

## Features

- Supports for synchronous rectification (CH1, CH2 and CH5)
- Supports for down or up-down Zeta conversions (CH1 and HPW7095 CH2)
- Supports for up, flyback or up-down SEPIC conversions HPW7095A CH2, CH3, APW7095 CH4, CH5 and CH6)
- Supports for Inverting conversion (HPW7095A CH4)
- Low Start-up Voltage : 1.4V (CH6)
- Power Supply Voltage Range
  - CH1 to CH5 : 3.0V to 6.5V
  - CH6 : 2.4V to 6.5V
- 1% Reference Voltage Accuracy
- Wide Operating Frequency 100kHz to 1MHz
- Soft-Start Function (CH1 to 6)
- Power Good (PGOOD) Indicator for CH1
- Low Shutdown Current
- Output Short-Circuit Detections

## Applications

- Digital Camera
- Camcorder
- Hand-held Instrument

## General Description

The HPW7095/A is a 6-channel, frequency-settable, voltage-mode, DC/DC control IC providing a complete power supply solution for high-performance portable digital cameras. The HPW7095/A uses pulse-width-modulation (PWM) and synchronous rectification for high efficiency step-up, step-down, up-down and inverting converters with free input and output settings in 2 or 4-cell AA, 1-cell lithium-ion (Li+), and dual-battery designs. The HPW7095/A incorporates error amplifiers, output short-circuit detection, under-voltage lockout, soft-start and output switch control into a chip. The HP7095/A improves performance, component count, and size compared to conventional multi-channel controllers.

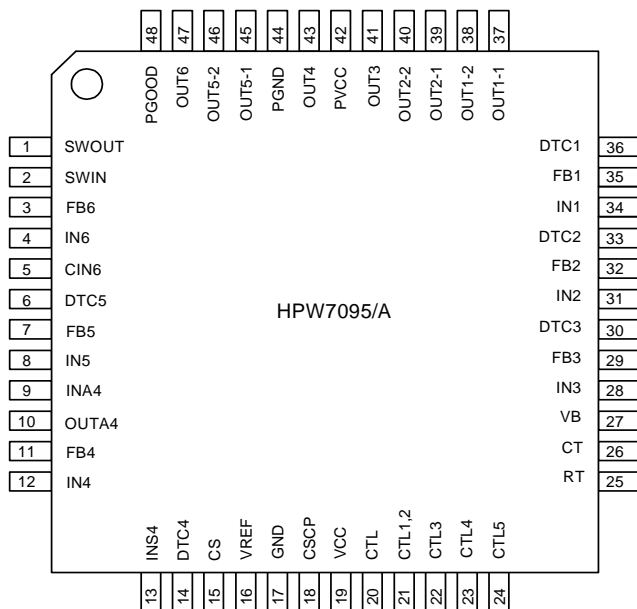
The APW7095/A has a power-good indicator (PGOOD) that signals when CH1 output is within  $\pm 10\%$  of the set voltage by monitoring IN1 pin.

The HPW7095/A is available in compact 48-pin plastic LQFP and TQFN packages.

## Ordering and Marking Information

|                  |                   |  |
|------------------|-------------------|--|
| HPW7095/A        |                   | Package Code<br>QD : LQFP                      QB : TQFN<br>Temp. Range<br>E : -30 to 85 °C<br>Handling Code<br>TY : Tray<br>Lead Free Code<br>L : Lead Free Device    Blank : Original Device |
| HPW7095 QD/QB :  | HPW7095<br>XXXXX  | XXXXX - Date Code  |
| HPW7095A QD/QB : | HPW7095A<br>XXXXX | XXXXX - Date Code  |

## Pinouts



| IC  | HPW7095               | HPW7095A                   |
|-----|-----------------------|----------------------------|
| CH1 | Synchronous Step-down | Synchronous Step-down      |
| CH2 | Synchronous Up-down   | Synchronous <b>Step-up</b> |
| CH3 | Step-up               | Step-up                    |
| CH4 | Step-up               | <b>Inverting</b>           |
| CH5 | Synchronous Step-up   | Synchronous Step-up        |
| CH6 | Step-up               | Step-up                    |

## Pin Description

| PIN |       | I/O | DESCRIPTION   |
|-----|-------|-----|---|
| No. | Name  |     |   |
| 1   | SWOUT | O   | Output Switch Control Circuit Output Pin.   |
| 2   | SWIN  | I   | Output Switch Control Circuit Input Pin.  |
| 3   | FB6   | O   | CH6 Error Amplifier Output Pin.   |
| 4   | IN6   | I   | CH6 Inverted Input Pin of Error Amplifier.  |
| 5   | CIN6  | I   | CH6 Soft-Start Capacitor Connection Pin.<br>Leave this pin "Open" to disable the soft-start function.   |
| 6   | DTC5  | I   | CH5 Dead Time Control Pin.<br>Connect this pin to VREF directly when the dead-time control is not used. |

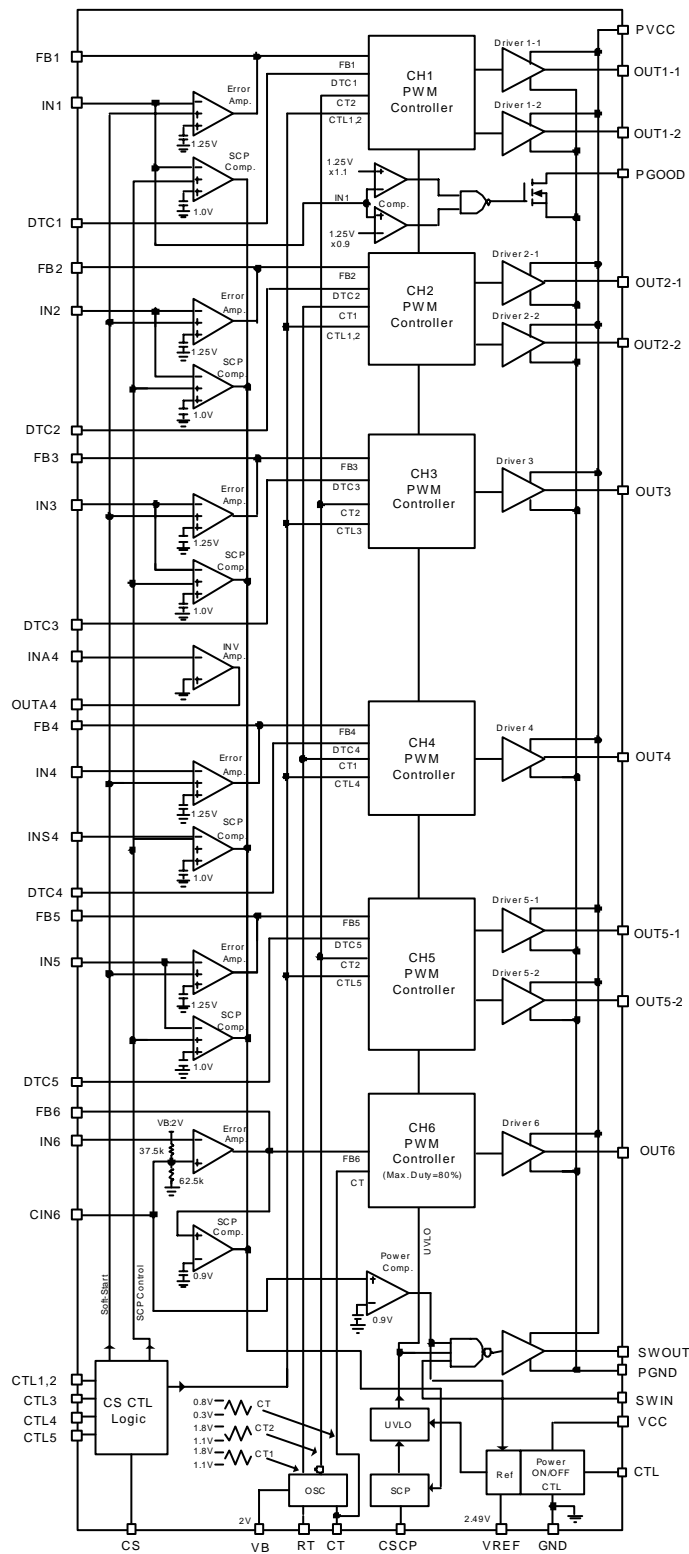
## Pin Description (Cont.)

