

MAS6254

Piezo Driver with built in Boost Converter

This is preliminary information on a new product under development. Micro Analog Systems Oy reserves the right to make any changes without notice.

Preliminary

- Up to 60Vpp Output
- 4 Step Output Voltage Control in pin mode;
8 Step Output Voltage Control via I2C Bus
- Wide Supply Voltage Range 2.6V...5.5V
- Self-Drive for 3-Terminal Piezo
- Soft-Start
- Piezo Outputs Short Circuit Protection
- High Efficiency
- External Schottky Diode Not Needed
- Very Low Leakage Current

DESCRIPTION

MAS6254 is a piezo driver device that can drive piezo transducers up to 60Vpp using wide range of supply voltage from 2.6V to 5.5V. An internal high efficiency DC/DC boost converter with adjustable output voltage generates up to 30V supply voltage for piezo driver stage. Two piezo driver outputs (VOP, VON) allow driving piezo transducer in either single-ended or differential bridge-tied load (BTL) configuration. MAS6254 supports also self-drive of a 3-terminal piezo.

MAS6254 is activated by setting EN pin to logic high. When disabled (EN at logic low), the device is in shutdown state during which it draws only a minimal leakage current (I_Q).

Two different output control modes are supported. In pin control mode, there are four different output voltage options to choose from just by logic state of SCL and SDA pins. In I2C bus control mode there are eight different output voltage options available.

To drive piezo transducer, it is needed to apply desired frequency signal to the DIN pin. The VOP piezo driver output provides non-inverted and the VON inverted output relative to the DIN signal. In case of 3-terminal piezo, the DIN input is connected to GND and piezo feedback terminal signal is fed to FB pin.

The MAS6254 prototypes are available in TSSOP-16 package. Production is planned in small 3x3x0.75 mm DFN-12 package.

FEATURES

- Up to 60Vpp
- High Efficiency Boost DC/DC Converter
- Adjustable Output Voltage
- Low Inrush Current by Soft-Start Feature
- External Schottky Diode Not Needed
- Small Inductor
- Wide Supply Voltage Range 2.6V...5.5V
- 1.8V Compatible Digital Pins
- Very Low Leakage Current typ. 40nA
- Piezo Outputs Short Circuit Protection
- Thermal Shutdown

APPLICATIONS

- Mobile Phones
- Tablets
- Portable Tracker Devices
- Sport Smart Watches
- Smoke Alarms
- Personal Safety Sirens
- Alarm Clocks
- Atomizers
- Ultrasonic Cleaners
- Piezo Pumps
- Battery Powered Devices with Sound or Atomizer Feature

ABSOLUTE MAXIMUM RATINGS

All voltages with respect to ground.

Parameter	Symbol	Conditions	Min	Max	Unit
Supply Voltage	V _{DD}		-0.3	6	V
High Voltage Pins	V _{OUT} , V _{OP} , V _{ON} , SW		-0.3	34	V
Piezo Feedback Pin	FB		-30	40	V
Voltage Range for Input Pins	EN, DIN, SCL, SDA		-0.3	V _{DD} + 0.3	V
Storage Temperature			-40	+150	°C
Junction Temperature			-40	+180	°C
ESD Rating	V _{HBM}	Human Body Mode ⁽¹⁾	±1000		V
	V _{CDM}	Charged Device Model ⁽²⁾	±500		V

Note: Stresses beyond the values listed may cause a permanent damage to the device. The device may not operate under these conditions, but it will not be destroyed.

Note 1: JEDEC document JEP155 states that 500V HBM allows safe manufacturing with a standard ESD control process.

Note 2: JEDEC document JEP157 states that 250V CDM allows safe manufacturing with a standard ESD control process.

RECOMMENDED OPERATING CONDITIONS

All voltages with respect to ground.

