynQor for official safety certificates on new releases or download from the SynQor website.

PATENTS

SynQor holds numerous U.S. patents, one or more of which apply to most of its power conversion products. Any that apply to the product(s) listed in this document are identified by markings on the product(s) or on internal components of the product(s) in accordance with U.S. patent laws. SynQor’s patents include the following:

6,545,890 6,894,468 6,896,526 6,927,987 7,050,309 7,085,146
7,119,524 7,765,687 7,787,261 8,149,597 8,644,027

WARRANTY

SynQor offers a two (2) year limited warranty. Complete warranty information is listed on our website or is available upon request from SynQor.