

## Compact 500KHz PWM/PFM, Step-Down DC/DC Converters

### FEATURES

- Tiny 5-Lead SOT-23 package
- Uses Tiny Capacitors and Inductor
- High Frequency Operation: 500KHz
- High Output Current: 500mA
- Low  $R_{DS(ON)}$  Internal Switch:  $0.6\Omega$
- High Efficiency: Up to 90%
- Current Mode Operation for Excellent Line and Load Transient Response
- Short-Circuit Protected
- Low Quiescent Current:  $22\mu A$
- Low Dropout Operation: 100% Duty Cycle
- Ultralow Shutdown Current:  $I_Q < 1\mu A$
- Peak Inductor Current Independent of Inductor Value
- Low Output Voltages: Down to 0.75V

### APPLICATIONS

- Cellular Phones.
- PDAs and Handy-Terminals.
- CPU I/O Supplies.
- Cordless Phones.
- Notebook Chipset Supplies.
- Handheld Equipment

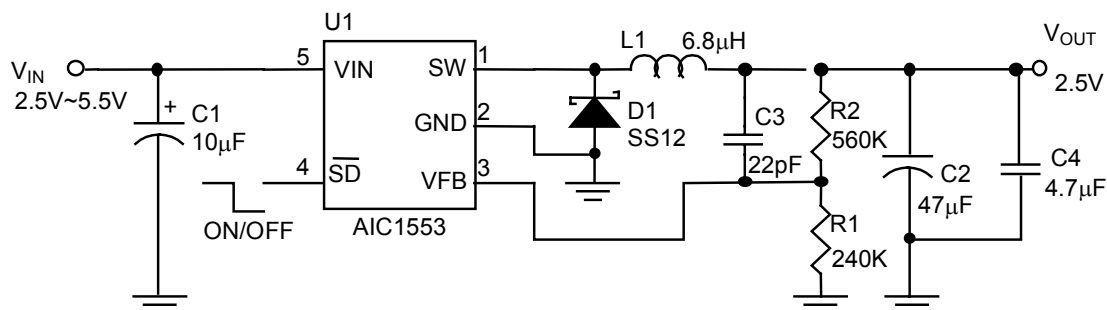
### DESCRIPTION

The AIC1553 is a step-down, current mode, DC/DC converter. It operates from 2.5V to 5.5V input voltage range and switches at 500KHz, allowing the use of tiny, low cost capacitors and inductors. The output voltage is adjustable from 0.75V to 5V. A built-in  $0.6\Omega$  switch allows up to 0.5A of output current at high efficiency.

The AIC1553 operates continuously to very low load currents to provide low ripple at the expense of light load efficiency. With no load, the AIC1553 draws only  $22\mu A$ . In shutdown mode, it draws less than  $1\mu A$ , making it ideal for current sensitive applications.

The tiny 5-lead SOT-23 package makes it easy to save the layout area.

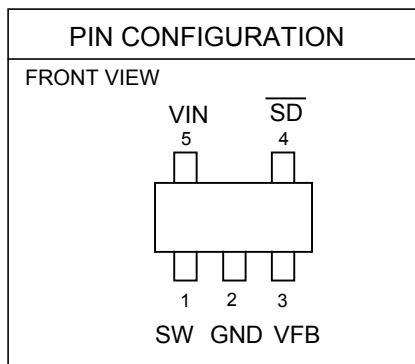
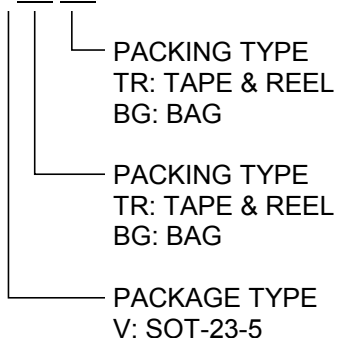
### TYPICAL APPLICATION CIRCUIT



**2.5V/500mA Step-Down Converter**

## ORDERING INFORMATION

AIC1553CXXX XX



Example: AIC1553CVTR  
→ In SOT-23-5 Package & Tape & Reel Packing Type

### SOT-23-5 MARKING

Part No.	Marking
AIC1553CV	EP01

## ABSOLUTE MAXIMUM RATINGS

(Voltage Referred to GND Pin)

VIN Pin Voltage .....	- 0.3 to + 6V
SD Voltage (Pin 4).....	- 0.3 to + 6V
V <sub>FB</sub> Voltage (Pin 3).....	- 0.3 to + 6V
VIN – SW (Max Switch Voltage).....	7.0V to - 0.3V
Operating Temperature Range .....	-40°C ~ 85°C
Junction Temperature Range.....	125°C
Storage Temperature Range.....	- 65°C ~ 150°C

## TEST CIRCUIT

Refer to TYPICAL APPLICATION CIRCUIT.

