AP2001
MONOLITHIC DUAL CHANNEL PWM CONTROLLER

## Features

- Dual PWM control circuitry
- Operating voltage can be up to 50 V
- Adjustable Dead Time Control (DTC)
- Under Voltage Lockout (UVLO) protection
- Short Circuit Protection (SCP)
- Variable oscillator frequency: 500 KHz Max
- $\quad 2.5 \mathrm{~V}$ voltage reference output
- SOP-16L package
- Lead Free Finish/RoHS Compliant for Lead Free products (Note 1)


## General Description

The AP2001 integrates Pulse-width-Modulation (PWM) control circuit into a single chip, mainly designed for power-supply regulator. All the functions included are an on-chip 2.5 V reference output, two error amplifiers, an adjustable oscillator two dead-time comparators, UVLO, SCP, DTC circuitry, and dual common-emitter (CE) output transistor circuit.

Recommend the output CE transistors as pre-driver for Driving externally. The DTC can provide from 0\% to 100\%. Switching frequency can be adjustable by trimming RT and CT. During low $\mathrm{V}_{\mathrm{cc}}$ situation, the UVLO makes sure that the outputs are off until the internal circuit is operating normally.

## Applications

- Backlight inverter
- DC/DC converts in computers, etc.


## Ordering Information



Note:

1. RoHS revision 13.2.2003. Glass and High Temperature Solder Exemptions Applied, see EU Directive Annex Notes 5 and 7.

| Device | Package <br> Code | Packaging <br> (Note 2) | Tube |  | 13" Tape and Reel |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Quantity |  | Quantity | Part Number Suffix |  |  |  |
| AP2001S | S | SOP-16L | 50 | $-U$ | $2500 /$ Tape \& Reel | -13 |

Note: 2. Pad layout as shown on Diodes Inc. suggested pad layout document AP02001, which can be found on our website at http://www.diodes.com/datasheets/ap02001.pdf.

## Pin Assignments



## Pin Descriptions

| Name | Description |
| :---: | :--- |
| CT | Timing Capacitor |
| RT | Timing Resistor |
| EA+ | Error Amplifier Input(+) |
| EA - | Error Amplifier Input(-) |
| FB | Feedback Loop Compensation |
| DTC | Dead Time Control |
| OUT | Pre-driver Output |
| GND | Ground |
| VCC | Supply Voltage |
| SCP | Short Circuit Protection |
| REF | Voltage Reference |



## Absolute Maximum Ratings

| Symbol | Parameter | Rating | Unit |
| :---: | :--- | :---: | :---: |
| $\mathrm{V}_{\mathrm{CC}}$ | Supply Voltage | 40 | V |
| $\mathrm{~V}_{\mathrm{I}}$ | Amplifier Input Voltage | 20 | V |
| $\mathrm{~V}_{\mathrm{O}}$ | Collector Output Voltage | 40 | V |
| lo | Collector Output Current | 21 | mA |
| $\mathrm{~T}_{\mathrm{OP}}$ | Operating Temperature Range | -20 to +85 | ${ }^{\circ} \mathrm{C}$ |
| $\mathrm{T}_{\mathrm{ST}}$ | Storage Temperature Range | -65 to +150 | ${ }^{\circ} \mathrm{C}$ |
| $\mathrm{T}_{\text {LEAD }}$ | Lead Temperature 1.6 mm (1/16 inch) from Case for 5 Seconds | 245 | ${ }^{\circ} \mathrm{C}$ |

