Description

This reference design demonstrates a power supply system for infotainment display modules with common system requirements like cold crank, load dump, and Automotive Safety Integrity Level (ASIL). The LM74900-Q1 is the first stage of the design playing a role of protection for negative input voltage, undervoltage, locked output, and overcurrent protection. The LM5152-Q1 is the second stage to function as pre-boost controller which can boost up to a specific voltage if battery voltage is low when starting up. The device supports battery voltages down to 4.2V and 100W power output. At the third stage, the design uses LMQ644A2-Q1, TPS62813-Q1, and TPS745-Q1 to provide the desired voltage to the subsystem like local dimming backlight, TCON, and SerDes. Lastly the design uses voltage monitors to monitor each rail and to aid ISO 26262 system design to achieve the targeted ASIL.

Features

- LM74900-Q1 is the automotive ideal diode with circuit breaker, undervoltage (UV), and overvoltage (OV) protection with fault output
- LM5152-Q1 is the automotive low-I_Q synchronous boost controller for start-stop and backup battery power supply
- LMQ644A2-Q1 is the 3V to 36V, low-I_Q, dual 6A automotive buck converter optimized for power density and low EMI
- TPS37-Q1 is the wide V_IN, 65V dual channel OV and UV detector with programmable sense and reset delay function for automotive
- TPS3704-Q1 is the low V_IN automotive quad window or standard voltage supervisor
- Total 100W power rating with 4.2V battery voltage input
- Reference design aids ISO 26262 system design to achieve the targeted ASIL

Applications

- Automotive display module
Block Diagram

4.2V to 18V
LM74900-Q1  Protection
LM5152-Q1  Pre-boost
LMQ644A2-Q1

TP578B1-Q1  Standby power
3.3V

TP537A-Q1

TP53704-Q1

3.3V

Sense

TP5745-Q1

1.8V

Sense

TP5628503-Q1

1.15V

SerDes
TCON
...

SerDes/TCON

6V
Backlight

3.3V

FuSa

McU

FuSa

FuSa
1 Test Prerequisites

1.1 Voltage and Current Requirements

Table 1-1. Key System Specifications

<table>
<thead>
<tr>
<th>Device</th>
<th>Parameter</th>
<th>Value (MIN)</th>
<th>Value (TYP)</th>
<th>Value (MAX)</th>
<th>Unit</th>
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</thead>
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<tr>
<td>LM74900-Q1</td>
<td>Input voltage</td>
<td>4.2</td>
<td>13.5</td>
<td>18</td>
<td>Volt</td>
</tr>
<tr>
<td></td>
<td>Output voltage</td>
<td>4.2</td>
<td>13.5</td>
<td>18</td>
<td>Volt</td>
</tr>
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<td></td>
<td>Output current</td>
<td>24</td>
<td>7.4</td>
<td>5.55</td>
<td>Amp</td>
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<tr>
<td>LM5152-Q1</td>
<td>Input voltage</td>
<td>4.2</td>
<td>13.5</td>
<td>18</td>
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<td>8.5</td>
<td>13.5</td>
<td>18</td>
<td>Volt</td>
</tr>
<tr>
<td></td>
<td>Output current</td>
<td>11.76</td>
<td>7.4</td>
<td>5.55</td>
<td>Amp</td>
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<td></td>
<td>Switching frequency</td>
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<td></td>
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<td>kHz</td>
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<tr>
<td></td>
<td>Output voltage</td>
<td>3.3</td>
<td></td>
<td></td>
<td>Volt</td>
</tr>
<tr>
<td></td>
<td>Output current</td>
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<td>Amp</td>
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<td>Volt</td>
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<td></td>
<td>Volt</td>
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<td></td>
<td>Output current_1</td>
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<td>Output voltage_2</td>
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<td>Volt</td>
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<tr>
<td></td>
<td>Output current_2</td>
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<td>Amp</td>
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<td></td>
<td>Switching frequency</td>
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<td>kHz</td>
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<td>TPS628503-Q1</td>
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<td></td>
<td>Volt</td>
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<td></td>
<td>Output voltage</td>
<td>1.15</td>
<td></td>
<td></td>
<td>Volt</td>
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<td></td>
<td>Output current</td>
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<td>Volt</td>
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<td></td>
<td>Output voltage</td>
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<td></td>
<td>Volt</td>
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<td>Output current</td>
<td>0.5</td>
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<td></td>
<td>Amp</td>
</tr>
</tbody>
</table>