**■ ELECTRICAL CHARACTERISTICS** ( $V_{IN}=3.6V$ ,  $T_A=25^{\circ}C$ , unless otherwise specified.)

PARAMETER	SYMBOL	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Operating Voltage Range	$V_{IN}$		2.5		5.5	V
Feedback Pin Input Current	$I_{FB}$				$\pm 0.1$	$\mu A$
Feedback Voltage	$V_{FB}$			0.75		V
Reference Voltage Line Regulation	$\Delta V_{LINE\ REG}$	$V_{IN}=2.5V$ to $5V$ , $I_{LOAD}=200mA$		5	15	mV
Output Voltage Load Regulation	$\Delta V_{LOAD\ REG}$	$I_{LOAD}=100mA$ to $500mA$		5	20	mV
Quiescent Current	$I_Q$			22		$\mu A$
Shutdown Mode Input DC Supply Current				0.25	1	$\mu A$
Shutdown Threshold High Shutdown Threshold Low	$V_{SD}$		0.3	1.4 0.6	1.6	V
Peak Switch Current Threshold	$I_{SW(PEAK)}$	$V_{FB} = 0V$	0.7	1.1		A
Switch ON Resistance	$R_{DS(ON)}$	$V_{IN} = 3.3V$ , $V_{FB} = 0V$		0.6		$\Omega$