## Recommended Operating Conditions

| Symbol | Parameter | Min. | Max. | Unit |
| :---: | :--- | :---: | :---: | :---: |
| $\mathrm{V}_{\mathrm{CC}}$ | Supply Voltage | 3.6 | 40 | V |
| $\mathrm{~V}_{\mathrm{I}}$ | Amplifier Input Voltage | 1.05 | 1.45 | V |
| $\mathrm{~V}_{\mathrm{O}}$ | Collector Output Voltage |  | 40 | V |
| $\mathrm{I}_{\mathrm{O}}$ | Collector Output Current |  | 20 | mA |
| $\mathrm{I}_{\mathrm{FB}}$ | Current into Feedback Terminal |  | 45 | $\mu \mathrm{~A}$ |
| $\mathrm{R}_{\mathrm{F}}$ | Feedback Resistor | 100 |  | $\mathrm{k} \Omega$ |
| $\mathrm{C}_{\mathrm{T}}$ | Timing Capacitor | 150 | 15000 | pF |
| $\mathrm{R}_{\mathrm{T}}$ | Timing Resistor | 5.1 | 100 | $\mathrm{k} \Omega$ |
| $\mathrm{F}_{\mathrm{OSC}}$ | Oscillator Frequency | 1 | 500 | KHz |
| $\mathrm{T}_{\mathrm{OP}}$ | Operating Free-air Temperature | -20 | 85 | ${ }^{\circ} \mathrm{C}$ |

Electrical Characteristics $\left(\mathrm{T}_{\mathrm{A}}=25^{\circ} \mathrm{C}, \mathrm{V}_{\mathrm{CC}}=6 \mathrm{~V}, \mathrm{f}=200 \mathrm{KHz}\right)$

Reference (REF)

| Symbol | Parameter | Conditions | Min. | Typ. | Max. | Unit |
| :---: | :--- | :--- | :---: | :---: | :---: | :---: |
| $\mathrm{V}_{\mathrm{O}}$ | Output Voltage (pin 16) | $\mathrm{I}_{\mathrm{O}}=1 \mathrm{~mA}$ | 2.4 | 2.5 | 2.6 | V |
|  | Output Voltage Change with <br> Temperature | $\mathrm{T}_{\mathrm{A}}=-20^{\circ} \mathrm{C} \sim 25^{\circ} \mathrm{C}$ |  | -0.1 | $\pm 1$ | $\%$ |
|  | $\mathrm{~T}_{\mathrm{A}}=25^{\circ} \mathrm{C} \sim 85^{\circ} \mathrm{C}$ |  | -0.2 | $\pm 1$ | $\%$ |  |
| $\mathrm{~V}_{\mathrm{DLI}}$ | Input Stability | $\mathrm{V}_{\mathrm{CC}}=3.6 \mathrm{~V} \sim 40 \mathrm{~V}$ |  | 2 | 12.5 | mV |
| $\mathrm{V}_{\mathrm{DLO}}$ | Output Stability | $\mathrm{I}_{\mathrm{O}}=0.1 \mathrm{~mA} \sim 1 \mathrm{~mA}$ |  | 1 | 7.5 | mV |
| $\mathrm{I}_{\mathrm{O}}$ | Short-circuit Output Current | $\mathrm{V}_{\mathrm{O}}=0$ | 3 | 10 | 30 | mA |

Under voltage lockout (UVLO)

| Symbol | Parameter | Conditions | Min. | Typ. | Max. | Unit |
| :---: | :--- | :--- | :---: | :---: | :---: | :---: |
| $\mathrm{V}_{\mathrm{UT}}$ | Upper Threshold Voltage $\left(\mathrm{V}_{\mathrm{CC}}\right)$ |  |  | 2.65 |  | V |
| $\mathrm{~V}_{\mathrm{LWT}}$ | Lower Threshold Voltage $\left(\mathrm{V}_{\mathrm{CC}}\right)$ | $\mathrm{I}_{(R E F)}=0.1 \mathrm{~mA}$ |  | 2.45 |  | V |
| $\mathrm{~V}_{\mathrm{HT}}$ | Hysteresis $\left(\mathrm{V}_{\mathrm{CC}}\right)$ | $25^{\circ} \mathrm{C}$ |  | 80 | 200 |  |
|  |  |  | mV |  |  |  |