1.2 Required Equipment

- DC Source: Chroma 62006P-100-50
- DC electronic load: Chroma 6314A
- Oscilloscope: Tektronix DPO3054
- Electrical thermography: Fluke TiS55
- Digital Power meter: Yokogama WT310E
- Vector Network Analyzer: OMICRON Bode100
- Multimeter: Fluke 287C
1.3 Dimensions

The board dimensions are 137mm (length) × 90.7mm (width) × 15mm (height).

Figure 1-1. Board Dimension
2 Testing and Results

2.1 Thermal Images

LM5152-Q1 thermal images are shown in the following figures. The test conditions include room temperature with no airflow.

Figure 2-1. Thermal Image at 13.5 V\textsubscript{IN}, 13.5 V\textsubscript{OUT}, 7.4A I\textsubscript{OUT}

Figure 2-2. Thermal Image at 18 V\textsubscript{IN}, 18 V\textsubscript{OUT}, 5.55A I\textsubscript{OUT}

Figure 2-3. Thermal Image at 4.2 V\textsubscript{IN}, 8.5 V\textsubscript{OUT}, 11.76A I\textsubscript{OUT}
LM74900-Q1 thermal images are shown in the following figures. The test conditions include room temperature, no airflow.

Figure 2-4. Thermal Image at 4.2 $V_{IN}$, 4.2 $V_{OUT}$, 24A $I_{OUT}$

Figure 2-5. Thermal Image at 13.5 $V_{IN}$, 13.5 $V_{OUT}$, 7.48A $I_{OUT}$

Figure 2-6. Thermal Image at 18 $V_{IN}$, 18 $V_{OUT}$, 5.55A $I_{OUT}$
LMQ644A2-Q1 thermal images are shown in the following figures. The test conditions include room temperature, output1 3.3V, 4A, output2 6V, 6A with no airflow.

Figure 2-7. Thermal Image at 8.5 $V_{\text{IN}}$

Figure 2-8. Thermal Image at 13.5 $V_{\text{IN}}$

Figure 2-9. Thermal Image at 18 $V_{\text{IN}}$
Thermal images of TPS7B81-Q1 are shown in the following figure. The test conditions include room temperature, no airflow.

**Figure 2-10.** Thermal Image at 4.2 $V_{IN}$, 3.3 $V_{OUT}$, 0.15A $I_{OUT}$

**Figure 2-11.** Thermal Image at 13.5 $V_{IN}$, 3.3 $V_{OUT}$, 0.15A $I_{OUT}$

**Figure 2-12.** Thermal Image at 18 $V_{IN}$, 3.3 $V_{OUT}$, 0.15A $I_{OUT}$
Thermal images of TPS628503-Q1 are shown in the following figure. The test conditions include room temperature, no airflow.

Figure 2-13. Thermal Image at 3.3 V\text{IN}, 1.15 V\text{OUT}, 3A I\text{OUT}
2.2 Bode Plots

Bode plots of LMQ644A2-Q1 are shown in the following figures.

Figure 2-14. Bode Plot at 8.5 V\textsubscript{IN}, 3.3 V\textsubscript{OUT}, 0A I\textsubscript{OUT}

Figure 2-15. Bode Plot at 8.5 V\textsubscript{IN}, 3.3 V\textsubscript{OUT}, 4A I\textsubscript{OUT}
Figure 2-16. Bode Plot at 13.5 V IN, 3.3 V OUT, 4A I OUT

Figure 2-17. Bode Plot at 18 V IN, 3.3 V OUT, 4A I OUT
Figure 2-18. Bode Plot at 8.5 V_IN, 6 V_OUT, 6A I_OUT

Figure 2-19. Bode Plot at 13.5 V_IN, 6 V_OUT, 6A I_OUT
Bode plots of TPS628503-Q1 are shown in the following figures.

