FEATURES

- 40 Vdc to 3.3 Vdc 25 A transformer
  - Operating from standard 48 V or 24 V PRM™ regulators
- High efficiency (>93%) reduces system power consumption
- High density (167 A/in³)
- “Half Chip” V•I Chip package enables surface mount, low impedance interconnect to system board
- Contains built-in protection features:
  - Overvoltage Lockout
  - Overcurrent
  - Short Circuit
  - Over Temperature

- Provides enable / disable control, internal temperature monitoring, current monitoring
- ZVS / ZCS resonant Sine Amplitude Converter topology
- Less than 50°C temperature rise at full load in typical applications

TYPICAL APPLICATIONS

- High End Computing Systems
- Automated Test Equipment
- High Density Power Supplies
- Communications Systems

DESCRIPTION

The V•I Chip™ transformer is a high efficiency (>93%) Sine Amplitude Converter™ (SAC™) operating from a 26 to 55 Vdc primary bus to deliver an isolated output. The Sine Amplitude Converter offers a low AC impedance beyond the bandwidth of most downstream regulators, which means that capacitance normally at the load can be located at the input to the Sine Amplitude Converter. Since the K factor of the VIV0104THJ is 1/12, that capacitance value can be reduced by a factor of 144, resulting in savings of board area, materials and total system cost.

The VIV0104THJ is provided in a V•I Chip package compatible with standard pick-and-place and surface mount assembly processes. The co-molded V•I Chip package provides enhanced thermal management due to large thermal interface area and superior thermal conductivity. With high conversion efficiency the VIV0104THJ increases overall system efficiency and lowers operating costs compared to conventional approaches. The VIV0104THJ enables the utilization of Factorized Power Architecture™ providing efficiency and size benefits by lowering conversion and distribution losses and promoting high density point of load conversion.

\[
\begin{align*}
V_{IN} &= 26 \text{ to } 55 \text{ V} & I_{OUT} &= 25 \text{ A (nom)} \\
V_{OUT} &= 2.2 \text{ to } 4.6 \text{ V (no load)} & K &= 1/12
\end{align*}
\]

<table>
<thead>
<tr>
<th>PART NUMBER</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>VIV0104THJ</td>
<td>-40°C to 125°C Tj</td>
</tr>
<tr>
<td>VIV0104MHJ</td>
<td>-55°C to 125°C Tj</td>
</tr>
</tbody>
</table>

SEE APPLICATION NOTE AN-024
1.0 ABSOLUTE MAXIMUM VOLTAGE RATINGS

The absolute maximum ratings below are stress ratings only. Operation at or beyond these maximum ratings can cause permanent damage to the device.

<table>
<thead>
<tr>
<th>ATTRIBUTE</th>
<th>SYMBOL</th>
<th>CONDITIONS / NOTES</th>
<th>MIN</th>
<th>MAX</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>+ IN to - IN</td>
<td>+ IN</td>
<td>No external VC applied</td>
<td>-1.0</td>
<td>60</td>
<td>VDC</td>
</tr>
<tr>
<td>PC to - IN</td>
<td>PC</td>
<td>VC applied</td>
<td>0</td>
<td>3.15</td>
<td>VDC</td>
</tr>
<tr>
<td>TM to - IN</td>
<td>TM</td>
<td>+ IN / - IN to + OUT / - OUT (hipot)</td>
<td>0</td>
<td>2250</td>
<td>VDC</td>
</tr>
<tr>
<td>VC to - IN</td>
<td>VC</td>
<td>+ IN / - IN to + OUT / - OUT (working)</td>
<td>0</td>
<td>60</td>
<td>VDC</td>
</tr>
<tr>
<td>+ OUT to - OUT</td>
<td>OUT</td>
<td>+ OUT to - OUT</td>
<td>-1.0</td>
<td>10</td>
<td>VDC</td>
</tr>
</tbody>
</table>

2.0 ELECTRICAL CHARACTERISTICS

Specifications apply over all line and load conditions unless otherwise noted; Boldface specifications apply over the temperature range of -40°C < TJ < 125°C (T-Grade); All other specifications are at TJ = 25°C unless otherwise noted.