MONOLITHIC DUAL CHANNEL PWM CONTROLLER

## Electrical Characteristics ( Continued)

Short-circuit protection (SCP) control

| Symbol | Parameter | Conditions | Min. | Typ. | Max. | Unit |
| :---: | :--- | :--- | :---: | :---: | :---: | :---: |
| $\mathrm{V}_{\mathrm{IT}}$ | Input Threshold Voltage | $\mathrm{T}_{\mathrm{A}}=25^{\circ} \mathrm{C}$ | 0.65 | 0.7 | 0.75 | V |
| $\mathrm{~V}_{\mathrm{STB}}$ | Standby Voltage | No pull up | 140 | 185 | 230 | mV |
| $\mathrm{V}_{\mathrm{LT}}$ | Latched Input Voltage | No pull up |  | 60 | 120 | mV |
| $\mathrm{I}_{\mathrm{SCP}}$ | Input (Source) Current | $\mathrm{V}_{\mathrm{I}}=0.7 \mathrm{~V}, \mathrm{~T}_{\mathrm{A}}=25^{\circ} \mathrm{C}$ | -10 | -15 | -20 | $\mu \mathrm{~A}$ |
| $\mathrm{~V}_{\mathrm{CT}}$ | Comparator Threshold Voltage (FB) |  |  | 1.18 |  | V |

## Oscillator (OSC)

| Symbol | Parameter | Conditions | Min. | Typ. | Max. | Unit |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| $\mathrm{F}_{\text {OSC }}$ | Frequency | $\mathrm{C}_{\mathrm{T}}=330 \mathrm{pF}, \mathrm{R}_{\mathrm{T}}=10 \mathrm{~K} \Omega$ |  | 200 |  | KHz |
| $\Delta \mathrm{F}_{\text {Osc }}$ | Standard Deviation of Frequency | $\mathrm{C}_{\mathrm{T}}=330 \mathrm{pF}, \mathrm{R}_{\mathrm{T}}=10 \mathrm{~K} \Omega$ |  | 10 |  | \% |
|  | Frequency Change with Voltage | $\mathrm{V}_{\mathrm{CC}}=3.6 \mathrm{~V} \sim 40 \mathrm{~V}$ |  | 1 |  |  |
|  | Frequency Change with Temperature | $\mathrm{T}_{\mathrm{A}}=-20^{\circ} \mathrm{C} \sim 25^{\circ} \mathrm{C}$ |  | -0.4 | $\pm 2$ |  |
|  |  | $\mathrm{T}_{\mathrm{A}}=25^{\circ} \mathrm{C} \sim 85^{\circ} \mathrm{C}$ |  | -0.2 | $\pm 2$ |  |

Dead-time control (DTC)

| Symbol | Parameter | Conditions | Min. | Typ. | Max. | Unit |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| $\mathrm{I}_{\text {BDT }}$ | Input Bias Current |  |  |  | 1 |  |
| $\mathrm{l}_{\text {DT }}$ | Latch Mode (Source) Current | $\mathrm{T}_{\mathrm{A}}=25^{\circ} \mathrm{C}$ | -80 | -145 |  |  |
| $V_{D T}$ | Latched Input Voltage | $\mathrm{I}_{\mathrm{O}}=40 \mu \mathrm{~A}$ | 2.3 |  |  | V |
| $\mathrm{V}_{\text {T0 }}$ | Input Threshold Voltage at $\mathrm{f}=10 \mathrm{KHz}$ | Zero duty cycle |  | 2.05 | 2.25 |  |
| $\mathrm{V}_{\mathrm{T} 100}$ |  | Maximum duty cycle | 1.2 | 1.45 |  |  |