| PIN |        | I/O | DESCRIPTION  |
|-----|--------|-----|--|
| No. | Name   |     |  |
| 7   | FB5    | O   | CH5 Error Amplifier Output Pin.  |
| 8   | IN5    | I   | CH5 Inverted Input Pin of Error Amplifier.   |
| 9   | INA4   | I   | CH4 Inverting Amplifier Input Pin.   |
| 10  | OUTA4  | O   | CH4 Inverting Amplifier Output Pin.<br>Connect this pin to INA4 when the inverting amplifier is not used.  |
| 11  | FB4    | O   | CH4 Error Amplifier Output Pin.  |
| 12  | IN4    | I   | CH4 Inverted Input Pin of Error Amplifier.   |
| 13  | INS4   | I   | CH4 Inverted Input Pin of Short Detection Comparator.  |
| 14  | DTC4   | I   | CH4 Dead Time Control Pin.<br>Connect this pin to VREF directly when the dead-time control is not used.  |
| 15  | CS     | -   | CH1 to CH5 Soft-Start Capacitor Connection Pin.<br>Leave this pin "Open" to disable the soft-start function.   |
| 16  | VREF   | O   | Reference Voltage Output Pin.  |
| 17  | GND    | P   | Reference Voltage and Control Circuit Ground Pin.  |
| 18  | CSCP   | -   | Short-Circuit Detection Capacitor Connection Pin.<br>Connect this pin to GND with the shortest distance to disable the timer-latch short-circuit protection circuit. |
| 19  | VCC    | P   | Reference Voltage and Control Circuit Power Supply Pin.  |
| 20  | CTL    | I   | Power Supply and CH6 Control Pin.<br>"H" Level : Operation Mode.<br>"L" Level : Standby Mode   |
| 21  | CTL1,2 | I   | CH1 and CH2 Control Pin.<br>"H" Level : Operation Mode.<br>"L" Level : OFF Mode  |
| 22  | CTL3   | I   | CH3 Control Pin.<br>"H" Level : Operation Mode.<br>"L" Level : OFF Mode  |
| 23  | CTL4   | I   | CH4 Control Pin.<br>"H" Level : Operation Mode.<br>"L" Level : OFF Mode  |
| 24  | CTL5   | I   | CH5 Control Pin.<br>"H" Level : Operation Mode.<br>"L" Level : OFF Mode  |
| 25  | RT     | -   | Oscillator Frequency Setting Resistor Connection Pin.  |
| 26  | CT     | -   | Oscillator Frequency Setting Capacitor Connection Pin.   |
| 27  | VB     | O   | Triangular Wave Oscillator Regulator Output Pin.   |
| 28  | IN3    | I   | CH3 Inverted Input Pin of Error Amplifier.   |
| 29  | FB3    | O   | CH3 Error Amplifier Output Pin.  |
| 30  | DTC3   | I   | CH3 Dead Time Control Pin.<br>Connect this pin to VREF directly when the dead-time control is not used.  |
| 31  | IN2    | I   | CH2 Inverted Input Pin of Error Amplifier.   |
| 32  | FB2    | O   | CH2 Error Amplifier Output Pin.  |
| 33  | DTC2   | I   | CH2 Dead Time Control Pin.<br>Connect this pin to VREF directly when the dead-time control is not used.  |
| 34  | IN1    | I   | CH1 Inverted Input Pin of Error Amplifier.   |
| 35  | FB1    | O   | CH1 Error Amplifier Output Pin.  |
| 36  | DTC1   | I   | CH1 Dead Time Control Pin.<br>Connect this pin to VREF directly when the dead-time control is not used.  |
| 37  | OUT1-1 | O   | CH1 Main-side MOSFET Drive Pin. Connect OUT1-1 to the main MOSFET.   |
| 38  | OUT1-2 | O   | CH1 MOSFET Drive Pin for Synchronous Rectifier.  |
| 39  | OUT2-1 | O   | CH2 Main-side MOSFET Drive Pin.<br>APW7095 : Drive a p-channel MOSFET for a step-down converter.<br>APW7095A : Drive an n-channel MOSFET for a step-up converter.    |
| 40  | OUT2-2 | O   | CH2 MOSFET Drive Pin for Synchronous Rectifier   |

## Pin Description (Cont.)

| PIN |        | I/O | DESCRIPTION  |
|-----|--------|-----|--|
| No. | Name   |     |  |
| 41  | OUT3   | O   | CH3 MOSFET Drive Pin.  |
| 42  | PVCC   | P   | Drive Circuit Power Supply Pin.  |
| 43  | OUT4   | O   | CH4 MOSFET Drive Pin.<br>APW 7095 : Drive an n-channel MOSFET for a step-up converter.<br>APW 7095A : Drive a p-channel MOSFET for a inverting step-up/down converter. |
| 44  | PGND   | P   | Drive Circuit Ground Pin.  |
| 45  | OUT5-1 | O   | CH5 Main-side MOSFET Drive Pin. Connect OUT5-1 to the main MOSFET.   |
| 46  | OUT5-2 | O   | CH5 MOSFET Drive Pin for Synchronous Rectifier.  |
| 47  | OUT6   | O   | CH6 MOSFET Drive Pin.  |
| 48  | PGOOD  | O   | Indicator Output Pin. This pin is an open-drain output used to indicate status of the CH1 output voltage.  |

Block Diagram



## Absolute Maximum Ratings

| Symbol            | Parameter                                 | Rating                      | Unit |
|-------------------|---|-----------------------------|------|
| V <sub>CC</sub>   | VCC Supply Voltage (VCC to GND)           | -0.3 ~ 7                    | V    |
| V <sub>PVCC</sub> | PVCC Supply Voltage (PVCC to GND)         | -0.3 ~ 7                    | V    |
|                   | IN1~6, INA4, INS4, DTC1~5 Input Voltages  | -0.3 ~ V <sub>CC</sub> +0.3 | V    |
|                   | CTL, CTL1~5, SWIN Input Voltages          | -0.3 ~ 7                    | V    |
|                   | PGOOD Pull High Voltage                   | -0.3 ~ 7                    | V    |
|                   | Maximum Junction Temperature              | 150                         | °C   |
| T <sub>STG</sub>  | Storage Temperature                       | -65 ~ 150                   | °C   |
| T <sub>SDR</sub>  | Maximum Soldering Temperature, 10 Seconds | 300                         | °C   |

## Thermal Characteristics

| Symbol          | Parameter   | Value | Unit |
|-----------------|---|-------|------|
| θ <sub>JA</sub> | Junction-to-Ambient Resistance in free air<br>48-pin Plastic QFP<br>QFN | 80    | °C/W |

## Recommended Operating Conditions

| Symbol           | Parameter                        | Condition                   | HPW7095/A |       |                 | Unit |
|------------------|----------------------------------|-----------------------------|-----------|-------|-----------------|------|
|                  |                                  |                             | Min.      | Typ.  | Max.            |      |
| V <sub>CC</sub>  | Start-up Power Supply Voltage    | CH6                         | 1.4       | -     | 6.5             | V    |
| V <sub>CC</sub>  | Operating Voltage                | CH6                         | 2.4       | 5.0   | 6.5             | V    |
|                  |                                  | CH1 to CH5                  | 3.0       | 5.0   | 6.5             |      |
| I <sub>REF</sub> | Reference Voltage Output Current | VREF Pin                    | -1        | -     | 0               | mA   |
| I <sub>B</sub>   | VB Output Current                | VB Pin                      | -0.5      | -     | 0               | mA   |
| V <sub>IN</sub>  | Input Voltage                    | IN1 to IN5, INA4, INS4 Pins | 0         | -     | V <sub>CC</sub> | V    |
|                  |                                  | IN6 Pin                     | 0         | -     | V <sub>CC</sub> |      |
| V <sub>CTL</sub> | Control Voltage                  | CTL Pin                     | 0         | -     | 6.5             | V    |
| I <sub>O</sub>   | Output Current                   | OUT Pin (CH1 to CH5)        | -         | 2     | 15              | mA   |
|                  |                                  | OUT Pin (CH6)               | -         | 2     | 15              |      |
|                  |                                  | SWOUT Pin                   | -         | 1     | 4               |      |
| F <sub>OSC</sub> | Oscillator Frequency             |                             | 100       | 500   | 1000            | kHz  |
| C <sub>T</sub>   | Timing Capacitor                 |                             | 47        | 100   | 560             | pF   |
| R <sub>T</sub>   | Timing Resistor                  |                             | 8.2       | 18    | 100             | kΩ   |
| C <sub>S</sub>   | Soft-Start Capacitor             | CH1 to CH5                  | -         | 0.027 | 1.0             | μF   |
|                  |                                  | CH6                         | -         | 0.47  | 1.0             |      |
| C <sub>SCP</sub> | Short Detection Capacitor        |                             | -         | 0.1   | 1.0             | μF   |
| C <sub>VB</sub>  | VB Pin Capacitor                 |                             | 0.082     | 0.1   | -               | μF   |
| T <sub>A</sub>   | Operating Ambient Temperature    |                             | -30       | 25    | 85              | °C   |

## Electrical Characteristics

Refer to the typical application circuit. These specifications apply over,  $V_{CC}=5V$  and  $T_A=-30$  to  $85^{\circ}C$ , unless otherwise specified. Typical values refer to  $T_A=25^{\circ}C$ .