<table>
<thead>
<tr>
<th>ATTRIBUTES</th>
<th>SYMBOL</th>
<th>CONDITIONS / NOTES</th>
<th>MIN</th>
<th>MAX</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input Voltage Range</td>
<td>V IN</td>
<td>No external VC applied</td>
<td>26</td>
<td>55</td>
<td>VDC</td>
</tr>
<tr>
<td>V IN Slew Rate</td>
<td>dV IN/dt</td>
<td>Module latched shutdown, No external VC applied, I OUT = 25A</td>
<td>1</td>
<td>19</td>
<td>V/µs</td>
</tr>
<tr>
<td>VIN UV Turn Off</td>
<td>V IN_UV</td>
<td>26.0</td>
<td>25ºC</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No Load Power Dissipation</td>
<td>P NL</td>
<td>VIN = 42 V</td>
<td>1.2</td>
<td>4.0</td>
<td>W</td>
</tr>
<tr>
<td>Inrush Current Peak</td>
<td>I INRP</td>
<td>VC enable, VIN = 42 V C OUT = 4000 µF, R LOAD = 134 mΩ</td>
<td>7.3</td>
<td>12</td>
<td>A</td>
</tr>
<tr>
<td>DC Input Current</td>
<td>I IN_DC</td>
<td>3</td>
<td>12</td>
<td>A</td>
<td></td>
</tr>
<tr>
<td>Transfer Ratio</td>
<td>K</td>
<td>K = V OUT/V IN, I OUT = 0 A</td>
<td>1/12</td>
<td>1</td>
<td>V/V</td>
</tr>
<tr>
<td>Output Voltage</td>
<td>V OUT</td>
<td>V OUT = V IN • K - I OUT • R OUT, Section 11</td>
<td>25</td>
<td>4.0</td>
<td>A</td>
</tr>
<tr>
<td>Output Current (Average)</td>
<td>I OUT_AVG</td>
<td>T PEAK &lt; 10 ms, I OUT_AVG ≤ 25 A</td>
<td>37.5</td>
<td>115</td>
<td>A</td>
</tr>
<tr>
<td>Output Current (Peak)</td>
<td>I OUT_PK</td>
<td>90.5</td>
<td>92.4</td>
<td>%</td>
<td></td>
</tr>
<tr>
<td>Output Power (Average)</td>
<td>P OUT_AVG</td>
<td>90.4</td>
<td>92.3</td>
<td>%</td>
<td></td>
</tr>
<tr>
<td>Efficiency (Ambient)</td>
<td>η AMB</td>
<td>V IN = 42 V, I OUT = 25 A</td>
<td>90.3</td>
<td>91.8</td>
<td>%</td>
</tr>
<tr>
<td>Efficiency (Over Load Range)</td>
<td>η 20%</td>
<td>V IN = 42 V, I OUT = 25 A</td>
<td>81.0</td>
<td>85.7</td>
<td>%</td>
</tr>
<tr>
<td>Output Resistance (Cold)</td>
<td>R OUT_COLD</td>
<td>5 A &lt; I OUT &lt; 25 A</td>
<td>4.2</td>
<td>5.3</td>
<td>mΩ</td>
</tr>
<tr>
<td>Output Resistance (Ambient)</td>
<td>R OUT_AMB</td>
<td>5.0</td>
<td>6.2</td>
<td>mΩ</td>
<td></td>
</tr>
<tr>
<td>Output Resistance (Hot)</td>
<td>R OUT_HOT</td>
<td>5.8</td>
<td>7.3</td>
<td>mΩ</td>
<td></td>
</tr>
<tr>
<td>Switching Frequency</td>
<td>F SW</td>
<td>1.50</td>
<td>1.80</td>
<td>MHz</td>
<td></td>
</tr>
<tr>
<td>Output Ripple Frequency</td>
<td>F OUT_RP</td>
<td>3.00</td>
<td>3.60</td>
<td>MHz</td>
<td></td>
</tr>
<tr>
<td>Output Voltage Ripple</td>
<td>V OUT_RP</td>
<td>C OUT = 0 f, I OUT = 25 A, V IN = 42 V, 20 MHz BW, Section 12</td>
<td>88</td>
<td>400</td>
<td>mΩ</td>
</tr>
<tr>
<td>Output Inductance (Parasitic)</td>
<td>L OUT_PAR</td>
<td>Frequency up to 30 MHz, Simulated J-lead model</td>
<td>600</td>
<td>pH</td>
<td></td>
</tr>
<tr>
<td>Output Capacitance (Internal)</td>
<td>C OUT_INT</td>
<td>V OUT = 3.3 V</td>
<td>68</td>
<td>µF</td>
<td></td>
</tr>
<tr>
<td>Output Capacitance (External)</td>
<td>C OUT_EXT</td>
<td>VTM Standalone Operation</td>
<td>4000</td>
<td>µF</td>
<td></td>
</tr>
</tbody>
</table>

PROTECTION

| OVLO | V IN_OVLO+ | Module latched shutdown | 55.5 | 57.2 | 59.8 | V |
| Overvoltage Lockout Response Time | T OVLDO | Effective internal RC filter | 2.4 | µs |
| Output Overcurrent Trip | I OCP | 30 | 55 | 90 | A |
| Short Circuit Protection Trip Current | I SCP | 40 | A |
| Output Overcurrent Response Time Constant | T OCP | Effective internal RC filter (Integrative). | 6.6 | ms |
| Short Circuit Protection Response Time | T SCP | From detection to cessation of switching (Instantaneous) | 1 | µs |
| Thermal Shutdown Setpoint | T J_OTP | 125 | 130 | 135 | ºC |
### 3.0 SIGNAL CHARACTERISTICS

Specifications apply over all line and load conditions unless otherwise noted; **Boldface** specifications apply over the temperature range of -40°C < T<sub>J</sub> < 125°C (T-Grade); All other specifications are at T<sub>J</sub> = 25°C unless otherwise noted.