Parameter	Symbol	Conditions	Min	Typ	Max	Unit
Operating Supply Voltage	V _{DD}		2.6	3.6	5.5	V
Operating Ambient Temperature	T _A		-40	+27	+85	°C
Operating Junction Temperature	T _J		-40		+125	°C
Inductor Specification	L ⁽¹⁾	Li-ion/LiPo battery; 5V USB	-30%	2.2 2.7	30%	μH
	I _{PEAK}	L=2.2μH (Li-ion/LiPo battery) L=2.7μH (USB)		1.1 1.1	2.2 2.2	A
	R _{DC}	L=2.2μH (Li-ion/LiPo battery) L=2.7μH (USB)		0.1 0.1	0.25 0.25	Ω
Piezo Input Signal Frequency	F _{DIN}	V _{DD} = 3.0V, V _{OUT} = 15V L = 2.2μH, C _{LOAD} = 14 nF	-		26	kHz
		V _{DD} = 3.6V, V _{OUT} = 30V L = 2.2μH, C _{LOAD} = 3.2 nF	-		200	kHz
		V _{DD} = 5.0V, V _{OUT} = 15V L = 2.7μH, C _{LOAD} = 1 nF	-		2000	kHz

Note 1: Shielded inductor recommended for low EMI. See "Inductor (L) selection" on page 6 for further information.

ELECTRICAL CHARACTERISTICS

$T_A = -40^{\circ}\text{C}$ to $+85^{\circ}\text{C}$, typical values at $T_A = 27^{\circ}\text{C}$, $V_{DD} = 3.6\text{ V}$, $L = 2.2\text{ }\mu\text{H}$, $C_{IN} = 47\text{ }\mu\text{F}$, $C_{OUT} = 1\text{ }\mu\text{F}$, $C_{LOAD} = 3.2\text{ nF}$, $F_{DIN} = 100\text{ kHz}$; unless otherwise specified

Parameter	Symbol	Conditions	Min	Typ	Max	Unit
Thermal Shutdown Temperature	T_{TSD}	Rising temperature (device off) Falling temperature (device on)		+150 +135		$^{\circ}\text{C}$
Undervoltage-Lockout Threshold Levels	$UVLO_{RISE}$ $UVLO_{FALL}$	Turn on level at VDD rising Turn off level at VDD falling	1.4 1.3	1.5 1.4	1.6 1.5	V
DC/DC Converter Output Voltage	V_{OUT}	$L=2.2\text{ }\mu\text{H}$, $V_{DD}=3.6\text{ V}$, $I_{LOAD}=50\text{ mA}$ $SCL = \text{low}$; $SDA = \text{low}$	-5%	30	+5%	V
Piezo Driver Output Voltage	V_{OP} , V_{ON}	VOP (single-ended) VOP-VON		V_{OUT} $2 \cdot V_{OUT}$		Vpp
Shutdown Current	I_{SD}	EN = low		0.04	0.5	μA
Quiescent Current ⁽¹⁾	I_Q	EN = high, no load, $V_{OUT}=30\text{ V}$ $V_{DD}=3.6\text{ V}$		TBD		μA
DC/DC Converter Soft Start Current	I_{IN_SS}	$V_{DD} = 3.6\text{ V}$, $L=2.2\text{ }\mu\text{H}$		TBD		mA
Current Consumption at Shorted Piezo Driver Outputs	I_{IN_SC}	VOP=VON or VOP=GND or VON=GND $V_{DD} = 3.6\text{ V}$ (Li-ion/LiPo), $L=2.2\text{ }\mu\text{H}$		TBD		mA
Average Current Consumption	I_{IN}	$V_{DD} = 3.6\text{ V}$, $V_{OUT} = 30\text{ V}$, $L=2.2\text{ }\mu\text{H}$ VOP-VON: $C_{LOAD}=3.2\text{ nF}$, $F_{DIN}=100\text{ kHz}$		TBD		mA
Power-on-Reset (POR) Time ⁽²⁾	t_{POR}		2			ms
DC/DC Converter Soft-Start Time	$t_{START-UP}$	$V_{OUT}=30\text{ V}$ $C_{OUT}=1\text{ }\mu\text{F}$		TBD		ms
Boost DC/DC Converter Switch ON-Resistance	$R_{DS(ON)_LS}$	Low side switch		0.3		Ω
	$R_{DS(ON)_HS}$	High side switch		0.5		
Control Input Threshold ⁽³⁾	V_{IH}	DIN, SCL, SDA, EN pins	0.9			V
	V_{IL}	DIN, SCL, SDA, EN pins			0.4	V
Control Input Current ⁽⁴⁾	I_{IH}	DIN, SCL, SDA, EN = 3.6V			0.2	μA
	I_{IL}	DIN, SCL, SDA, EN = 0V	-0.2			μA

Note 1. Current consumption when boost converter is active but outputs are not loaded

Note 2: To guarantee proper power-on-reset (POR) operation the supply voltage must rise within maximum 2ms.