### Figure 2-20. Bode Plot at 18 V\(_{\text{IN}}\), 6 V\(_{\text{OUT}}\), 6A I\(_{\text{OUT}}\)

<table>
<thead>
<tr>
<th>Frequency (kHz)</th>
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<th>Trace 2</th>
</tr>
</thead>
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<tr>
<td>Capacitor 1</td>
<td>109.251</td>
<td>-96.16 dB</td>
</tr>
<tr>
<td>Capacitor 2</td>
<td>49.496 kHz</td>
<td>0.98</td>
</tr>
<tr>
<td>Others</td>
<td>-164.78 kHz</td>
<td>19.333 dB</td>
</tr>
</tbody>
</table>

### Figure 2-21. Bode Plot at 3.3 V\(_{\text{IN}}\), 1.15 V\(_{\text{OUT}}\), 0A I\(_{\text{OUT}}\)

<table>
<thead>
<tr>
<th>Frequency (kHz)</th>
<th>Trace 1</th>
<th>Trace 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capacitor 1</td>
<td>541.687 kHz</td>
<td>-21.495 dB</td>
</tr>
<tr>
<td>Capacitor 2</td>
<td>68.616 kHz</td>
<td>0.98</td>
</tr>
<tr>
<td>Others</td>
<td>-472.266 kHz</td>
<td>21.495 dB</td>
</tr>
</tbody>
</table>
Figure 2-22. Bode Plot at 3.3 V\textsubscript{IN}, 1.15 V\textsubscript{OUT}, 3A I\textsubscript{OUT}
3 Waveforms

3.1 Cold Crank

The cold crank waveform of the board is shown in the following figure by setting appropriate UVLO circuit.

Figure 3-1. Cold Crank at 2.8V\text{IN}, 8.5V\text{OUT}, 3A I\text{OUT}

3.2 Start-up

Start-up behaviors of the LM5152-Q1 are shown in the following figures.

Figure 3-2. Start-up at 4.2 V\text{IN}, 8.5 V\text{OUT}, 11.76A I\text{OUT}
Figure 3-3. Start-up at 13.5 $V_{IN}$, 13.5 $V_{OUT}$, 7.48A $I_{OUT}$

Figure 3-4. Start-up at 18 $V_{IN}$, 18 $V_{OUT}$, 5.55A $I_{OUT}$
Start-up behaviors of LM74900-Q1 are shown in the following figures.

**Figure 3-5.** Start-up at 18 V\textsubscript{IN}, 18 V\textsubscript{OUT}, 5.78A I\textsubscript{OUT}

**Figure 3-6.** Start-up at 4.2 V\textsubscript{IN}, 4.2 V\textsubscript{OUT}, 24A I\textsubscript{OUT}
Start-up behaviors of LMQ644A2-Q1 are shown in the following figures.

Figure 3-7. Start-up at 8.5 V\textsubscript{IN}, 6 V\textsubscript{OUT}, 6A I\textsubscript{OUT}

Figure 3-8. Start-up at 13.5 V\textsubscript{IN}, 6 V\textsubscript{OUT}, 6A I\textsubscript{OUT}
**Figure 3-9.** Start-up at 18 V\textsubscript{IN}, 6 V\textsubscript{OUT}, 6A I\textsubscript{OUT}

**Figure 3-10.** Start-up at 8.5 V\textsubscript{IN}, 3.3 V\textsubscript{OUT}, 3A I\textsubscript{OUT}
Figure 3-11. Start-up at 13.5 V\text{IN}, 3.3 V\text{OUT}, 3A I\text{OUT}

Figure 3-12. Start-up at 18 V\text{IN}, 3.3 V\text{OUT}, 3A I\text{OUT}
Start-up behaviors of TPS7B81-Q1 are shown in the following figures.

Figure 3-13. Start-up at 4.2 V<sub>IN</sub>, 6 V<sub>OUT</sub>, 0.15A I<sub>OUT</sub>

Figure 3-14. Start-up at 13.5 V<sub>IN</sub>, 6 V<sub>OUT</sub>, 0.15A I<sub>OUT</sub>
Start-up behaviors of TPS745-Q1 are shown in the following figures.

**Figure 3-15. Start-up at 18 V\textsubscript{IN}, 6 V\textsubscript{OUT}, 0.15A I\textsubscript{OUT}**

**Figure 3-16. Start-up at 3.3 V\textsubscript{IN}, 1.8 V\textsubscript{OUT}, 0.5A I\textsubscript{OUT}**
Start-up behaviors of the TPS628503-Q1 are shown in the following figures.