#### VTM CONTROL : VC

- **Steady**
  - **External VC Voltage** \( V_{VC_{-EXT}} \)
    - Required for startup, and operation below 26 V. See Section 7.
    - Min: 12 V, Typ: 16.5 V, Max: 16.5 V
  - **VC Current Draw Threshold** \( I_{VC_{-TH}} \)
    - Low VC current draw for \( V_{IN} > 26 \) V
    - VC = 13 V, \( V_{IN} = 0 \) V
    - 90 mA
  - **VC Current Draw** \( I_{VC} \)
    - VC = 16.5 V, \( V_{IN} > 26 \) V
    - 150 mA
  - **VC Internal Resistor** \( R_{VC_{-INT}} \)
    - 8.87 kΩ

#### PRIMARY CONTROL : PC

- **Steady**
  - **PC Voltage** \( V_{PC} \)
    - Internal pull down resistor
    - Min: 4.7 V, Typ: 5.0 V, Max: 5.3 V

#### TEMPORATURE MONITOR : TM

- **Steady**
  - **TM Voltage** \( V_{TM_{-AMB}} \)
    - Controller = 27°C
    - Min: 2.95 V, Typ: 3.00 V, Max: 3.05 V
3.0 SIGNAL CHARACTERISTICS (CONT.)
Specifications apply over all line and load conditions unless otherwise noted; **Boldface** specifications apply over the temperature range of -40°C < T<sub>J</sub> < 125°C (T-Grade); All other specifications are at T<sub>J</sub> = 25°C unless otherwise noted.

**CURRENT MONITOR : IM**
- The nominal IM pin voltage varies between 0.2 V and 1.39 V representing the output current within ±25% under all operating line temperature conditions between 50% and 100%.
- The IM pin provides a DC analog voltage proportional to the output current of the VTM.

<table>
<thead>
<tr>
<th>SIGNAL TYPE</th>
<th>STATE</th>
<th>ATTRIBUTE</th>
<th>SYMBOL</th>
<th>CONDITIONS / NOTES</th>
<th>MIN</th>
<th>TYP</th>
<th>MAX</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>ANALOG OUTPUT</td>
<td>Steady</td>
<td>IM Voltage (No Load)</td>
<td>V&lt;sub&gt;IM_NL&lt;/sub&gt;</td>
<td>TC = 25°C, VIN = 42 V, I&lt;sub&gt;OUT&lt;/sub&gt; = 0 A</td>
<td>0.14</td>
<td>0.2</td>
<td>0.28</td>
<td>V</td>
</tr>
<tr>
<td></td>
<td></td>
<td>IM Voltage (50%)</td>
<td>V&lt;sub&gt;IM_50%&lt;/sub&gt;</td>
<td>TC = 25°C, VIN = 42 V, I&lt;sub&gt;OUT&lt;/sub&gt; = 12.5 A</td>
<td>0.67</td>
<td></td>
<td></td>
<td>V</td>
</tr>
<tr>
<td></td>
<td></td>
<td>IM Voltage (Full Load)</td>
<td>V&lt;sub&gt;IM_FL&lt;/sub&gt;</td>
<td>TC = 25°C, VIN = 42 V, I&lt;sub&gt;OUT&lt;/sub&gt; = 25 A</td>
<td>1.39</td>
<td></td>
<td></td>
<td>V</td>
</tr>
<tr>
<td></td>
<td></td>
<td>IM Gain</td>
<td>A&lt;sub&gt;IM&lt;/sub&gt;</td>
<td>TC = 25°C, VIN = 42 V, I&lt;sub&gt;OUT&lt;/sub&gt; &gt; 12.5 A</td>
<td>58</td>
<td>mV/A</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>IM Resistance (External)</td>
<td>R&lt;sub&gt;IM_EXT&lt;/sub&gt;</td>
<td>TC = 25°C, VIN = 42 V, I&lt;sub&gt;OUT&lt;/sub&gt; &gt; 12.5 A</td>
<td>2.5</td>
<td></td>
<td></td>
<td>MΩ</td>
</tr>
</tbody>
</table>

4.0 TIMING DIAGRAM

---

Notes:
- Timing and voltage is not to scale
- Error pulse width is load dependent
5.0 APPLICATION CHARACTERISTICS

The following values, typical of an application environment, are collected at $T_C = 25^\circ C$ unless otherwise noted. See associated figures for general trend data.