## TYPICAL PERFORMANCE CHARACTERISTICS

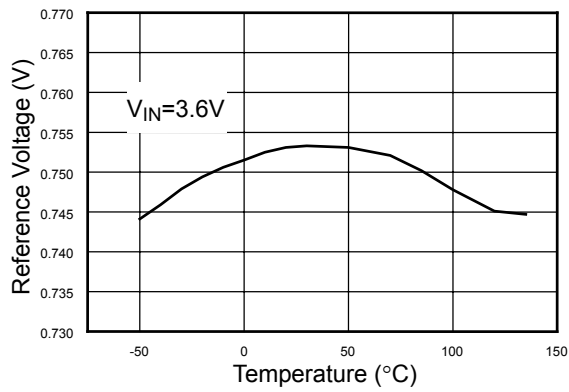


Fig. 2 Reference Voltage vs. Temperature

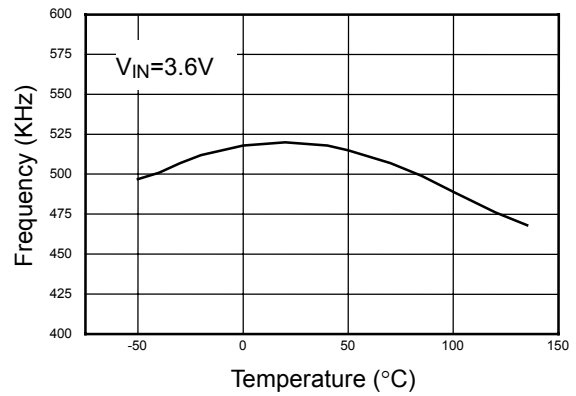


Fig. 2 Frequency vs. Temperature

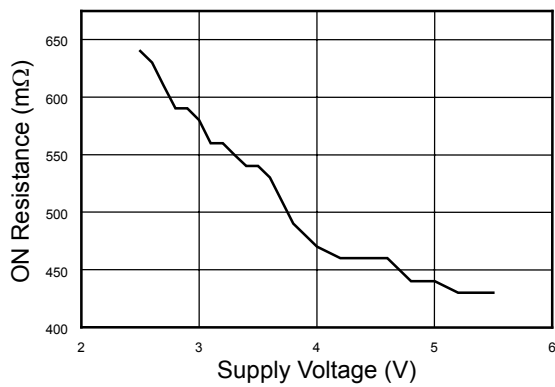


Fig. 3 Switch Resistance vs. Supply Voltage

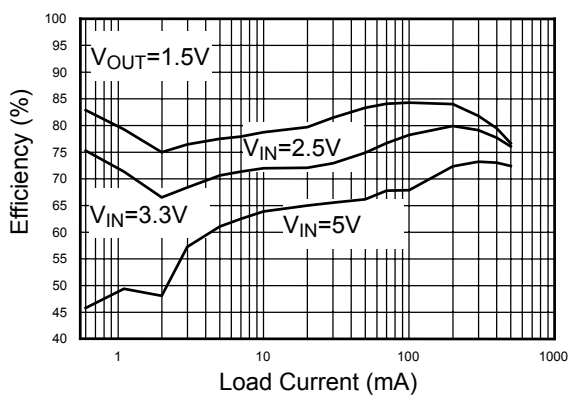


Fig. 4 Efficiency vs. Load Current

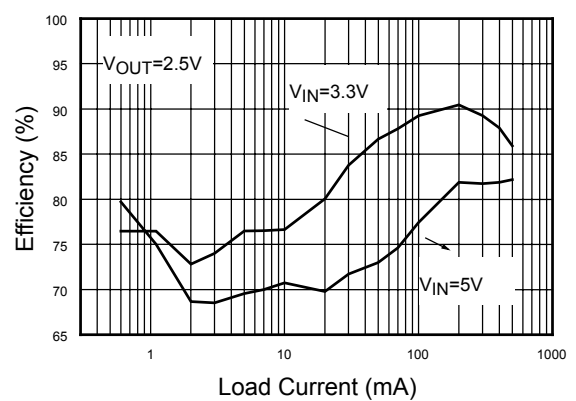


Fig. 5 Efficiency vs. Load Current

# **TYPICAL PERFORMANCE CHARACTERISTICS (Continued)**

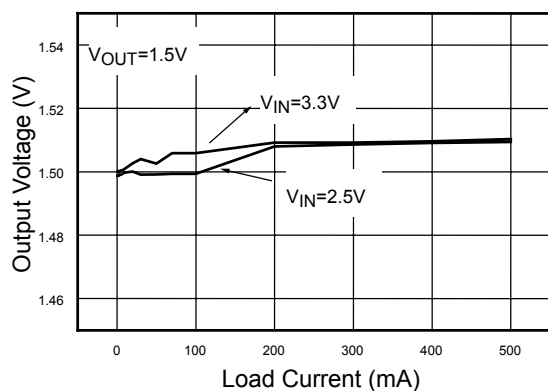