| Symbol                              | Parameter                            | Test Condition                      | HPW7095/A        |      |      | Unit    |   |
|-------------------------------------|--------------------------------------|-------------------------------------|------------------|------|------|---------|---|
|                                     |                                      |                                     | Min.             | Typ. | Max. |         |   |
| $I_{CCS}$                           | VCC Standby Current                  | CTL=0V                              | -                | -    | 10   | $\mu A$ |   |
| $I_{PVCC}$                          | PVCC Standby Current                 | CTL=0V                              | -                | -    | 10   |         |   |
| $I_{CC}$                            | VCC Nominal Supply Current           | CTL, CTL1 to CTL5=5V                | -                | 1.8  | 5    | mA      |   |
| <b>Under Voltage Lockout</b>        |                                      |                                     |                  |      |      |         |   |
| $V_{TH}$                            | CH1 to CH5                           | Threshold Voltage                   | Rising $V_{CC}$  | 2.5  | 2.7  | 2.9     | V |
| $V_H$                               |                                      | Hysteresis Width                    |                  | -    | 0.2  | -       |   |
| $V_{RST}$                           |                                      | Reset Voltage                       | Falling $V_{CC}$ | 1.2  | 1.3  | 1.4     |   |
| $V_{TH}$                            | CH6                                  | Threshold Voltage                   | Rising $V_{CC}$  | 1.25 | 1.4  | 1.55    |   |
| <b>Reference Voltage</b>            |                                      |                                     |                  |      |      |         |   |
| $V_{REF}$                           | Reference Voltage                    | $I_{REF}=0mA$                       | 2.46             | 2.49 | 2.51 | V       |   |
| $\Delta V_{REF}/V_{REF}$            | Output Voltage Temperature Stability | $T_A=-30^{\circ}C$ to $85^{\circ}C$ | -                | 0.5  | -    | %       |   |
| Line                                | Input Stability                      | $V_{CC}=3.0V$ to $6.5V$             | -10              | -    | 10   | mV      |   |
| Load                                | Load Stability                       | $I_{REF}=0mA$ to $-1mA$             | -10              | -    | 10   | mV      |   |
| $I_{OS}$                            | Short-Circuit Output Current         | $V_{REF}=2V$                        | -25              | -18  | -1   | mA      |   |
| <b>Soft-Start</b>                   |                                      |                                     |                  |      |      |         |   |
| $V_{STB}$                           | Input Standby Voltage                |                                     | -                | 50   | 100  | mV      |   |
| $I_{CS}$                            | Soft-Start Charge Current            |                                     | -1.4             | -1.0 | -0.6 | $\mu A$ |   |
| <b>Short-Circuit Detection</b>      |                                      |                                     |                  |      |      |         |   |
| $V_{TH}$                            | Threshold Voltage                    |                                     | 0.65             | 0.70 | 0.75 | V       |   |
| $V_{STB}$                           | Input Standby Voltage                |                                     | -                | 50   | 100  | mV      |   |
| $V_I$                               | Input Latch Voltage                  |                                     | -                | 50   | 100  | mV      |   |
| $I_{CSCP}$                          | Input Source Current                 |                                     | -1.4             | -1.0 | -0.6 | $\mu A$ |   |
| <b>Triangular Wave Oscillator</b>   |                                      |                                     |                  |      |      |         |   |
| $f_{OSC}$                           | Oscillator Frequency                 | CT=100pF, RT=18 $\Omega$ , VB=2V    | 450              | 500  | 550  | kHz     |   |
| $\Delta f/fdv$                      | Frequency Stability for Voltage      | $V_{CC}=3V$ to $6.5V$               | -                | 1    | 10   | %       |   |
| $\Delta f/fdt$                      | Frequency Stability for Temperature  | $T_A=-30^{\circ}C$ to $85^{\circ}C$ | -                | 1    | -    | %       |   |
| <b>Error Amplifier (CH1 to CH5)</b> |                                      |                                     |                  |      |      |         |   |
| $V_{TH}$                            | Threshold Voltage                    | FB=1.45V                            | 1.23             | 1.25 | 1.27 | V       |   |
| $\Delta V_T/V_T$                    | $V_T$ Temperature Stability          | $T_A=-30^{\circ}C$ to $85^{\circ}C$ | -                | 0.5  | -    | %       |   |
| $I_B$                               | Input Bias Current                   | IN=0V (CH1 to CH5)                  | -50              | -    | -    | nA      |   |
| $A_V$                               | Voltage Gain                         | DC                                  | 60               | 100  | -    | dB      |   |
| BW                                  | Frequency Bandwidth                  | $A_V=0dB$                           | -                | 1.0  | -    | MHz     |   |
| $V_{OH}$                            | Maximum Output Voltage               |                                     | 4.9              | 4.99 | -    | V       |   |
| $V_{OL}$                            | Minimum Output Voltage               |                                     | -                | 3    | 50   | mV      |   |
| $I_{SOURCE}$                        | Output Source Current                | FB=1.45V                            | -                | -25  | -10  | mA      |   |
| $I_{SINK}$                          | Output Sink Current                  | FB=1.45V                            | 5                | 16   | -    | mA      |   |
| <b>Error Amplifier (CH6)</b>        |                                      |                                     |                  |      |      |         |   |
| $V_{TH}$                            | Threshold Voltage                    | FB=0.55V                            | 1.24             | 1.26 | 1.28 | V       |   |
| $\Delta V_{TH}/V_{TH}$              | $V_{TH}$ Temperature Stability       | $T_A=-30^{\circ}C$ to $85^{\circ}C$ | -                | 0.5  | -    | %       |   |
| $I_B$                               | Input Bias Current                   | IN6=0V                              | -50              | -    | -    | nA      |   |

## Electrical Characteristics (Cont.)

Refer to the typical application circuit. These specifications apply over,  $V_{CC}=5V$  and  $T_A = -30$  to  $85^{\circ}C$ , unless otherwise specified. Typical values refer to  $T_A = 25^{\circ}C$ .

| Symbol   | Parameter              | Test Condition            | HPW7095/A |      |      | Unit     |
|--|------------------------|---------------------------|-----------|------|------|----------|
|  |                        |                           | Min.      | Typ. | Max. |          |
| $A_V$  | Voltage Gain           | DC                        | 60        | 75   | -    | dB       |
| BW   | Frequency Bandwidth    | $A_V=0dB$                 | -         | 1.0  | -    | MHz      |
| $V_{OH}$   | Maximum Output Voltage |                           | 4.9       | 4.99 | -    | V        |
| $V_{OL}$   | Minimum Output Voltage |                           | -         | 3    | 50   | mV       |
| $I_{SOURCE}$   | Output Source Current  | FB=0.55V                  | -         | -50  | -10  | mA       |
| $I_{SINK}$   | Output Sink Current    | FB=0.55V                  | 60        | 120  | -    | $\mu A$  |
| <b>Inverted Amplifier (CH4)</b>                          |                        |                           |           |      |      |          |
| $V_{IO}$   | Input Offset Voltage   | OUT=1.25V                 | -10       | 0    | 10   | mV       |
| $I_B$  | Input Bias Current     | IN=0V                     | -50       | -    | -    | nA       |
| $A_V$  | Voltage Gain           | DC                        | 60        | 100  | -    | dB       |
| BW   | Frequency Bandwidth    | AV=0dB                    | -         | 1.0  | -    | MHz      |
| $V_{OH}$   | Maximum Output Voltage |                           | 4.9       | 4.99 | -    | V        |
| $V_{OL}$   | Minimum Output Voltage |                           | -         | 3    | 50   | mV       |
| $I_{SOURCE}$   | Output Source Current  | OUT=1.25V                 | -         | -26  | -1.0 | mA       |
| $I_{SINK}$   | Output Sink Current    | OUT=1.25V                 | 5         | 16   | -    | mA       |
| <b>Short Detect Comparator (CH1 to CH5)</b>              |                        |                           |           |      |      |          |
| $V_{TH}$   | Threshold Voltage      | CH1 to CH5                | 0.97      | 1.00 | 1.03 | V        |
| $I_B$  | Input Bias Current     | IN=0V (CH1 to CH3, CH5)   | -50       | -    | -    | nA       |
|  |                        | INS4=0V (CH4)             | -50       | -    | -    |          |
| <b>Short Detect Comparator (CH6)</b>                     |                        |                           |           |      |      |          |
| $V_{TH}$   | Threshold Voltage      |                           | 0.8       | 0.9  | 1.0  | V        |
| <b>PWM Comparator (CH1 to CH5)</b>                       |                        |                           |           |      |      |          |
| $V_{T0}$<br>$V_{T100}$                                   | Threshold Voltage      | Duty=0%                   | 1.0       | 1.1  | -    | V        |
|  |                        | Duty=100%                 | -         | 1.8  | 1.9  |          |
| $I_{DTC}$  | Input Current          | DTC=0.4V (CH1 to CH5)     | -50       | -    | -    | nA       |
| <b>PWM Comparator (CH6)</b>                              |                        |                           |           |      |      |          |
| $V_{T0}$<br>$V_{Tmax}$                                   | Threshold Voltage      | Duty=0%                   | 0.2       | 0.3  | -    | V        |
|  |                        | Duty=Max.                 | -         | 0.74 | 0.84 |          |
| $D_{tr}$   | Maximum Duty Cycle     | CT=100pF, RT=18k $\Omega$ | 70        | 80   | 90   | %        |
| <b>PWM Controller Driver for P-MOS (CH1,CH2,CH5)</b>     |                        |                           |           |      |      |          |
| $I_{SOURCE}$   | Output Source Current  | Duty $\leq$ 5%, OUT=0V    | -         | -130 | -80  | mA       |
| $I_{SINK}$   | Output Sink Current    | Duty $\leq$ 5%, OUT=5V    | 100       | 160  | -    |          |
| $R_{OH}$<br>$R_{OL}$                                     | Output ON Resistance   | OUT= -15mA                | -         | 18   | 30   | $\Omega$ |
|  |                        | OUT= 15mA                 | -         | 10   | 20   |          |
| <b>PWM Controller Driver for N-MOS (CH1,CH2,CH5,CH6)</b> |                        |                           |           |      |      |          |
| $I_{SOURCE}$   | Output Source Current  | Duty $\leq$ 5%, OUT=0V    | -         | -130 | -80  | mA       |
| $I_{SINK}$   | Output Sink Current    | Duty $\leq$ 5%, OUT=5V    | 100       | 160  | -    |          |
| $R_{OH}$<br>$R_{OL}$                                     | Output ON Resistance   | OUT= -15mA                | -         | 18   | 30   | $\Omega$ |
|  |                        | OUT= 15mA                 | -         | 10   | 20   |          |
| <b>PWM Controller Driver for P-MOS (CH3,CH4)</b>         |                        |                           |           |      |      |          |
| $I_{SOURCE}$   | Output Source Current  | Duty $\leq$ 5%, OUT=0V    | -         | -290 | -180 | mA       |
| $I_{SINK}$   | Output Sink Current    | Duty $\leq$ 5%, OUT=5V    | 300       | 470  | -    |          |
| $R_{OH}$<br>$R_{OL}$                                     | Output ON Resistance   | OUT= -15mA                | -         | 7    | 15   | $\Omega$ |
|  |                        | OUT= 15mA                 | -         | 4    | 10   |          |