<table>
<thead>
<tr>
<th>ATTRIBUTE</th>
<th>SYMBOL</th>
<th>CONDITIONS / NOTES</th>
<th>TYP</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Load Power Dissipation</td>
<td>$P_{NL}$</td>
<td>$V_{IN} = 42 , V$</td>
<td>2.5</td>
<td>W</td>
</tr>
<tr>
<td>Efficiency (Ambient)</td>
<td>$\eta_{AMB}$</td>
<td>$V_{IN} = 42 , V$, $I_{OUT} = 25 , A$</td>
<td>92.3</td>
<td>%</td>
</tr>
<tr>
<td>Efficiency (Hot)</td>
<td>$\eta_{HOT}$</td>
<td>$V_{IN} = 42 , V$, $I_{OUT} = 25 , A$, $T_C = 100^\circ C$</td>
<td>91.4</td>
<td>%</td>
</tr>
<tr>
<td>Output Resistance (Ambient)</td>
<td>$R_{OUT,AMB}$</td>
<td>$V_{IN} = 42 , V$, $I_{OUT} = 25 , A$</td>
<td>6.3</td>
<td>m$\Omega$</td>
</tr>
<tr>
<td>Output Resistance (Hot)</td>
<td>$R_{OUT,HOT}$</td>
<td>$V_{IN} = 42 , V$, $I_{OUT} = 25 , A$, $T_C = 100^\circ C$</td>
<td>7.7</td>
<td>m$\Omega$</td>
</tr>
<tr>
<td>Output Resistance (Cold)</td>
<td>$R_{OUT,COLD}$</td>
<td>$V_{IN} = 42 , V$, $I_{OUT} = 25 , A$, $T_C = -40^\circ C$</td>
<td>5.5</td>
<td>m$\Omega$</td>
</tr>
<tr>
<td>Output Voltage Ripple</td>
<td>$V_{OUT,pp}$</td>
<td>$C_{OUT} = 0 , F$, $I_{OUT} = 25 , A$, $V_{IN} = 42 , V$, 20 MHz BW, Section 12</td>
<td>229</td>
<td>mV</td>
</tr>
<tr>
<td>$V_{OUT}$ Transient (Positive)</td>
<td>$V_{OUT,TRAN+}$</td>
<td>$I_{OUT,STEP} = 0 , A$ TO $25A$, $V_{IN} = 42 , V$, $I_{SLEW} &gt; 10 , A/\mu s$</td>
<td>175</td>
<td>mV</td>
</tr>
<tr>
<td>$V_{OUT}$ Transient (Negative)</td>
<td>$V_{OUT,TRAN-}$</td>
<td>$I_{OUT,STEP} = 25 , A$ TO $0 , A$, $V_{IN} = 42 , V$, $I_{SLEW} &gt; 10 , A/\mu s$</td>
<td>175</td>
<td>mV</td>
</tr>
</tbody>
</table>

Figure 1 – No load power dissipation vs. $V_{IN}$

Figure 2 – Full load efficiency vs. temperature

Figure 3 – Efficiency and power dissipation at $-40^\circ C$

Figure 4 – Efficiency and power dissipation at $25^\circ C$
Figure 5 – Efficiency and power dissipation at 100°C

Figure 6 – ROUT vs. temperature

Figure 7 – V_RIPPLE vs. I_OUT; No external C_OUT. Board mounted module, scope setting: 20 MHz analog BW

Figure 8 – IM voltage vs. load

Figure 9 – IM voltage vs. load

Figure 10 – Full load IM voltage vs. T_CASE
Figure 11 – Safe operating area

Figure 12 – Full load ripple, 100 µF CIN; No external COUT.
Board mounted module, scope setting: 20 MHz analog BW

Figure 13 – Start up from application of VIN; VC pre-applied
COUT = 0 µF

Figure 14 – Start up from application of VC; VIN pre-applied
COUT = 0 µF

Figure 15 – 0 A – 25 A transient response:
CIN = 100 µF; no external COUT

Figure 16 – 25 A – 0 A transient response:
CIN = 100 µF; no external COUT
# 6.0 General Characteristics

Specifications apply over all line and load conditions unless otherwise noted; **Boldface** specifications apply over the temperature range of -40°C < T<sub>J</sub> < 125°C (T-Grade); All Other specifications are at T<sub>J</sub> = 25°C unless otherwise noted.