Fig. 6 Load Regulation

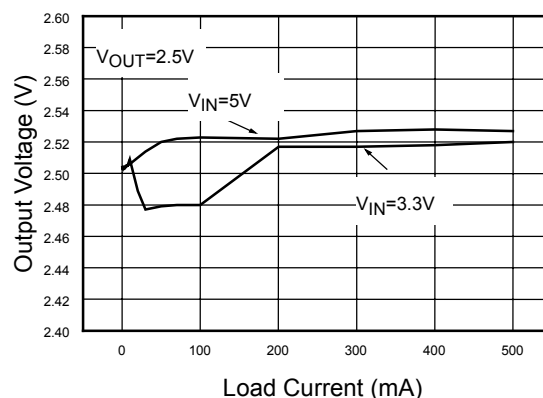


Fig. 7 Load Regulation

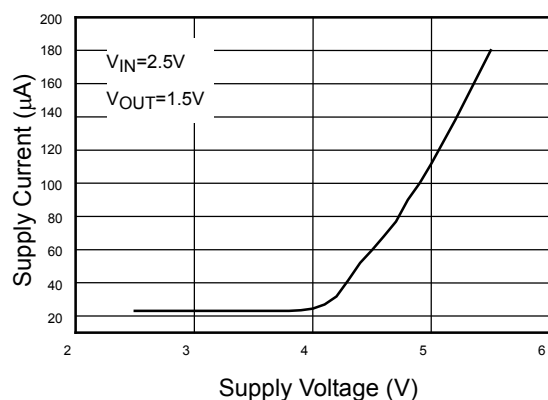


Fig. 8 DC Supply Current

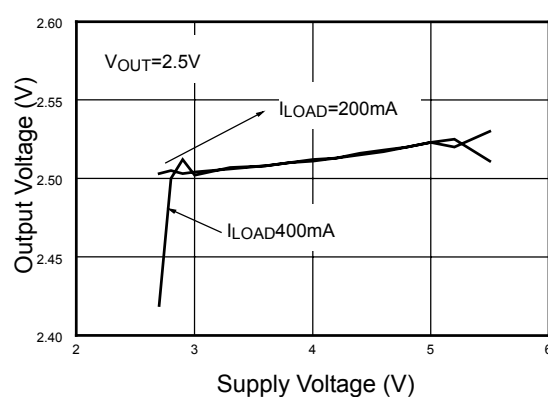


Fig. 9 Line Regulation

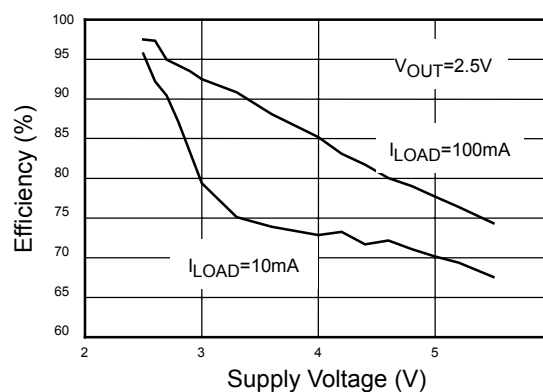


Fig. 10 Efficiency vs. Input Voltage

## ■ TYPICAL PERFORMANCE CHARACTERISTICS (Continued)

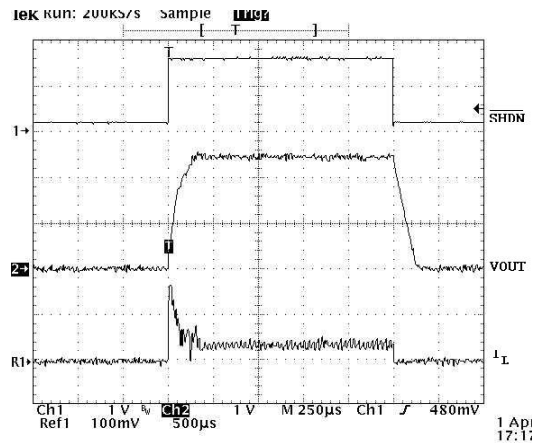


Fig. 11 Start-up  $I_{LOAD}=400mA$   
 $V_{IN}=3.3V$ ,  $V_{OUT}=2.5V$

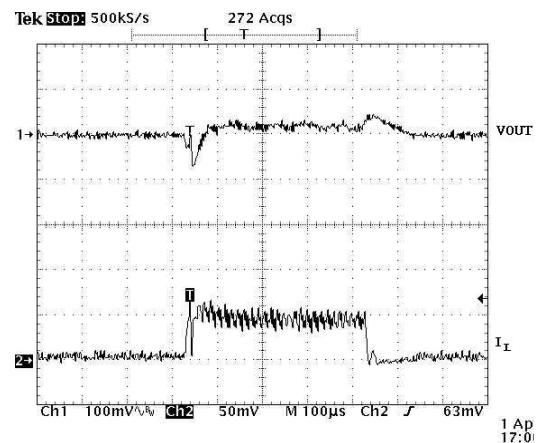
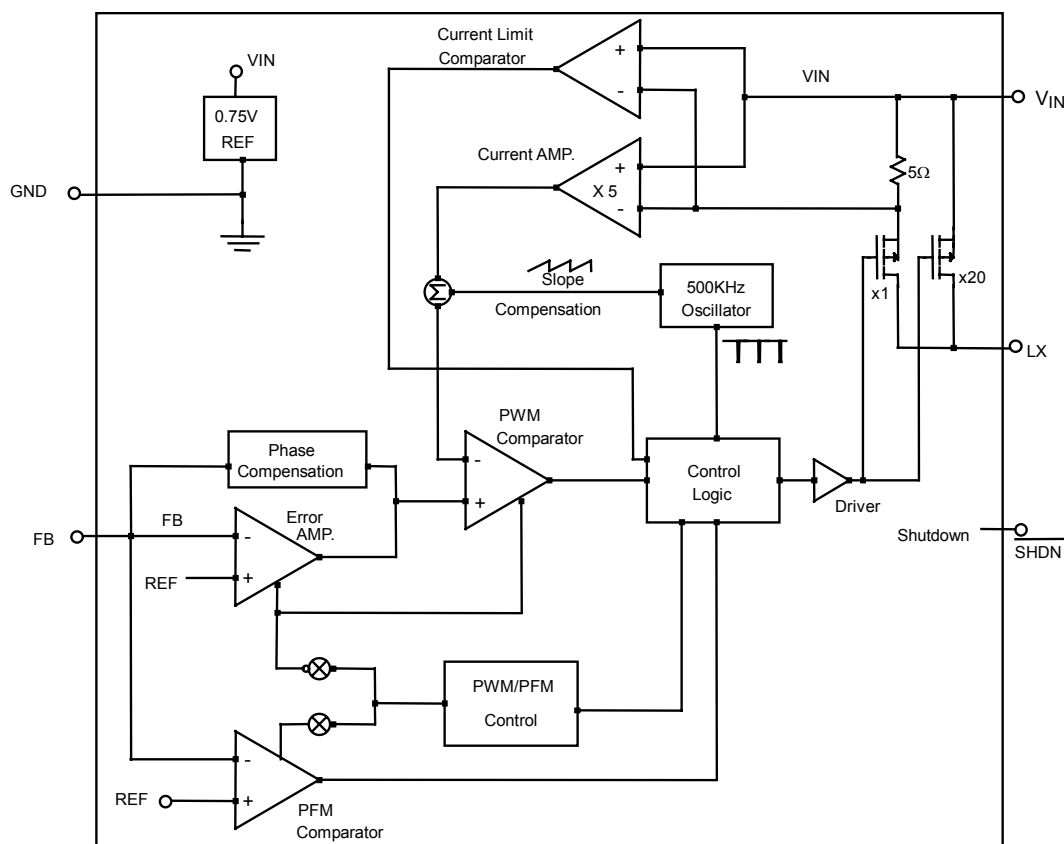