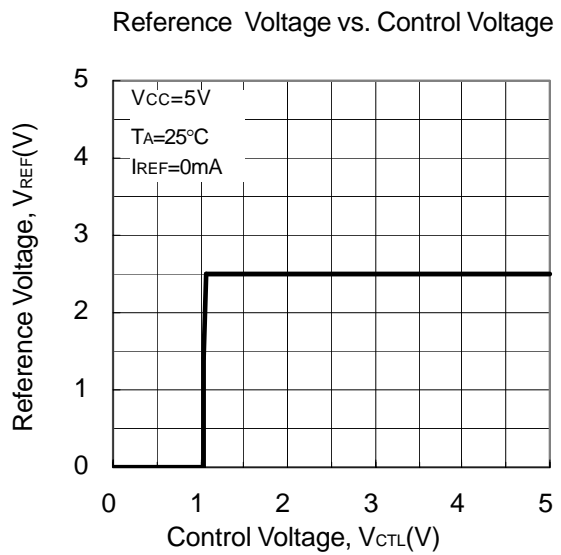
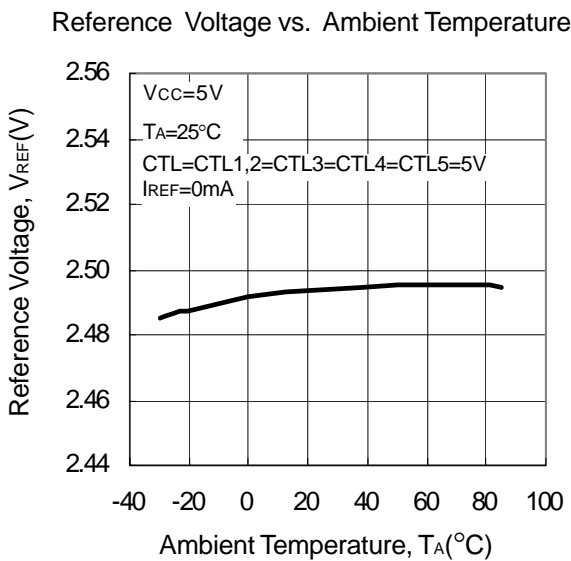
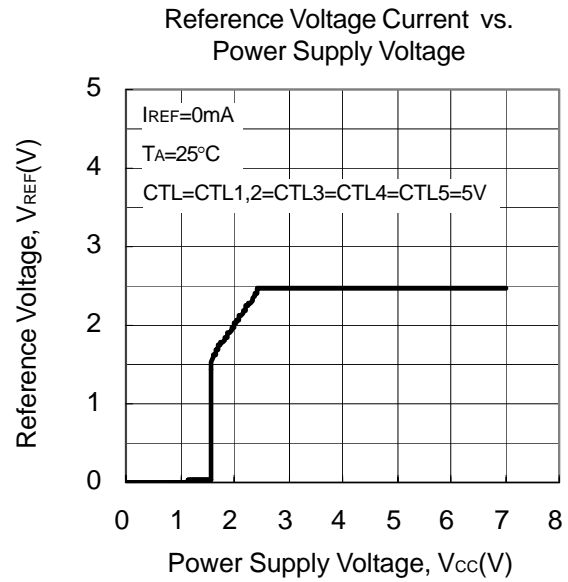
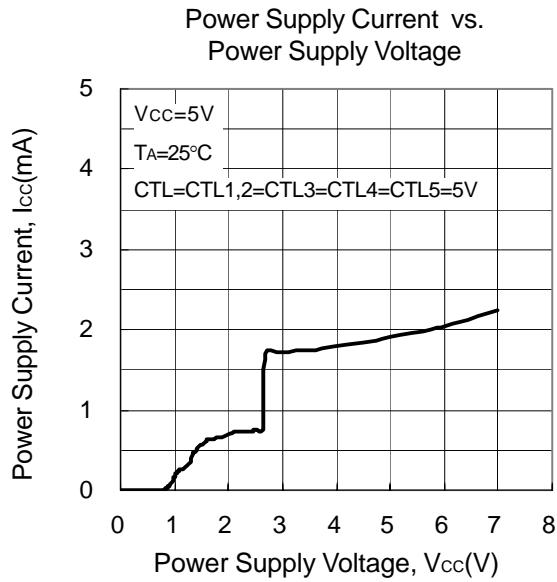


## Electrical Characteristics (Cont.)

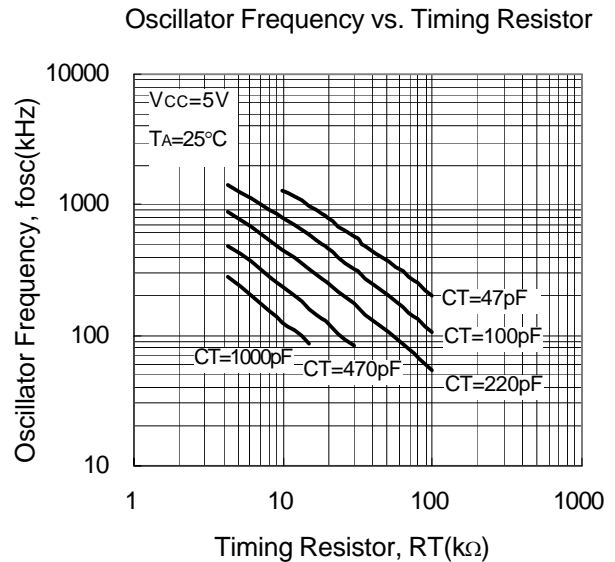
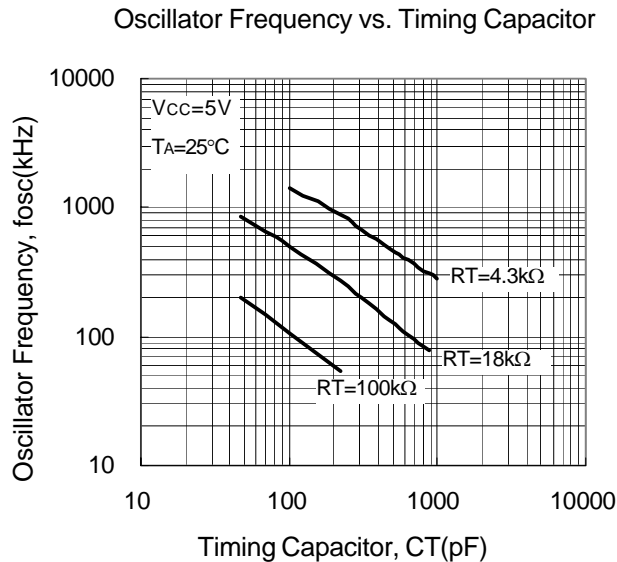
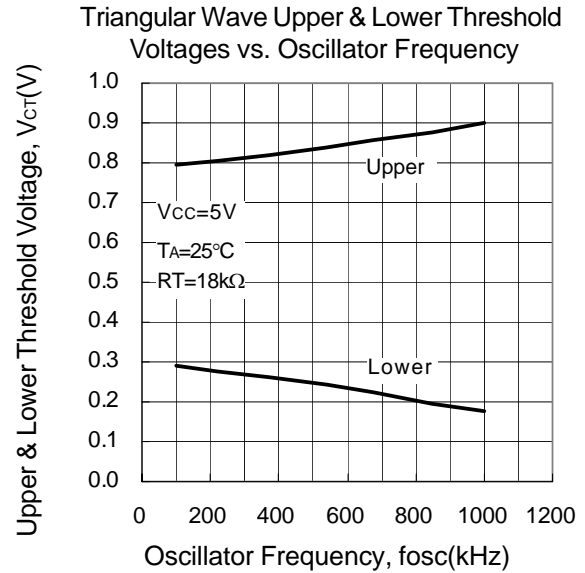
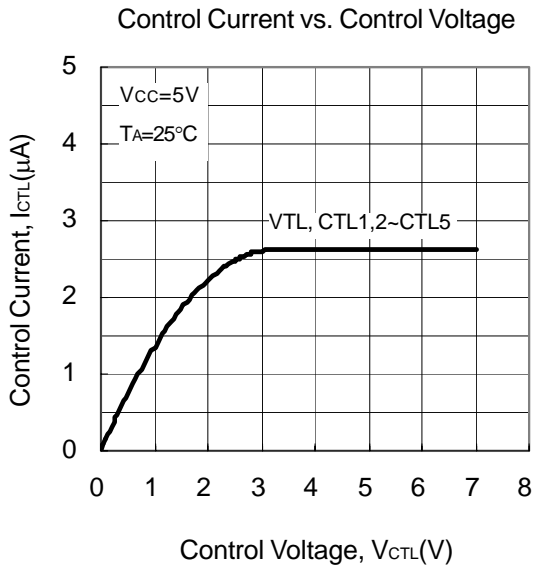
Refer to the typical application circuit. These specifications apply over,  $V_{CC}=5V$  and  $T_A = -30$  to  $85^{\circ}C$ , unless otherwise specified. Typical values refer to  $T_A = 25^{\circ}C$ .