<table>
<thead>
<tr>
<th>ATTRIBUTE</th>
<th>SYMBOL</th>
<th>CONDITIONS / NOTES</th>
<th>MIN</th>
<th>TYP</th>
<th>MAX</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MECHANICAL</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Length</td>
<td>L</td>
<td></td>
<td>21.7 / [0.85]</td>
<td>22.0 / [0.87]</td>
<td>22.3 / [0.88]</td>
<td>mm/in</td>
</tr>
<tr>
<td>Width</td>
<td>W</td>
<td></td>
<td>16.4 / [0.64]</td>
<td>16.5 / [0.65]</td>
<td>16.6 / [0.66]</td>
<td>mm/in</td>
</tr>
<tr>
<td>Height</td>
<td>H</td>
<td></td>
<td>6.48 / [0.255]</td>
<td>6.73 / [0.265]</td>
<td>6.98 / [0.275]</td>
<td>mm/in</td>
</tr>
<tr>
<td>Volume</td>
<td>Vol</td>
<td>No heat sink</td>
<td>2.44 / [0.150]</td>
<td></td>
<td></td>
<td>cm³/in³</td>
</tr>
<tr>
<td>Weight</td>
<td>W</td>
<td></td>
<td>8.0 / 0.28</td>
<td></td>
<td></td>
<td>g/oz</td>
</tr>
<tr>
<td>Lead Finish</td>
<td></td>
<td>Nickle</td>
<td>0.51</td>
<td>2.03</td>
<td></td>
<td>µm</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Palladium</td>
<td>0.02</td>
<td>0.15</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Gold</td>
<td>0.003</td>
<td>0.051</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>THERMAL</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operating Tempe</td>
<td>T&lt;sub&gt;J&lt;/sub&gt;</td>
<td>VIV0104THJ (T-Grade)</td>
<td>-40</td>
<td>125</td>
<td></td>
<td>°C</td>
</tr>
<tr>
<td></td>
<td></td>
<td>VIV0104MHJ (M-Grade)</td>
<td>-55</td>
<td>125</td>
<td></td>
<td>°C</td>
</tr>
<tr>
<td>Thermal Capacity</td>
<td></td>
<td></td>
<td>5</td>
<td></td>
<td></td>
<td>Ws/°C</td>
</tr>
<tr>
<td><strong>ASSEMBLY</strong></td>
<td></td>
<td>Supported by J-lead only</td>
<td></td>
<td>2.5</td>
<td>3</td>
<td>lbs</td>
</tr>
<tr>
<td>Storage Temper</td>
<td>T&lt;sub&gt;ST&lt;/sub&gt;</td>
<td>VIV0104THJ (T-Grade)</td>
<td>-40</td>
<td>125</td>
<td></td>
<td>°C</td>
</tr>
<tr>
<td></td>
<td></td>
<td>VIV0104MHJ (M-Grade)</td>
<td>-65</td>
<td>125</td>
<td></td>
<td>°C</td>
</tr>
<tr>
<td>ESD Withstand</td>
<td>ESD&lt;sub&gt;HBM&lt;/sub&gt;</td>
<td>Human Body Model, <em>JEDEC JESD 22-A114C.01</em></td>
<td>1500</td>
<td></td>
<td></td>
<td>V&lt;sub&gt;DC&lt;/sub&gt;</td>
</tr>
<tr>
<td></td>
<td>ESD&lt;sub&gt;MM&lt;/sub&gt;</td>
<td>Machine Model, <em>JEDEC JESD 22-A115-A</em></td>
<td>400</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>SOLDERING</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Peak Temperature During Reflow</td>
<td>MSL 5</td>
<td>225 °C</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>MSL 6, TOB = 4hrs</td>
<td>245 °C</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Peak Time Above 183°C</td>
<td></td>
<td>150 s</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Peak Heating Rate During Reflow</td>
<td>1.5</td>
<td>3 °C/s</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Peak Cooling Rate Post Reflow</td>
<td>1.5</td>
<td>6 °C/s</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>SAFETY</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Working Voltage (IN – OUT)</td>
<td>V&lt;sub&gt;IN, OUT&lt;/sub&gt;</td>
<td></td>
<td>60 V&lt;sub&gt;DC&lt;/sub&gt;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Isolation Voltage (hipot)</td>
<td>V&lt;sub&gt;HIPOT&lt;/sub&gt;</td>
<td></td>
<td>2250 V&lt;sub&gt;DC&lt;/sub&gt;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Isolation Capacitance</td>
<td>C&lt;sub&gt;IN, OUT&lt;/sub&gt;</td>
<td>Unpowered Unit</td>
<td>1350 pF</td>
<td>1750 pF</td>
<td>2150 pF</td>
<td></td>
</tr>
<tr>
<td>Isolation Resistance</td>
<td>R&lt;sub&gt;IN, OUT&lt;/sub&gt;</td>
<td></td>
<td>10 MΩ</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MTBF</td>
<td></td>
<td>MIL HDBK 217, 25°C, Ground Benign</td>
<td></td>
<td>4.5</td>
<td></td>
<td>Mhrs</td>
</tr>
<tr>
<td>Agency Approvals / Standards</td>
<td>cTUVus</td>
<td>cCURus</td>
<td>CE Mark</td>
<td>RoHS 6 of 6</td>
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7.0 USING THE CONTROL SIGNALS VC, PC, TM, IM

The VTM Control (VC) pin is an input pin which powers the internal VCC circuitry when within the specified voltage range of 12 V to 16.5 V. This voltage is required in order for the VTM to start, and must be applied as long as the input is below 26 V. In order to ensure a proper start, the slew rate of the applied voltage must be within the specified range.

Some additional notes on the using the VC pin:
- In most applications, the VTM will be powered by an upstream PRM which provides a 10 ms VC pulse during startup. In these applications the VC pins of the PRM and VTM should be tied together.
- The VC voltage can be applied indefinitely allowing for continuous operation down to 0 Vn.
- The fault response of the VTM is latching. A positive edge on VC is required in order to restart the unit. If VC is continuously applied the PC pin may be toggled to restart the VTM.