**Figure 3-17. Start-up at 3.3 Vₜᵢₙ, 1.8 Vₜᵢₜ, 3A Iₜᵢₜ**
3.3 Steady State

Steady state waveforms of LM5152-Q1 are shown in the following figures.

Figure 3-18. Steady State at 4.2 V\textsubscript{IN}, 8.5 V\textsubscript{OUT}, 11.76A I\textsubscript{OUT}

Figure 3-19. Steady State at 18 V\textsubscript{IN}, 18 V\textsubscript{OUT}, 5.5A I\textsubscript{OUT}
Figure 3-20. Steady State at 13.5 \( V_{IN} \), 13.5 \( V_{OUT} \), 7.48A \( I_{OUT} \)

Steady state waveforms of LM74900-Q1 are shown in the following figures.

Figure 3-21. Steady State at 4.2 \( V_{IN} \), 4.2 \( V_{OUT} \), 24A \( I_{OUT} \)
Figure 3-22. Steady State at 13.5 \text{V}_{\text{IN}}, 13.5 \text{V}_{\text{OUT}}, 7.48 \text{A}_{\text{OUT}}

Figure 3-23. Steady State at 18 \text{V}_{\text{IN}}, 18 \text{V}_{\text{OUT}}, 5.5 \text{A}_{\text{OUT}}
Steady state waveforms of LMQ644A2-Q1 are shown in the following figures.

Figure 3-24. Steady State at 8.5 V_IN, 3.3 V_OUT, 3A I_OUT

Figure 3-25. Steady State at 13.5 V_IN, 3.3 V_OUT, 3A I_OUT
Figure 3-26. Steady State at 18 $V_{IN}$, 3.3 $V_{OUT}$, 3A $I_{OUT}$

Figure 3-27. Steady State at 8.5 $V_{IN}$, 6 $V_{OUT}$, 6.13A $I_{OUT}$
Figure 3-28. Steady State at 13.5 V_{IN}, 6 V_{OUT}, 6.13A I_{OUT}

Figure 3-29. Steady State at 18 V_{IN}, 6 V_{OUT}, 6.13A I_{OUT}
Steady state waveforms of TPS7B81-Q1 are shown in the following figures.

**Figure 3-30. Steady State at 18 V\textsubscript{IN}, 3.3 V\textsubscript{OUT}, 0.15A I\textsubscript{OUT}**

**Figure 3-31. Steady State at 13.5 V\textsubscript{IN}, 3.3 V\textsubscript{OUT}, 0.15A I\textsubscript{OUT}**
Steady state waveforms of TPS745-Q1 are shown in the following figure.

Figure 3-32. Steady State at 4.2 $V_{IN}$, 3.3 $V_{OUT}$, 0.15A $I_{OUT}$

Figure 3-33. Steady State at 3.3 $V_{IN}$, 1.8 $V_{OUT}$, 0.5A $I_{OUT}$
Steady state waveforms of TPS628503-Q1 are shown in the following figure.

**Figure 3-34. Steady State at 3.3 V\textsubscript{IN}, 1.15 V\textsubscript{OUT}, 3A I\textsubscript{OUT}**
3.4 Short-Circuit Protection

Short-circuit protection waveforms of LM74900-Q1 are shown in the following figure.

Figure 3-35. Short-Circuit Protection at 4.2 $V_{\text{IN}}$

Short-circuit protection waveforms of LMQ644A2-Q1 are shown in the following figures.

Figure 3-36. Short-Circuit Protection at 8.5 $V_{\text{IN}}$, 3.3 $V_{\text{OUT}}$
Figure 3-37. Short-Circuit Protection at 13.5 V\textsubscript{IN}, 3.3 V\textsubscript{OUT}

Figure 3-38. Short-Circuit Protection at 18 V\textsubscript{IN}, 3.3 V\textsubscript{OUT}
Figure 3-39. Short-Circuit Protection at 8.5 V\textsubscript{IN}, 6 V\textsubscript{OUT}

Figure 3-40. Short-Circuit Protection at 13.5 V\textsubscript{IN}, 6 V\textsubscript{OUT}
Short-circuit protection waveforms of TPS745-Q1 are shown in the following figure.