| Symbol                                 | Parameter                   | Test Condition    | HPW7095/A |      |      | Unit     |
|--|-----------------------------|-------------------|-----------|------|------|----------|
|  |                             |                   | Min.      | Typ. | Max. |          |
| <b>Output Switch Control (SW)</b>      |                             |                   |           |      |      |          |
| $V_{IH}$                               | SW Input Voltage            | SWOUT="L" level   | 1.2       | -    | 6.5  | V        |
| $V_{IL}$                               |                             | SWOUT="H" level   | 0         | -    | 0.5  |          |
| $I_{SWIN}$                             | Input Current               | SWIN=5V           | -         | 2.5  | 20   | $\mu A$  |
| $I_{SOURCE}$                           | Output Source Current       | SWOUT=0V          | -         | -7   | -    | mA       |
| $I_{SINK}$                             | Output Sink Current         | SWOUT=5V          | -         | 19   | -    | mA       |
| $R_{OH}$                               | Output ON Resistance        | OUT= -4mA         | -         | 325  | 400  | $\Omega$ |
| $R_{OL}$                               |                             | OUT= 4mA          | -         | 85   | 150  |          |
| <b>Power Good</b>                      |                             |                   |           |      |      |          |
| $V_{TH}$                               | IN1 Upper Threshold Voltage | Rising IN1        | -         | 110  | -    | %        |
| $V_{TH}$                               | IN1 Lower Threshold Voltage | Rising IN1        | -         | 94   | -    | %        |
|  | Upper/Lower Hysteresis      |                   | -         | 2    | -    | %        |
| $V_{PGOOD}$                            | PGOOD Output Voltage        | $I_{PGOOD} = 4mA$ | -         | 0.17 | 0.8  | V        |
| <b>Control Block (CTL, CT1 to CT5)</b> |                             |                   |           |      |      |          |
| $V_{IH}$                               | CTL Input Voltage           | Active Mode       | 1.5       | -    | 6.5  | V        |
| $V_{IL}$                               |                             | Standby Mode      | 0         | -    | 0.5  |          |
| $I_{CTL}$                              | Input Current               | CTL=5V            | -         | 2.6  | 20   | $\mu A$  |

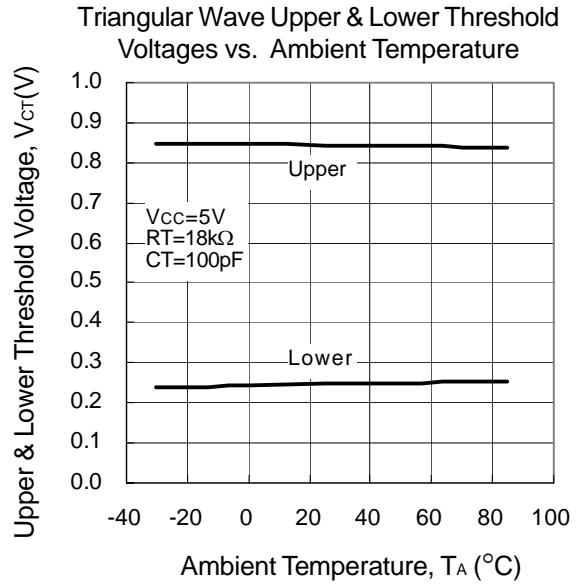
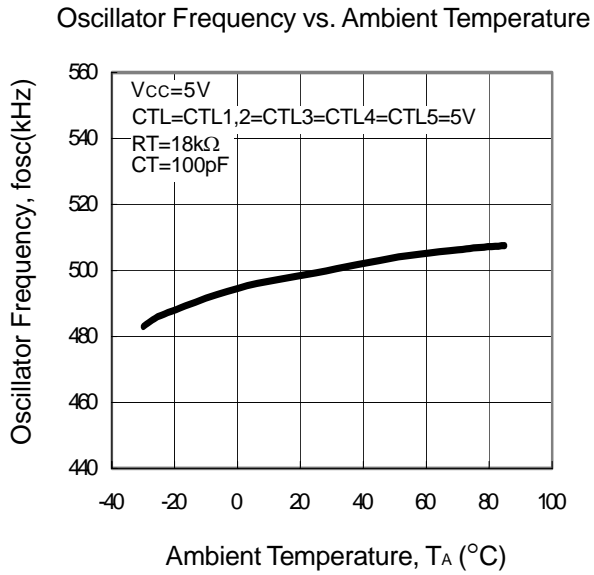
## Typical Characteristics



### Typical Characteristics (Cont.)

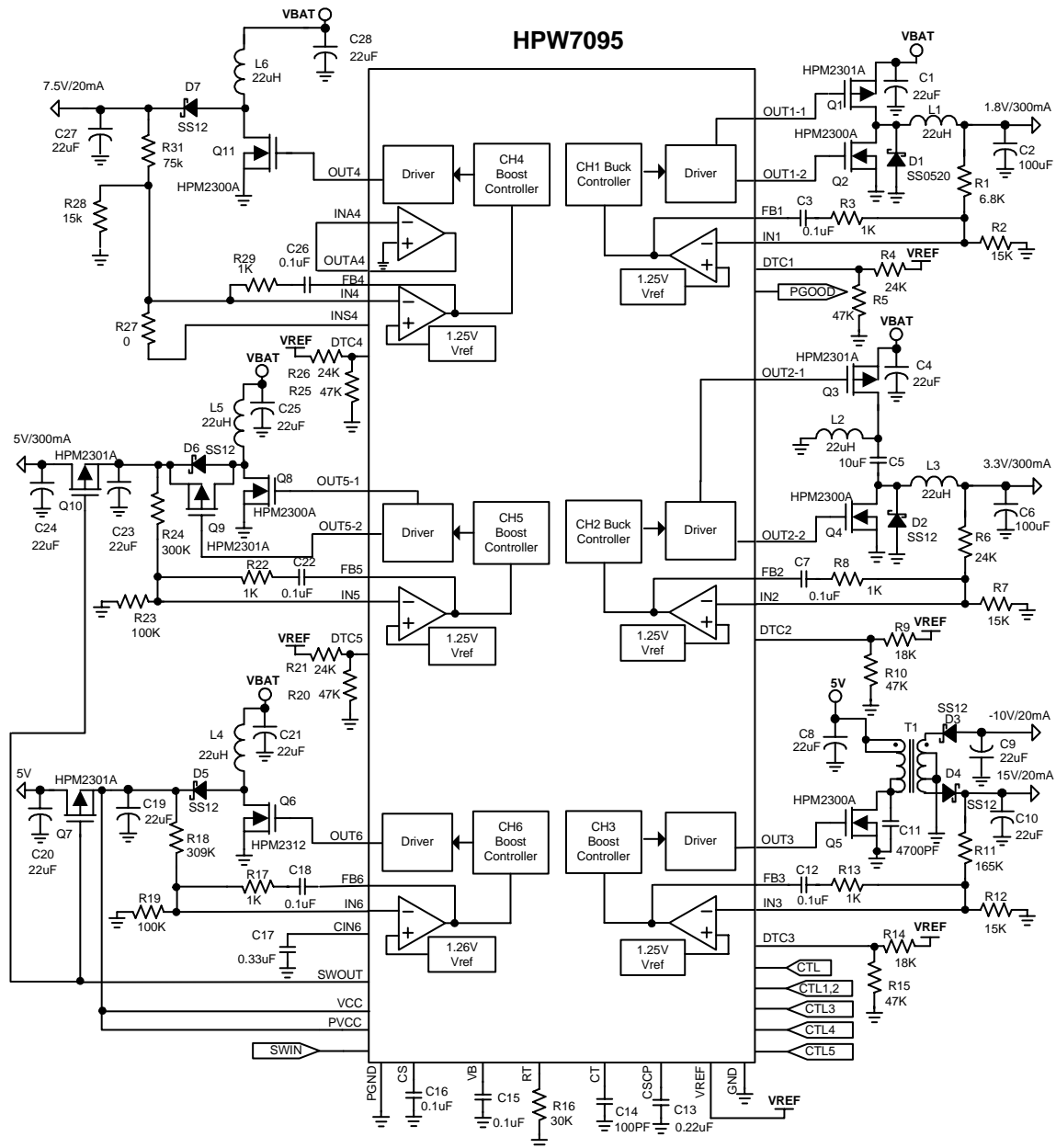


Typical Characteristics (Cont.)