Primary Control (PC) pin can be used to accomplish the following functions:
- Delayed start: Upon the application of VC, the PC pin will source a constant 100 μA current to the internal RC network. Adding an external capacitor will allow further delay in reaching the 2.5 V threshold for module start.
- Auxiliary voltage source: Once enabled in regular operational conditions (no fault), each VTM PC provides a regulated 5 V, 2 mA voltage source.
- Output disable: PC pin can be actively pulled down in order to disable the module. Pull down impedance shall be lower than 400 Ω.
- Fault detection flag: The PC 5 V voltage source is internally turned off as soon as a fault is detected. It is important to notice that PC doesn’t have current sink capability. Therefore, in an array, PC line will not be capable of disabling neighboring modules if a fault is detected.
- Fault reset: PC may be toggled to restart the unit if VC is continuously applied.

Temperature Monitor (TM) pin provides a voltage proportional to the absolute temperature of the converter control IC.

It can be used to accomplish the following functions:
- Monitor the control IC temperature: The temperature in Kelvin is equal to the voltage on the TM pin scaled by 100. (i.e. 3.0 V = 300 K = 27° C). If a heat sink is applied, TM can be used to thermally protect the system.
- Fault detection flag: The TM voltage source is internally turned off as soon as a fault is detected. For system monitoring purposes (microcontroller interface) faults are detected on falling edges of TM signal.

Current Monitor (IM) pin provides a voltage proportional to the output current of the VTM. The nominal voltage will vary between 0.2 V and 1.39 V over the output current range of the VTM (See Figures 8–10). The accuracy of the IM pin will be within 25% under all line and temperature conditions between 50% and 100% load.

8.0 STARTUP BEHAVIOR

Depending on the sequencing of the VC with respect to the input voltage, the behavior during startup will vary as follows:
- Normal Operation (VC applied prior to Vin): In this case the controller is active prior to ramping the input. When the input voltage is applied, the VTM output voltage will track the input (See Figure 13). The inrush current is determined by the input voltage rate of rise and output capacitance. If the VC voltage is removed prior to the input reaching 26 V, the VTM may shut down.
- Stand Alone Operation (VC applied after Vin): In this case the VTM output will begin to rise upon the application of the VC voltage (See Figure 14). The Adaptive Soft Start circuit (See Section 10) may vary the output rate of rise in order to limit the inrush current to its maximum level. When starting into high capacitance, or a short, the output current will be limited for a maximum of 900 μsec. After this period, the adaptive soft start circuit will time out and the VTM may shut down. No restart will be attempted until VC is re-applied, or PC is toggled. The maximum output capacitance is limited to 4000 μF in this mode of operation to ensure a sucessful start.

9.0 THERMAL CONSIDERATIONS

V•I Chip products are multi-chip modules whose temperature distribution varies greatly for each part number as well as with the input / output conditions, thermal management and environmental conditions. Maintaining the top of the VIV0104THJ case to less than 100ºC will keep all junctions within the V•I Chip below 125ºC for most applications. The percent of total heat dissipated through the top surface versus through the J-lead is entirely dependent on the particular mechanical and thermal environment. The heat dissipated through the top surface is typically 60%. The heat dissipated through the J-lead onto the PCB board surface is typically 40%. Use 100% top surface dissipation when designing for a conservative cooling solution.

It is not recommended to use a V•I Chip for an extended period of time at full load without proper heatsinking.
10.0 VIV0104THJ VTM BLOCK DIAGRAM
11.0 SINE AMPLITUDE CONVERTER POINT OF LOAD CONVERSION

The Sine Amplitude Converter (SAC) uses a high frequency resonant tank to move energy from input to output. (The resonant tank is formed by $C_r$ and leakage inductance $L_r$ in the power transformer windings as shown in the VTM Block Diagram. See Section 10). The resonant LC tank, operated at high frequency, is amplitude modulated as function of input voltage and output current. A small amount of capacitance embedded in the input and output stages of the module is sufficient for full functionality and is key to achieving power density.

The VIV0104THJ SAC can be simplified into the following model:

At no load:

$$V_{OUT} = V_{IN} \cdot K \quad (1)$$

$K$ represents the “turns ratio” of the SAC.

Rearranging Eq (1):

$$K = \frac{V_{OUT}}{V_{IN}} \quad (2)$$

In the presence of load, $V_{OUT}$ is represented by:

$$V_{OUT} = V_{IN} \cdot K - I_{OUT} \cdot R_{OUT} \quad (3)$$

and $I_{OUT}$ is represented by:

$$I_{OUT} = \frac{I_{IN} - I_Q}{K} \quad (4)$$

$R_{OUT}$ represents the impedance of the SAC, and is a function of the $R_{DSON}$ of the input and output MOSFETs and the winding resistance of the power transformer. $I_Q$ represents the quiescent current of the SAC control and gate drive circuitry.

The use of DC voltage transformation provides additional interesting attributes. Assuming for the moment that

$R_{OUT} = 0 \, \Omega$ and $I_Q = 0 \, A$, Eq. (3) now becomes Eq. (1) and is essentially load independent. A resistor $R$ is now placed in series with $V_{IN}$ as shown in Figure 18.