Fig. 12 Load Transient Response  
 $I_{LOAD}=20mA$  to  $400mA$   
 $V_{IN}=3.3V$ ,  $V_{OUT}=2.5V$

## ■ BLOCK DIAGRAM



## ■ PIN DESCRIPTIONS

- |  |   |
|--|---|
| <p>PIN 1: SW     - Switch Node. The Switch node connects to the inductor. This pin swings from <math>V_{IN}</math> to a Schottky diode (external) voltage drop below ground. The cathode of the Schottky diode must be closely connected to this pin.</p> <p>PIN 2: GND     - Ground Pin. Connect to the (-) terminal of <math>C_{OUT}</math>, the Schottky diode and (-) terminal of <math>C_{IN}</math>.</p> <p>PIN 3: VFB     - Output Feedback Pin. Receives the feedback voltage from the</p> | <p>external resistive divider across the output. Nominal voltage for this pin is 0.75V.</p> <p>PIN 4: <math>\overline{SD}</math>     - Shutdown Pin. Voltage at 1.6V or higher may enable the device. Connect this pin to Ground for shutdown.</p> <p>PIN 5: VIN     - Main Power Supply. Main supply pin and the (+) Input to the Current Comparator. Must be closely decoupled to ground.</p> |
|--|---|

## ■ APPLICATION INFORMATION

### Overview

AIC1553 is a step-down DC-DC converter using PWM current mode architecture. The 2.5V to 5.5V input voltage range ideally suited for single Li-ion or 3cell NiMH/NiCd batteries applications. 0.75V of feedback reference voltage allows low output voltages down to 0.75V. Switching frequency is set at 500kHz, allowing the use of tiny, small capacitors and inductor. Under morning load current AIC1553 operates in PWM mode with a fixed switching frequency of typical 500kHz. At light load current, the device automatically enters the PFM mode operation, the switching frequency is reducing to decrease gate charge losses. At the same time, the quiescent current is typically only 22 $\mu$ A to achieve the high efficiency. In shutdown mode, it draws less than 1 $\mu$ A, making it ideal for current sensitive applications.

### PWM Mode Operation

During PWM mode operation the converter uses a fast response, current mode, controller circuitry

with input voltage feed forward. The fixed switching frequency of typical 500kHz allowing the use of tiny, small capacitors and inductor. The current mode operation achieves excellent line and load transient response. At the beginning of each cycle, the high side P-MOSFET turns on. The current flowed the inductor ramps up and is sensed through an internal circuitry. The high side P-MOSFET turns off until the sensed current causes the PWM comparator to trip or the inductor current reaches the peak switch current threshold 0.7A. The inductor current flows through the external Schottky diode to output terminal. After the period, the switch turns on and the next clock cycle starts again.

When the output terminal is short to ground, the input peak current will be limit under the peak switch current threshold 0.7A.

### PFM Mode Operation

As the load is relatively light and the peak current doesn't reach the power save mode threshold,

the AIC1553 automatically enters a pulse frequency modulation (PFM) mode. The switching frequency depends on the loading condition and with a minimum quiescent current and maintains high efficiency. The high side P-MOSFET operates intermittently. When output voltage drops, the error comparator enable the PFM controller and the output voltage rises until the error comparator trips. When the output voltage falls below until the error comparator trips again and the next cycle will be started. At no load connection, the quiescent current is typically only 22μA.