Figure 3-41. Short-Circuit Protection at 18 \( V_{\text{IN}} \), 6 \( V_{\text{OUT}} \)

Figure 3-42. Short-Circuit Protection at 3.3 \( V_{\text{IN}} \), 1.8 \( V_{\text{OUT}} \)
Short-circuit protection waveforms of TPS7B81-Q1 are shown in the following figures.

**Figure 3-43.** Short-Circuit Protection at 8.5 V\textsubscript{IN}, 3.3 V\textsubscript{OUT}

**Figure 3-44.** Short-Circuit Protection at 13.5 V\textsubscript{IN}, 3.3 V\textsubscript{OUT}
Short-circuit protection waveforms of TPS628503-Q1 are shown in the following figure.

Figure 3-45. Short-Circuit Protection at 18 V\textsubscript{IN}, 3.3 V\textsubscript{OUT}

Figure 3-46. Short-Circuit Protection at 3.3 V\textsubscript{IN}, 1.15 V\textsubscript{OUT}
3.5 Load Transients

Load transient response waveforms of the LM5152-Q1 are shown in the following figures.

**Figure 3-47.** Load Transient at 4.2 \( V_{\text{IN}} \), 8.5 \( V_{\text{OUT}} \), 0A–5.88A

**Figure 3-48.** Load Transient at 4.2 \( V_{\text{IN}} \), 8.5 \( V_{\text{OUT}} \), 5.88A–11.48A
Figure 3-49. Load Transient at 13.5 $V_{\text{IN}}$, 13.5 $V_{\text{OUT}}$, 0A–3.74A

Figure 3-50. Load Transient at 13.5 $V_{\text{IN}}$, 13.5 $V_{\text{OUT}}$, 3.74A–7.48A
Figure 3-51. Load Transient at 18 \( V_{IN} \), 18 \( V_{OUT} \), 0A–2.78A

Figure 3-52. Load Transient at 18 \( V_{IN} \), 18 \( V_{OUT} \), 2.78A–5.55A
Load transient response waveforms of LM74900-Q1 are shown in the following figures.

**Figure 3-53. Load Transient at 4.2 V\textsubscript{IN}, 4.2 V\textsubscript{OUT}, 0A–24A**

**Figure 3-54. Load Transient at 13.5 V\textsubscript{IN}, 13.5 V\textsubscript{OUT}, 0A–7.48A**
Figure 3-55. Load Transient at 18 V\text{IN}, 18 V\text{OUT}, 0A–6A
Load transient response waveforms of LMQ644A2-Q1 are shown in the following figures.

**Figure 3-56.** Load Transient at 8.5 V\(_{\text{IN}}\), 3.3 V\(_{\text{OUT}}\), 0A–3A

**Figure 3-57.** Load Transient at 13.5 V\(_{\text{IN}}\), 3.3 V\(_{\text{OUT}}\), 0A–3A
Figure 3-58. Load Transient at 18 V_{IN}, 3.3 V_{OUT}, 0A–3A

Figure 3-59. Load Transient at 8.5 V_{IN}, 6 V_{OUT}, 0A–6A
Figure 3-60. Load Transient at 13.5 V_{IN}, 6 V_{OUT}, 0A–6A

Figure 3-61. Load Transient at 18 V_{IN}, 6 V_{OUT}, 0A–6A
Load transient response waveforms of TPS628503-Q1 are shown in the following figure.

Figure 3-62. Load Transient at 3.3 V\textsubscript{IN}, 1.15 V\textsubscript{OUT}, 0A–3A

Load transient response waveforms of TPS745-Q1 are shown in the following figure.

Figure 3-63. Load Transient at 3.3 V\textsubscript{IN}, 1.8 V\textsubscript{OUT}, 0A–0.5A
Load transient response waveforms of TPS7B81-Q1 are shown in the following figures.

Figure 3-64. Load Transient at 4.5 $V_{\text{IN}}$, 3.3 $V_{\text{OUT}}$, 0A–0.15A

Figure 3-65. Load Transient at 13.5 $V_{\text{IN}}$, 3.3 $V_{\text{OUT}}$, 0A–0.15A
Figure 3-66. Load Transient at 18 V<sub>IN</sub>, 3.3 V<sub>OUT</sub>, 0A–0.15A
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