The relationship between $V_{IN}$ and $V_{OUT}$ becomes:

$$V_{OUT} = (V_{IN} - I_{IN} \cdot R) \cdot K \quad (5)$$

Substituting the simplified version of Eq. (4) ($I_Q$ is assumed = 0 A) into Eq. (5) yields:

$$V_{OUT} = V_{IN} \cdot K - I_{OUT} \cdot R \cdot K^2 \quad (6)$$
This is similar in form to Eq. (3), where $R_{OUT}$ is used to represent the characteristic impedance of the SAC. However, in this case a real $R$ on the input side of the SAC is effectively scaled by $K^2$ with respect to the output.

Assuming that $R = 1 \, \Omega$, the effective $R$ as seen from the secondary side is $0.98 \, m\Omega$, with $K = 1/32$ as shown in Figure 18.

A similar exercise should be performed with the addition of a capacitor, or shunt impedance, at the input to the SAC. A switch in series with $V_{IN}$ is added to the circuit. This is depicted in Figure 19.

![Figure 19 – Sine Amplitude Converter with input capacitor](image)

A change in $V_{IN}$ with the switch closed would result in a change in capacitor current according to the following equation:

$$I_C(t) = C \frac{dV_{IN}}{dt} \quad (7)$$

Assume that with the capacitor charged to $V_{IN}$, the switch is opened and the capacitor is discharged through the idealized SAC. In this case,

$$I_C = I_{OUT} \cdot K \quad (8)$$

Substituting Eq. (1) and (8) into Eq. (7) reveals:

$$I_{OUT} = \frac{C}{K^2} \cdot \frac{dV_{OUT}}{dt} \quad (9)$$

Writing the equation in terms of the output has yielded a $K^2$ scaling factor for $C$, this time in the denominator of the equation. For a $K$ factor less than unity, this results in an effectively larger capacitance on the output when expressed in terms of the input. With a $K = 1/32$ as shown in Figure 19, $C = 1 \, \mu F$ would effectively appear as $C = 1024 \, \mu F$ when viewed from the output.

Low impedance is a key requirement for powering a high current, low voltage load efficiently. A switching regulation stage should have minimal impedance, while simultaneously providing appropriate filtering for any switched current. The use of a SAC between the regulation stage and the point of load provides a dual benefit, scaling down series impedance leading back to the source and scaling up shunt capacitance (or energy storage) as a function of its $K$ factor squared. However, these benefits are not useful if the series impedance of the SAC is too high. The impedance of the SAC must be low well beyond the crossover frequency of the system.

A solution for keeping the impedance of the SAC low involves switching at a high frequency. This enables magnetic components to be small since magnetizing currents remain low. Small magnetics mean small path lengths for turns. Use of low loss core material at high frequencies reduces core losses as well.

The two main terms of power loss in the VTM module are:
- No load power dissipation ($P_{NL}$): defined as the power used to power up the module with an enabled power train at no load.
- Resistive loss ($R_{OUT}$): refers to the power loss across the VTM modeled as pure resistive impedance.

$$P_{DISSIPATED} = P_{NL} + P_{ROUT} \quad (10)$$

Therefore,

$$P_{OUT} = P_{IN} - P_{DISSIPATED} = P_{IN} - P_{NL} - P_{ROUT} \quad (11)$$

The above relations can be combined to calculate the overall module efficiency:

$$\eta = \frac{P_{OUT}}{P_{IN}} = \frac{P_{IN} - P_{NL} - P_{ROUT}}{P_{IN}} \quad (12)$$

$$\eta = \frac{V_{IN} \cdot I_{IN} - P_{NL} - (I_{OUT})^2 \cdot R_{OUT}}{V_{IN} \cdot I_{IN}}$$

$$\quad = 1 - \left( \frac{P_{NL} + (I_{OUT})^2 \cdot R_{OUT}}{V_{IN} \cdot I_{IN}} \right)$$
12.0 INPUT AND OUTPUT FILTER DESIGN

A major advantage of a SAC system versus a conventional PWM converter is that the former does not require large functional filters. The resonant LC tank, operated at extreme high frequency, is amplitude modulated as a function of input voltage and output current and efficiently transfers charge through the isolation transformer. A small amount of capacitance embedded in the input and output stages of the module is sufficient for full functionality and is key to achieving high power density.

This paradigm shift requires system design to carefully evaluate external filters in order to:

   To take full advantage of the VTM dynamic response, the impedance presented to its input terminals must be low from DC to approximately 5 MHz. Input capacitance may be added to improve transient performance or compensate for high source impedance.

2. Further reduce input and/or output voltage ripple without sacrificing dynamic response.
   Given the wide bandwidth of the VTM, the source response is generally the limiting factor in the overall system response. Anomalies in the response of the source will appear at the output of the VTM multiplied by its K factor.

3. Protect the module from overvoltage transients imposed by the system that would exceed maximum ratings and cause failures.
   The V•I Chip input/output voltage ranges must not be exceeded. An internal overvoltage lockout function prevents operation outside of the normal operating input range. Even during this condition, the powertrain is exposed to the applied voltage and power MOSFETs must withstand it.