Note 3: Control inputs and serial bus can be driven even from down to 1.2V supply voltage controller due to low 0.9V V_{IH} min threshold.

Note 4: EN input pin has active pull-down by 400k Ω which is disabled to save current when input is pulled high ($\geq 0.9\text{ V}$).

TBD = To Be Defined

BLOCK AND APPLICATION DIAGRAMS

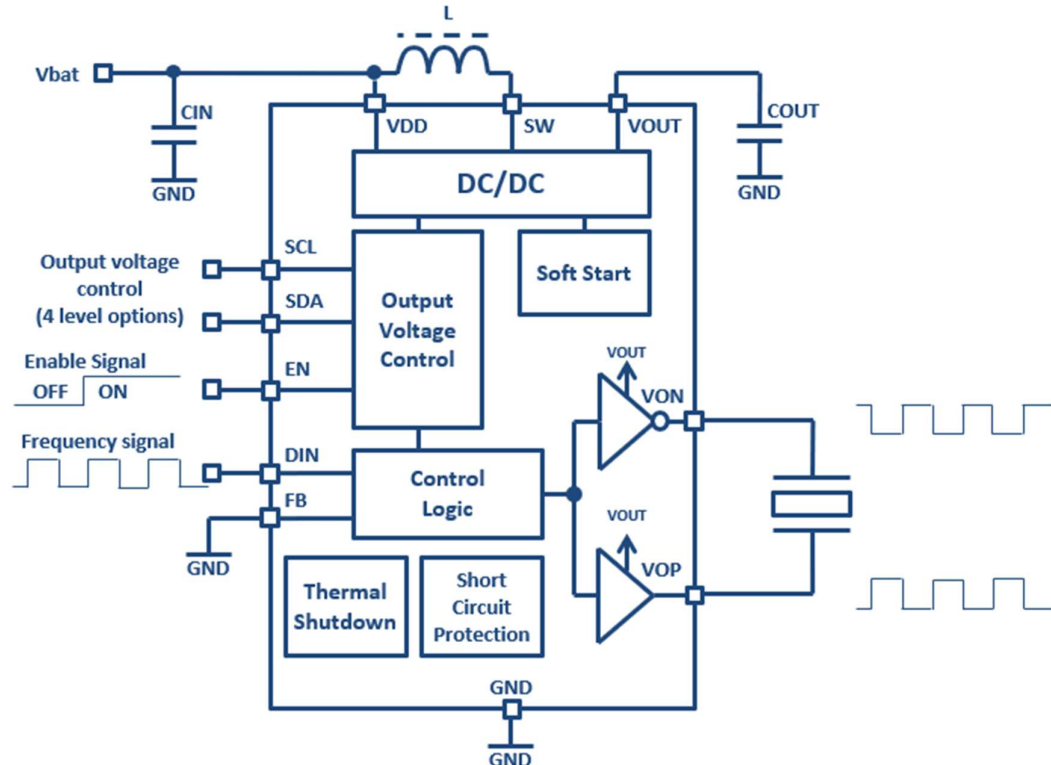


Figure 1. External drive mode application; output voltage level controlled by SCL and SDA pin state.