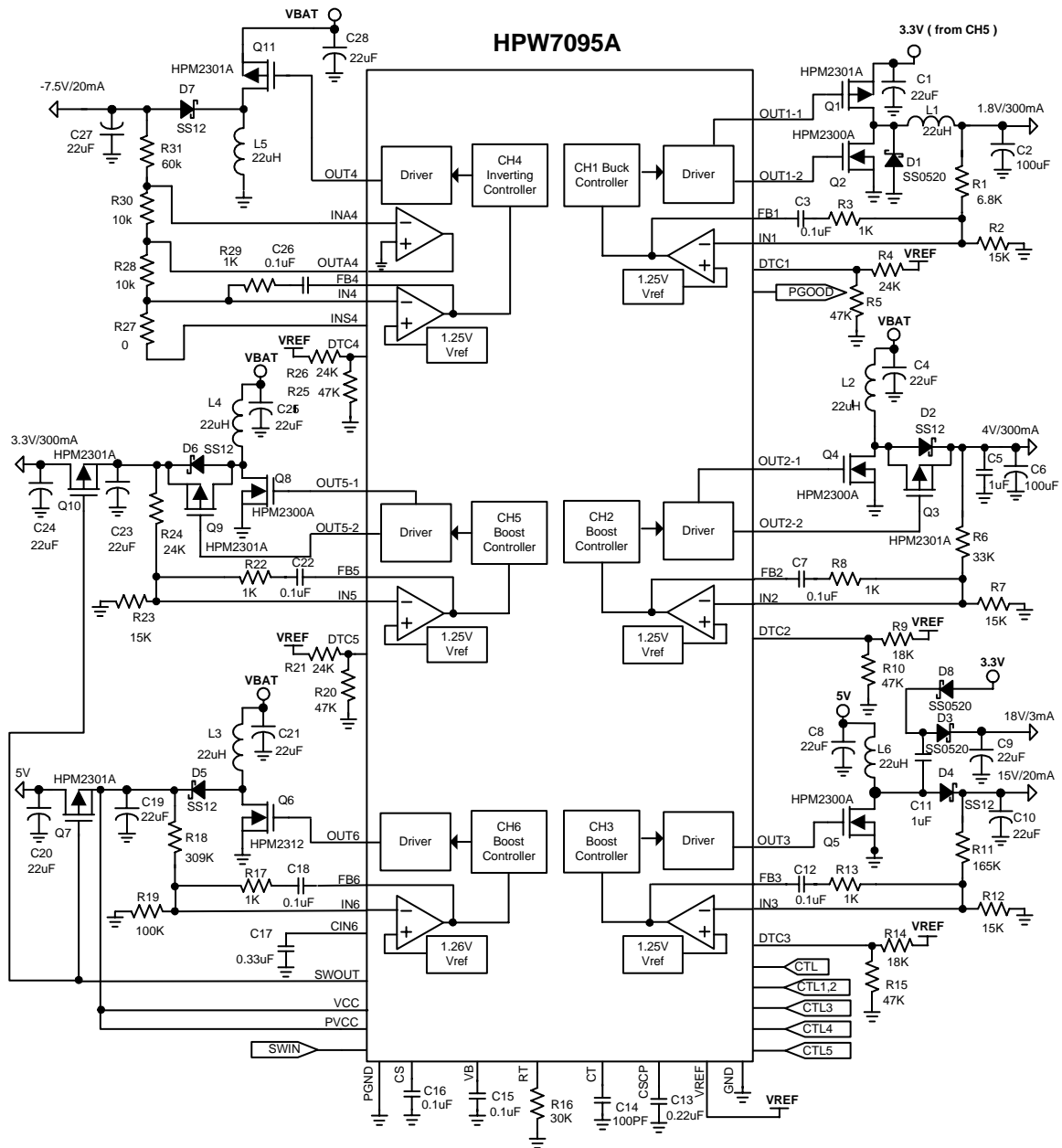
## Typical Applications

1. VBAT=2.7V~6V (4-Cell Battery or 1-Cell LI-ION) for 2 Buck and 4 Boost Converter (Using APW7095)



## Typical Applications (Cont.)

2.VBAT=1.4V~3V (2-Cell Battery) for 1 Buck , 1 Inverting and 4 Boost Converter s (Using APW7095A)



## Function Descriptions

### General

The HPW7095/A provides voltage-mode feedback controls for six DC/DC PWM converters(CH1 to CH6). Each channel operates with an error amplifier, PWM comparator, short-circuit comparator, ON/OFF control and output driver. An internal temperature-compensated voltage provides reference voltages for each channel. An triangular-wave oscillator(CT) with a timing resistor and capacitor generates triangular waves to each channel. A inverting amplifier(CH4) cooperates with the error amplifier for an inverting converter (with negative output voltage) .

### Reference Voltage

The HPW7095 outputs a temperature- compensated reference voltage(2.49V) at VREF pin. It is regulated from the voltage at VCC pin and can source current of max. 1mA to external loads. It also supplies bias for the IC's internal circuitry.

### Triangular-wave Oscillator

The triangular-wave oscillator is designed to generates a triangular oscillation signal (CT) with amplitude of 0.3V~0.8V at CT pin, providing signal to CH6. The oscillator frequency is settable from 100kHz to 1MHz and set by a timing resistor and a timing capacitor connected respectively from RT and CT pins to ground. Additional two triangular oscillation signals (CT1 and CT2) are also internally generated with amplitude of 1. 1V~1.8V. The CT1 is in phase with the CT to the PWM comparators of CH2 and CH4; the CT2 is out of phase with the CT to the PWM comparators of CH1, CH3 and CH5.

### Error Amplifier

The error amplifier is designed with unit-gain-bandwidth of 1MHz and to satisfy wide application requirements. It works with external resistor-capacitor network for each converter's feedback compensation. The loop gain can be set by connecting a feedback resistor and

capacitor from the output pin(FB) to inverted input pin of the error amplifier for stable operations.

### Inverting Amplifier (Inv Amp)

The inverting amplifier detects the inverting DC/DC converter output voltage (as a negative voltage) and outputs a control signal to the error amp.

### Channel Control Function

The channel control function turns on/off one or more channels depending on the states ("H" or "L" level) at CTL, CTL1,2 to CTL5 pins. The on/off control logic is shown as the following table:

Channel on/off Setting Table

| Voltage Level at CTL Pin |        |      |      |      | Channel ON/OFF State |          |     |     |     |     |
|--------------------------|--------|------|------|------|----------------------|----------|-----|-----|-----|-----|
| CTL                      | CTL1,2 | CTL3 | CTL4 | CTL5 | Power /CH6           | CH1 /CH2 | CH3 | CH4 | CH6 |     |
| L                        | x      | x    | x    | x    | OFF(Standby State)   |          |     |     |     |     |
| H                        | L      | L    | L    | L    | ON                   | OFF      | OFF | OFF | OFF |     |
|                          |        |      | H    | H    |                      |          |     | ON  | OFF |     |
|                          |        |      | L    | L    |                      |          |     | ON  | OFF |     |
|                          |        | H    | L    | L    |                      |          | ON  | OFF |     |     |
|                          |        |      | H    | H    |                      |          | ON  | OFF |     |     |
|                          |        |      | L    | L    |                      |          | ON  | OFF |     |     |
|                          | H      | L    | L    | L    |                      | ON       | ON  | OFF | OFF | OFF |
|                          |        |      | H    | H    |                      |          |     |     | ON  | OFF |
|                          |        |      | L    | L    |                      |          |     |     | ON  | OFF |
|                          |        | H    | L    | L    |                      |          |     | ON  | OFF |     |
|                          |        |      | H    | H    |                      |          |     | ON  | OFF |     |
|                          |        |      | L    | L    |                      |          |     | ON  | OFF |     |

### MOSFET Drive Circuits

HPW7095/A uses push-pull configuration at output of each MOSFET driver for providing large drive current to MOSFET gate. The following table shows the MOSFETs connected to the drivers:

| IC  | HPW7095       | HPW7095A      |
|-----|---------------|---------------|
| CH1 | OUT1-1 : PMOS | OUT1-1 : PMOS |
|     | OUT1-2 : NMOS | OUT1-2 : NMOS |
| CH2 | OUT2-1 : PMOS | OUT2-1 : NMOS |
|     | OUT2-2 : NMOS | OUT2-2 : PMOS |
| CH3 | OUT3 : NMOS   | OUT3 : NMOS   |
| CH4 | OUT4 : NMOS   | OUT4 : PMOS   |
| CH5 | OUT5-1 : NMOS | OUT5-1 : NMOS |
|     | OUT5-2 : PMOS | OUT5-2 : PMOS |
| CH6 | OUT6 : NMOS   | OUT6 : NMOS   |

## Function Descriptions (Cont.)

### Timer-latch short-circuit protection circuit

The short-circuit protection comparator in each channel (CH1 to CH5) monitors converter's output voltage via input pin of error amplifier. In CH6, the short-circuit comparator detects the voltage at output of error amplifier. As any detected voltages of CH1 to CH5 falls below 1.0V or the detected voltage of CH6 is larger than 0.9V, the timer circuits is actuated to start charging the external capacitor  $C_{SCP}$  connected from CSCP pin to ground. When the rising voltage of  $C_{SCP}$  reaches 0.7V, the IC turns off all external MOSFETs and pulls up the voltage at SWOUT pin. Then the IC is latched. Applying a signal from "L" to "H" to CTL pin enables operation again. The short-circuit detection function remains working during soft start operation on CH1 to CH5.

### Under-Voltage Lockout (UVLO) Circuit

The under-voltage lockout circuit monitors the supply voltage at VCC pin to prevent wrong logic control. The IC starts operation after the supply voltage rises above it's rising threshold. As the supply voltage falls below it's falling threshold, the IC turns off the external MOSFETs and pulls up the voltage at SWOUT pin.

### Soft-Start Operation

The soft-start function controls the output voltage rate of rise to limit the current surge at start-up. For CH1 to CH5, the soft-start interval is programmed by the soft-start capacitor,  $C_s$  connected from CS pin to ground and charged by an internal  $1\mu A$  current source. For CH6, a sourcing current from the internal resistor-divider charges the capacitor,  $C_{CIN6}$  connected from CIN6 pin to ground, providing soft-start control.