13.0 CAPACITIVE FILTERING CONSIDERATIONS FOR A SINE AMPLITUDE CONVERTER

It is important to consider the impact of adding input and output capacitance to a Sine Amplitude Converter on the system as a whole. Both the capacitance value, and the effective impedance of the capacitor must be considered. A Sine Amplitude Converter has a DC ROUT value which has already been discussed in section 11. The AC ROUT of the SAC contains several terms:

- Resonant tank impedance
- Input lead inductance and internal capacitance
- Output lead inductance and internal capacitance

The values of these terms are shown in the behavioral model in section 11. It is important to note on which side of the transformer these impedances appear and how they reflect across the transformer given the K factor.

The overall AC impedance varies from model to model but for most models it is dominated by DC ROUT value from DC to beyond 500 kHz. The behavioral model in section 11 should be used to approximate the AC impedance of the specific model.

Any capacitors placed at the output of the VTM reflect back to the input of the VTM by the square of the K factor (Eq. 9) with the impedance of the VTM appearing in series. It is very important to keep this in mind when using a PRM to power the VTM. Most PRMs have a limit on the maximum amount of capacitance that can be applied to the output. This capacitance includes both the PRM output capacitance and the VTM output capacitance reflected back to the input. In PRM remote sense applications, it is important to consider the reflected value of VTM output capacitance when designing and compensating the PRM control loop.

Capacitance placed at the input of the VTM appear to the load reflected by the K factor, with the impedance of the VTM in series. In step-down VTM ratios, the effective capacitance is increased by the K factor. The effective ESR of the capacitor is decreased by the square of the K factor, but the impedance of the VTM appears in series. Still, in most step-down VTMs an electrolytic capacitor placed at the input of the VTM will have a lower effective impedance compared to an electrolytic capacitor placed at the output. This is important to consider when placing capacitors at the output of the VTM. Even though the capacitor may be placed at the output, the majority of the AC current will be sourced from the lower impedance, which in most cases will be the VTM. This should be studied carefully in any system design using a VTM. In most cases, it should be clear that electrolytic output capacitors are not necessary to design a stable, well-bypassed system.
14.0 CURRENT SHARING

The SAC topology bases its performance on efficient transfer of energy through a transformer without the need of closed loop control. For this reason, the transfer characteristic can be approximated by an ideal transformer with some resistive drop and positive temperature coefficient.

This type of characteristic is close to the impedance characteristic of a DC power distribution system, both in behavior (AC dynamic) and absolute value (DC dynamic).

When connected in an array with the same K factor, the VTM module will inherently share the load current with parallel units, according to the equivalent impedance divider that the system implements from the power source to the point of load.

Some general recommendations to achieve matched array impedances:

- Dedicate common copper planes within the PCB to deliver and return the current to the modules.
- Provide the PCB layout as symmetric as possible.
- Apply same input / output filters (if present) to each unit.

For further details see AN:016 Using BCM™ Bus Converters in High Power Arrays.

16.0 REVERSE OPERATION

The VIV0104THJ is capable of reverse operation. If a voltage is present at the output which satisfies the condition $V_{OUT} > V_{IN} \cdot K$ at the time the VC voltage is applied, or after the unit has started, then energy will be transferred from secondary to primary. The input to output ratio will be maintained. The VIV0104THJ will continue to operate in reverse as long as the input and output are within the specified limits. The VIV0104THJ has not been qualified for continuous operation (>10 ms) in the reverse direction.

For further details see AN:016 Using BCM™ Bus Converters in High Power Arrays.

15.0 FUSE SELECTION

In order to provide flexibility in configuring power systems, V•I Chip products are not internally fused. Input line fusing of V•I Chip products is recommended at system level to provide thermal protection in case of catastrophic failure.

The fuse shall be selected by closely matching system requirements with the following characteristics:

- Current rating (usually greater than maximum VTM current)
- Maximum voltage rating (usually greater than the maximum possible input voltage)
- Ambient temperature
- Nominal melting $I^2t$
17.1 MECHANICAL DRAWING

17.2 RECOMMENDED LAND PATTERN

Notes:
1. Maintain 3.50 (0.138) Dia. keep-out zone free of copper, all PCB layers.
2. (A) Minimum recommended pitch is 24.00 (0.945) this provides 7.50 (0.295) component edge-to-edge spacing, and 0.50 (0.020) clearance between Vicor heat sinks.
3. V•I Chip land pattern shown for reference only, actual land pattern may differ. Dimensions from edges of land pattern to push-pin holes will be the same for all half-size V•I Chip Products.
4. RoHS compliant per CST–0001 latest revision.
5. Unless otherwise specified:
   - Dimensions are mm (inches)
   - Tolerances are:
     - ±0.13 (0.01)
     - ±0.005
6. Plated through holes for grounding clips shown for reference. Heat sink orientation and device pitch will dictate final grounding solution.
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