## Error-amplifier

| Symbol | Parameter | Conditions | Min. | Typ. | Max. | Unit |
| :---: | :--- | :--- | :---: | :---: | :---: | :---: |
| $\mathrm{V}_{\mathrm{IO}}$ | Input Offset Voltage | $\mathrm{V}_{\mathrm{O}}(\mathrm{FB})=1.25 \mathrm{~V}$ |  |  | $\pm 6$ | mV |
| $\mathrm{I}_{\mathrm{IO}}$ | Input Offset Current | $\mathrm{V}_{\mathrm{O}}(\mathrm{FB})=1.25 \mathrm{~V}$ |  |  | $\pm 100$ | nA |
| $\mathrm{I}_{\mathrm{IB}}$ | Input Bias Current | $\mathrm{V}_{\mathrm{O}}(\mathrm{FB})=1.25 \mathrm{~V}$ |  | 160 | 500 | nA |
| $\mathrm{V}_{\mathrm{CM}}$ | Common-mode Input Voltage <br> Range | $\mathrm{V}_{\mathrm{CC}}=3.6 \mathrm{~V} \sim 40 \mathrm{~V}$ | 1.05 <br> to <br> 1.45 |  |  | V |
| AV | Open-loop Voltage <br> Amplification | $\mathrm{R}_{\mathrm{F}}=200 \mathrm{~K} \Omega$ | 70 | 80 |  | dB |
| GBW | Unity-gain Bandwidth |  | 60 | 80 |  | dB |
| CMRR | Common-mode Rejection <br> Ratio |  | $\mathrm{V}_{\text {ref }}-0.1$ |  |  | V |
| $\mathrm{~V}_{\mathrm{OH}}$ | Max. Output Voltage |  |  |  | 1 | V |
| $\mathrm{~V}_{\mathrm{OL}}$ | Min. Output Voltage |  | 0.5 | 1.6 |  | mA |
| $\mathrm{I}_{\mathrm{OI}}$ | Output (Sink) Current (FB) | $\mathrm{V}_{\mathrm{ID}}=-0.1 \mathrm{~V}, \mathrm{~V}_{\mathrm{O}}=1.25 \mathrm{~V}$ | 0.5 |  |  |  |
| $\mathrm{I}_{\mathrm{OO}}$ | Output (Source) Current (FB) | $\mathrm{V}_{\mathrm{ID}}=0.1 \mathrm{~V}, \mathrm{~V}_{\mathrm{O}}=1.25 \mathrm{~V}$ | -45 | -70 |  | $\mu \mathrm{~A}$ |

## Electrical Characteristics (Continued)

Output section

| Symbol | Parameter | Conditions | Min. | Typ. | Max. | Unit |
| :---: | :--- | :--- | :---: | :---: | :---: | :---: |
| $\mathrm{I}_{\text {LEAK }}$ | Leakage Current | $\mathrm{V}_{\mathrm{O}}=40 \mathrm{~V}$ |  |  | 10 | $\mu \mathrm{~A}$ |
| $\mathrm{~V}_{\text {SAT }}$ | Output Saturation Voltage | $\mathrm{I}_{\mathrm{O}}=10 \mathrm{~mA}$ |  | 1.2 | 2 | V |
| $\mathrm{I}_{\mathrm{SC}}$ | Short-circuit Output Current | $\mathrm{V}_{\mathrm{O}}=6 \mathrm{~V}$ |  | 90 |  | mA |

PWM comparator

| Symbol | Parameter | Conditions | Min. | Typ. | Max. | Unit |
| :---: | :--- | :--- | :---: | :---: | :---: | :---: |
| $\mathrm{V}_{\text {T0 }}$ | Input Threshold Voltage at $\mathrm{f}=$ | Zero duty cycle |  | 2.05 | 2.25 | V |
|  | 10 KHz (FB) | Maximum duty cycle | 1.2 | 1.45 |  | V |

Total device

| Symbol | Parameter | Conditions | Min. | Typ. | Max. | Unit |
| :---: | :--- | :--- | :---: | :---: | :---: | :---: |
| $\mathrm{I}_{\mathrm{CCs}}$ | Standby Supply Current | Off-state |  | 2.5 | 3.0 | mA |
| $\mathrm{I}_{\mathrm{CCA}}$ | Average Supply Current | $\mathrm{R}_{\mathrm{T}}=10 \mathrm{~K} \Omega$ |  | 2.8 | 3.5 | mA |

## Typical Application Circuit



Dual output DCIDC converter

## Marking Information

(1) SOP-16L


SOP-16L

## Package Information

(1) Package Type: SOP-16L


IMPORTANT NOTICE
Diodes Incorporated and its subsidiaries reserve the right to make modifications, enhancements, improvements, corrections or other changes without further notice to any product herein. Diodes Incorporated does not assume any liability arising out of the application or use of any product described herein; neither does it convey any license under its patent rights, nor the rights of others. The user of products in such applications shall assume all risks of such use and will agree to hold Diodes Incorporated and all the companies whose products are represented on our website, harmless against all damages.

## LIFE SUPPORT

Diodes Incorporated products are not authorized for use as critical components in life support devices or systems without the expressed written approval of the President of Diodes Incorporated.