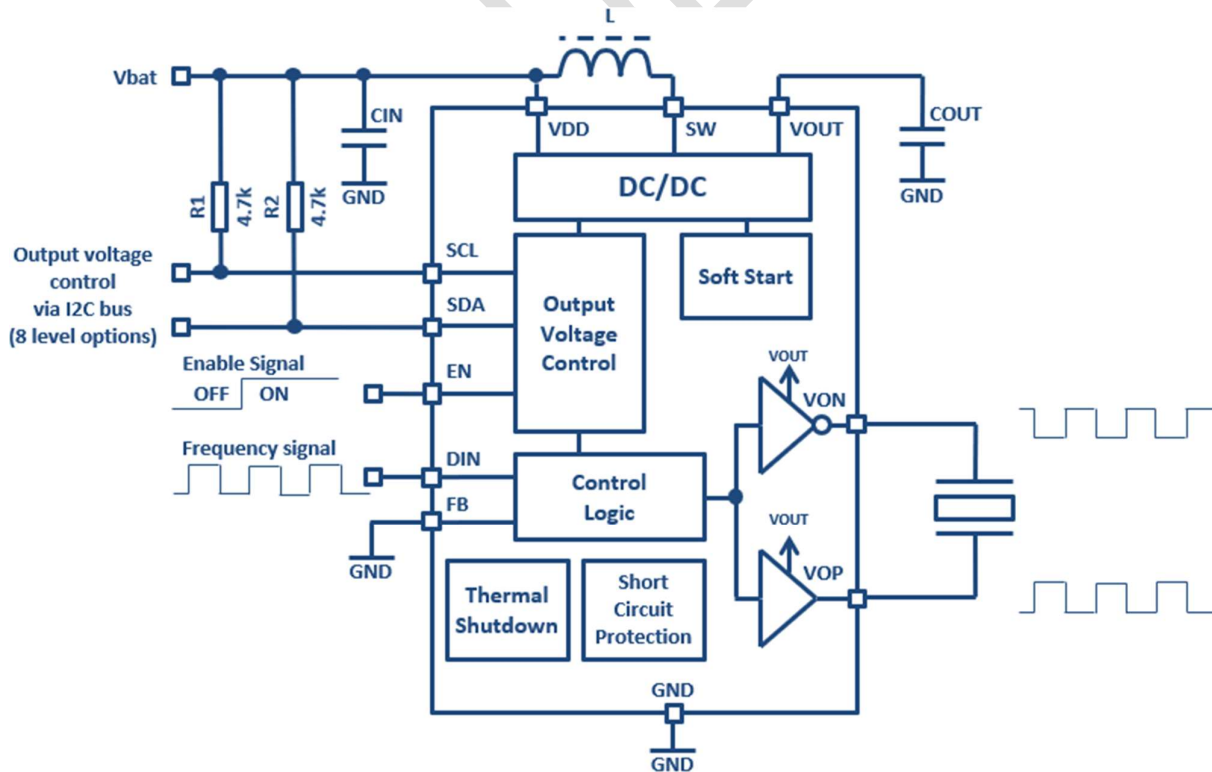


Figure 2. External drive mode application; output voltage level controlled by I2C bus.