### Shutdown

The whole circuit is shutdown when SD pin is low level. In shutdown mode, the supply current is reduced to less 1μA. For proper operation, the SD pin must be connected and must not be left floating.

### Low Dropout Operation

The dropout voltage of buck converter depends on the maximum duty cycle and the voltage across the high side switch. AIC1553 offers a low input to output voltage difference, while it operates in the 100% duty cycle mode. The minimum input voltage to maintain regulation, depending on the loading current and output voltage.

The minimum input voltage can be calculated as:

$$V_{IN(MIN)} \geq V_{OUT} + I_{OUT(MAX)}(R_{DS(ON)} + R_L)$$

Where:

$I_{OUT(MAX)}$  = maximum output current

$R_{DS(ON)}$  = maximum P-MOSFET turn on resistance

$R_L$  =DC resistance of the inductor

### Selecting the Output Voltage

The output voltage can be set by a resistive divider. Use the following equation to calculate:

$$V_{OUT} = 0.75V(1 + R_2/R_1)$$

The feedback reference voltage 0.75V allows low output voltages from 0.75V to input voltage.

For stability of feedback compensation, it is required a small bypass capacitor 22pF in parallel to the upper feedback resistor.

### Inductor Selecting

The inductor value directly determines the inductor ripple current. The larger the inductor value, the small inductor ripple current and small output ripple voltage. But, the larger the inductor value causes a slower load transient response and larger conduction losses of the inductor. The  $\Delta I_L$  can be calculated as:

$$\Delta I_L = \frac{V_{OUT}}{f \times L} \left( 1 - \frac{V_{OUT}}{V_{IN}} \right)$$

To avoid saturation of the inductor, the rated current of the inductor should be less than the peak current of the inductor.

$$I_{L(PEAK)} = I_{OUT(MAX)} + \Delta I_L / 2$$

### Input and Output Capacitor Selecting

The input capacitor must be sufficient to filter the pulsating input current. A low ESR capacitor provides the small drop voltage to stabilize the input voltage during the transient loading. The input capacitor should be larger than 10μF and the ceramic capacitors and low ESR value of tantalum capacitors are recommend.



The selection of output capacitor dominates the ESR of the capacitor. The capacitance is adequate for filtering and the low ESR value shows a low ripple voltage.

The output ripple voltage can be calculated as:

$$\Delta V_o \cong \Delta I_L \left( \frac{1}{8C_{OUT}} + ESR \right)$$

Ceramic capacitor with low ESR value provides the low output ripple. For required, the ceramic capacitor parallel a tantalum capacitor is satisfied.

## Layout Considerations

Due to the high switching frequency and large transient current, the layout is recommended to have a ground plane and short connections to each component. Minimize the length and the sufficient traces for power- flow loop. Fig. 13 is recommended placement for components.

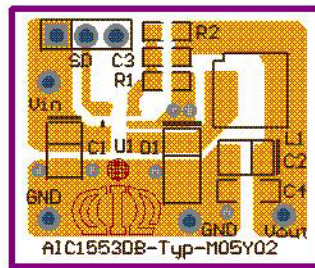
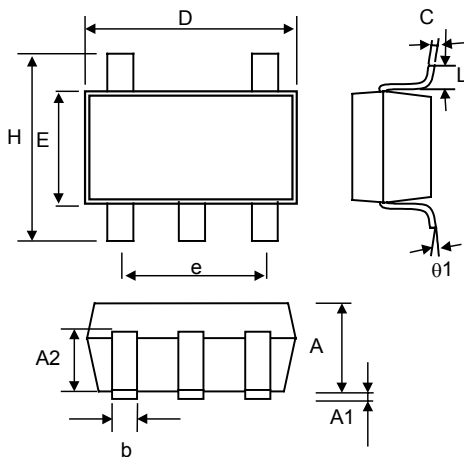


Fig. 13 The Recommended Placement and Routing of AIC1553

## PHYSICAL DIMENSIONS

- SOT-23-5 (unit: mm)



SYMBOL	MIN	MAX
A	1.00	1.30
A1	—	0.10
A2	0.70	0.90
b	0.35	0.50
C	0.10	0.25
D	2.70	3.10
E	1.40	1.80
e	1.90 (TYP)	
H	2.60	3.00
L	0.37	—
θ1	1°	9°