Figure 1 and 2 show the soft-start processes. In figure 1, when all control pins (CTL, CTL1,2 to CTL 5) are driven high ("H" level) at the same time, the voltage at CIN6 pin starts to rise up by charging the capacitor  $C_{CIN6}$ , starting a soft-start operation on CH6. After the

rising voltage at CIN6 reaches 0.9V, the reference voltage starts to regulate and the internal source current starts to charge the  $C_s$ , starting a soft-start operation on CH1 to CH5. During soft-start interval, the error amplifiers compares the CH1 to CH5 output voltage to the voltage at the CS pin. When any control pins (CH1, 2 to CH5) go "H" from "L" during the soft-start interval (CH1 to CH5), the output rises rapidly to follow the rising voltage at CS pin.

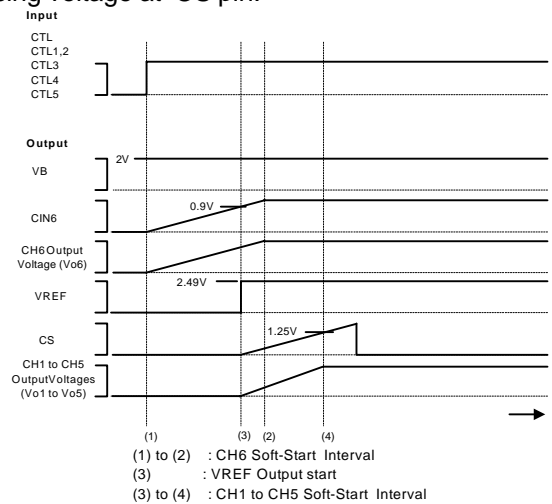


Figure 1 Soft-start waveforms

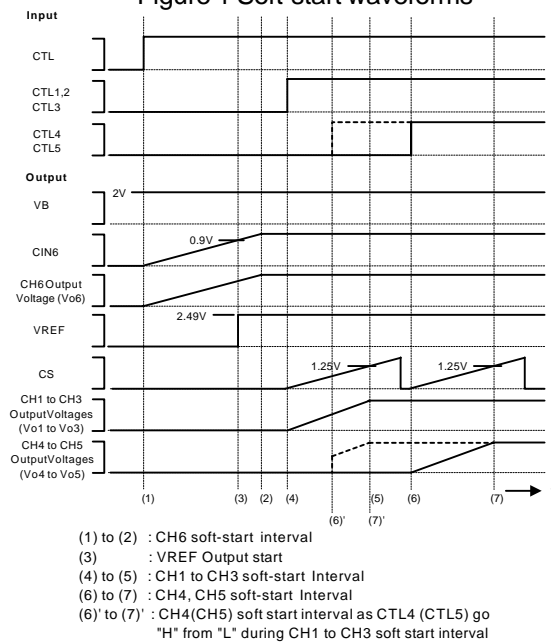


Figure 2 Soft-start waveforms



## Function Descriptions (Cont.)

### Output Switch Control Circuit

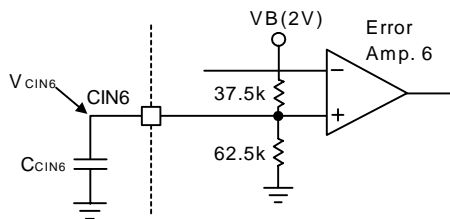
The output switch control circuit outputs a signal to control external p-channel MOSFETs for preventing reactive current flow to external step-up circuits on CH5 and CH6. When a “H” level signal is applied to SWIN pin after releasing the UVLO and the voltage at CIN6 pin rises above 0.9V(typical), the IC pulls low the voltage at SWOUT pin, turning on the external p-channel MOSFETs to generate output voltages.

## Application Information

### Soft-Start Interval Settings

The CH6 soft-start time depends on the capacitor  $C_{CIN6}$  and is determined as the following equation:

$$t_s(S) = \frac{C_{CIN6}(F) \cdot 37.5(k\Omega) \cdot 62.5(k\Omega)}{100(k\Omega)} \cdot \ln\left(1 - \frac{V_{CIN6}(V)}{1.26(V)}\right)$$



The soft-start time until CH6 output voltage reaches 95% of the set voltage is determined as the following equation:

$$t_s(S) \approx 0.07 \cdot C_{CIN6} (\mu F)$$

On CH1 to CH5, the soft-start time depending on the capacitor  $C_s$  determined as the following equation :

### Triangular Oscillator Frequency Setting

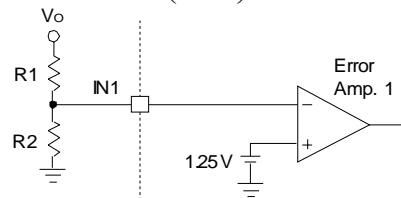
The triangular oscillator frequency set by the timing capacitor (CT) connected to the CT pin and the timing resistor (RT) connected to the RT pin determined as the following equation:

### Output Voltage Settings

The output voltage is set by the external resistor-divider connected with converter output, error amplifier input, and ground.

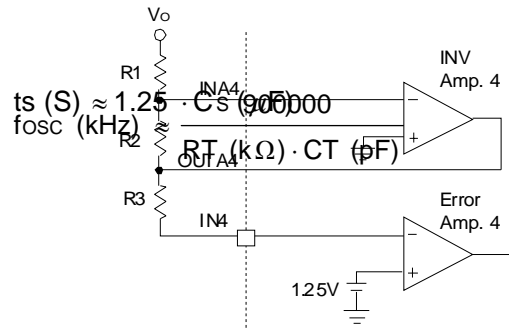
(1) CH1 to CH3, CH5

$$V_o(V) = 1.25V \cdot \left(1 + \frac{R1}{R2}\right)$$



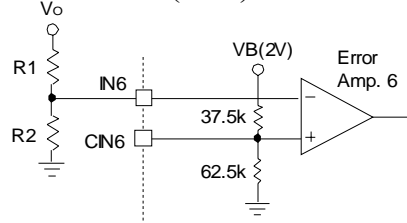
(2) CH4

$$V_o(V) = -1.25V \cdot \frac{R1}{R2}$$



(3) CH6

$$V_o(V) = 1.26V \cdot \left(1 + \frac{R1}{R2}\right)$$



### Time Constant Setting for Timer-Latch Short-Circuit Protection Circuit

The time constant for timer-latch short-circuit protection is set by the capacitor  $C_{SCP}$  and determined as the following equation :

$$t_{PE}(S) = 0.70 \cdot C_{SCP} (\mu F)$$

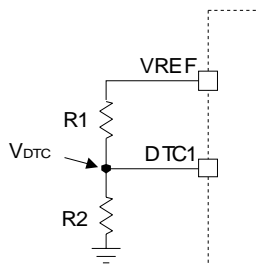
## Application Information (Cont.)

### Dead-Time Setting

The dead-time control pin (DTC) is designed to set the maximum ON duty of the main-side MOSFET. When the device is set for step-up inverted output based on the step-up or step-up/down Zeta method or flyback method, the FB pin voltage may reach and exceed the triangular wave voltage due to load fluctuation. If this is the case, the output MOSFET is fixed to a ON duty of 100 %. To prevent this, set the maximum duty of the output MOSFET. Connecting a resistor- divider between VREF, DTC and GND pins provides a voltage  $V_{DTC}$  to DTC pin. When the the voltage at the DTC pin is higher than the triangular wave voltage (CT1/ 2), the output transistor is turned on. The maximum duty is calculated as the following equation:

$$\text{ON Duty}_{(\max)} = \frac{V_{DTC} - 1.1V}{0.7V} \cdot 100 (\%)$$

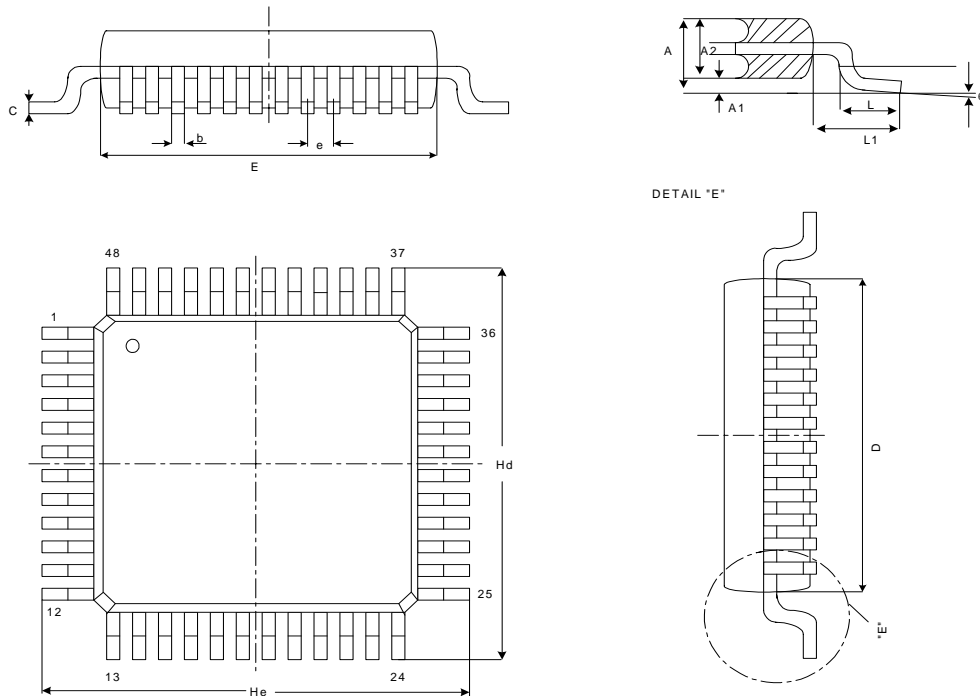
$$V_{DTC} (V) = \frac{R2}{R1 + R2} \cdot V_{REF}$$



where  $V_{REF}$  is the output of the reference voltage (2.49V typical) at VREF pin. The amplitude of the triangular waves CT1 and CT2 are typically 0.7V from 1.1V to 1.8V.

Package Information

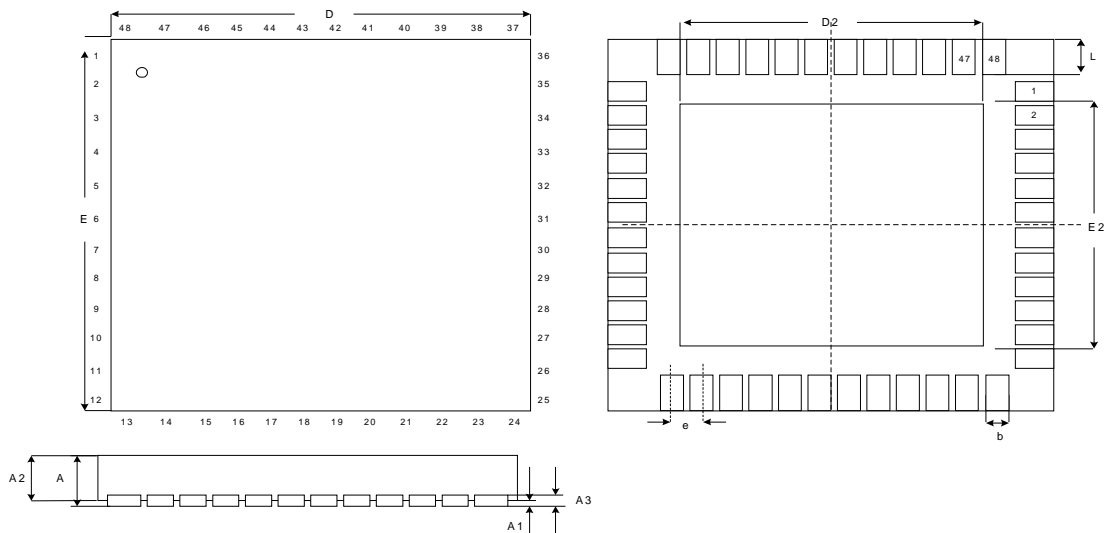
LQFP-48



| Dim | Millimeters |       | Inches        |        |
|-----|-------------|-------|---------------|--------|
|     | Min.        | Max.  | Min.          | Max.   |
| A   | -           | 1.600 | -             | 0.0630 |
| A1  | 0.050       | 0.150 | 0.0020        | 0.0059 |
| A2  | 1.400±0.05  |       | 0.0551±0.0020 |        |
| b   | 0.200TYP    |       | 0.0078TYP     |        |
| c   | 0.127TYP    |       | 0.0050TYP     |        |
| D   | 7.000±0.100 |       | 0.2756±0.0039 |        |
| E   | 7.000±0.100 |       | 0.2756±0.0039 |        |
| e   | 0.500TYP    |       | 0.0196TYP     |        |
| Hd  | 9.000±0.250 |       | 0.3543±0.0098 |        |
| He  | 9.000±0.250 |       | 0.3543±0.0098 |        |
| L   | 0.600±0.150 |       | 0.0236        | 0.006  |
| L1  | 1.000REF    |       | 0.0393REF     |        |
| y   | -           | 0.100 | -             | 0.0039 |
| θ   | 0°          | 7°    | 0°            | 7°     |

Package Information

TQFN-48

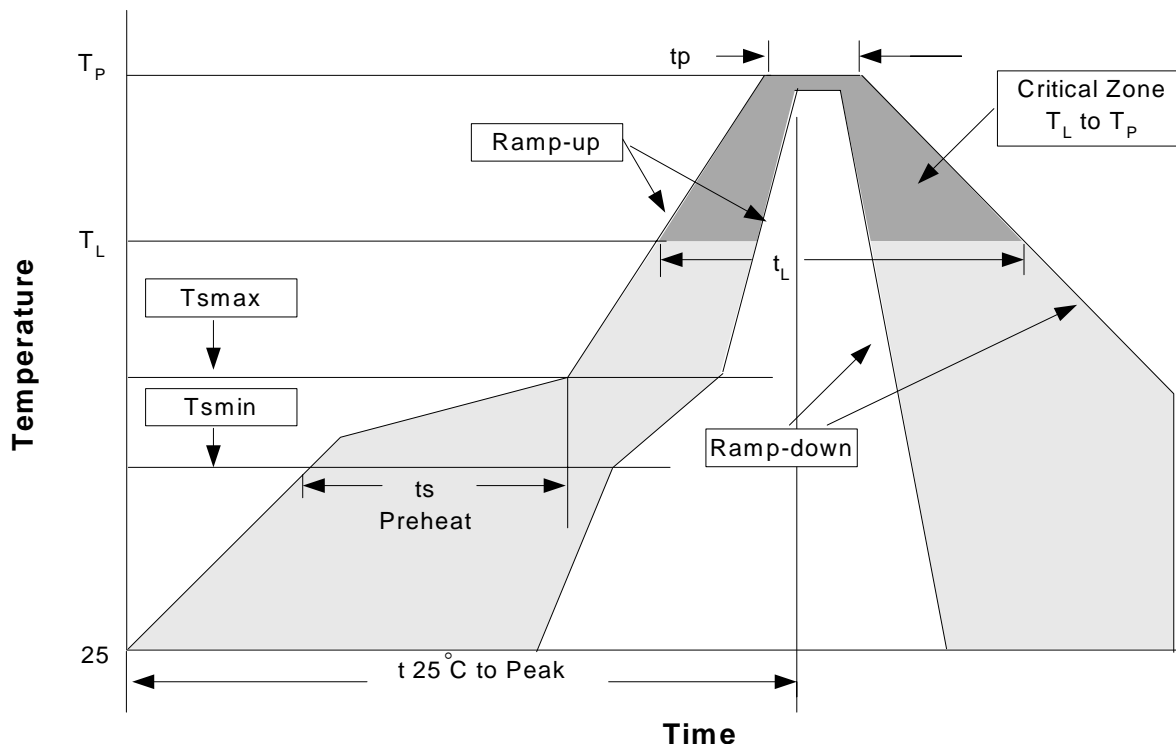


| Dim | Millimeters |      | Inches   |       |
|-----|-------------|------|----------|-------|
|     | Min.        | Max. | Min.     | Max.  |
| A   | 0.80        | 1.00 | 0.03     | 0.04  |
| A1  | 0           | 0.05 | 0        | 0.002 |
| A2  | 0           | 1.00 | 0        | 0.04  |
| A3  | 0.20REF     |      | 0.008REF |       |
| b   | 0.18        | 0.30 | 0.007    | 0.01  |
| D   | 7BSC        |      | 0.28BSC  |       |
| D2  | 4.15        | 5.25 | 0.09     | 0.21  |
| E   | 7BSC        |      | 0.28BSC  |       |
| E2  | 4.15        | 5.25 | 0.09     | 0.21  |
| e   | 0.50BSC     |      | 0.02BSC  |       |
| L   | 0.30        | 0.50 | 0.01     | 0.01  |

## Physical Specifications

|                    |  |
|--------------------|--|
| Terminal Material  | Solder-Plated Copper (Solder Material : 90/10 or 63/37 SnPb), 100%Sn |
| Lead Solderability | Meets EIA Specification RSI86-91, ANSI/J-STD-002 Category 3.         |

### Reflow Condition (IR/Convection or VPR Reflow)



### Classification Reflow Profiles

| Profile Feature                                     | Sn-Pb Eutectic Assembly |               | Pb-Free Assembly |               |
|---|-------------------------|---------------|------------------|---------------|
|   | Large Body              | Small Body    | Large Body       | Small Body    |
| Average ramp-up rate ( $T_L$ to $T_P$ )             | 3°C/second max.         |               | 3°C/second max.  |               |
| Preheat   |                         |               |                  |               |
| - Temperature Min ( $T_{smin}$ )                    | 100°C                   |               | 150°C            |               |
| - Temperature Mix ( $T_{smax}$ )                    | 150°C                   |               | 200°C            |               |
| - Time (min to max)( $t_s$ )                        | 60-120 seconds          |               | 60-180 seconds   |               |
| $T_{smax}$ to $T_L$                                 |                         |               | 3°C/second max   |               |
| - Ramp-up Rate                                      |                         |               |                  |               |
| $T_{smax}$ to $T_L$                                 |                         |               |                  |               |
| - Temperature( $T_L$ )                              | 183°C                   |               | 217°C            |               |
| - Time ( $t_L$ )                                    | 60-150 seconds          |               | 60-150 seconds   |               |
| Peak Temperature( $T_p$ )                           | 225 +0/-5°C             | 240 +0/-5°C   | 245 +0/-5°C      | 250 +0/-5°C   |
| Time within 5°C of actual Peak Temperature( $t_p$ ) | 10-30 seconds           | 10-30 seconds | 10-30 seconds    | 20-40 seconds |
| Ramp-down Rate                                      | 6°C/second max.         |               | 6°C/second max.  |               |
| Time 25°C to Peak Temperature                       | 6 minutes max.          |               | 8 minutes max.   |               |

Note: All temperatures refer to topside of the package. Measured on the body surface.



## CONTACT

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