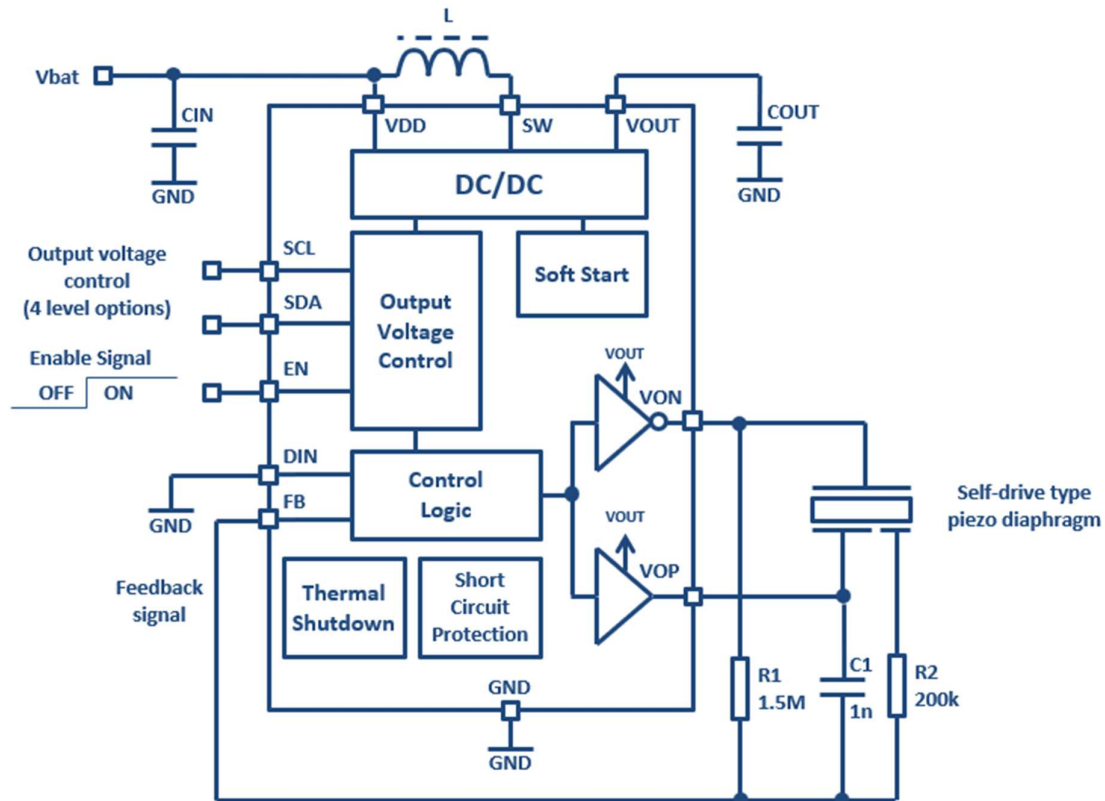


Figure 3. Self-drive mode application
(feedback component values and circuit need to be optimized for real piezo element in use).

APPLICATION INFORMATION

Inductor (L) selection

Shielded type inductors are recommended for low electromagnetic interference (EMI). Optimal inductance value of the inductor depends on both output power requirement and used energy source.

Table 2. Recommended inductor specifications

Application	Inductance	Saturation current	DC Resistance
5V USB	2.7 μ H	≥ 2.2 A	max 0.25 Ω
Li-ion battery	2.2 μ H	≥ 2.2 A	max 0.25 Ω
Coin cell battery (CR2032)	2.2 μ H	≥ 2.2 A	max 0.25 Ω

Note: Shielded inductor recommended for low EMI.

Input (C_{IN}) and output (C_{OUT}) capacitor value selection

The input (C_{IN}) and output (C_{OUT}) capacitors affect voltage ripple at input (V_{DD}) and output (V_{OUT}) respectively. For a proper operation and low ripple voltage they have to be low loss (low ESR) ceramic type capacitors with a sufficiently high value.

Minimum voltage rating of the input capacitor (C_{IN}) is 6.3V. Table 3 shows minimum input capacitor values in different applications and output load conditions.

Table 3. Recommended minimum input capacitor (C_{IN}) values in difference applications and load conditions

Application	F _{DIN} =24kHz; C _{LOAD} =14nF	F _{DIN} =100kHz; C _{LOAD} =3.2nF	F _{DIN} =1.7MHz; C _{LOAD} =1nF
5V USB	4.7 μ F	10 μ F	47 μ F
Li-ion/LiPo battery (internal resistance $\leq 3 \Omega$)	10 μ F	47 μ F	10 μ F 100 μ F
CR2032 coin cell battery (internal resistance $\geq 10 \Omega$)	10 μ F 100 μ F	-	-

Note: Input ripple voltage is proportional to piezo driver loading and inversely proportional to input capacitance (C_{IN}).

Minimum voltage rating of the output capacitor (C_{IN}) is 35V when covering the highest output voltage option. Voltage ripple (ΔV_{OUT}) at V_{OUT} output is proportional to output voltage (V_{OUT}) and ratio of piezo load capacitance (C_{LOAD}) and output capacitor (C_{OUT}) value. In differential load driving the output ripple voltage is as shown in equation 1.

$$\Delta V_{OUT} = V_{OUT} \cdot \frac{2 \cdot C_{LOAD}}{C_{OUT} + C_{LOAD}} = \frac{2 \cdot V_{OUT}}{\frac{C_{OUT}}{C_{LOAD}} + 1} \approx 2 \cdot V_{OUT} \cdot \frac{C_{LOAD}}{C_{OUT}} \quad \text{Equation 1.}$$

See table 4 showing minimum output capacitor (C_{OUT}) values for different capacitive loads (C_{LOAD}) which correspond to C_{OUT}/C_{LOAD} ratio about 21 and 9%*V_{OUT} ripple. Larger C_{OUT} capacitor values can be used to reduce the output ripple voltage lower.

Table 4. Recommended minimum output (C_{OUT}) capacitor values

Capacitor	C _{LOAD} =1nF	C _{LOAD} =3.2nF	C _{LOAD} =14nF	C _{LOAD} =20nF
C _{OUT} (rated voltage ≥ 35 V)	$\geq 0.33 \mu$ F	$\geq 1 \mu$ F	$\geq 0.68 \mu$ F	$\geq 1 \mu$ F

Note: The initial start-up time is proportional to C_{OUT}, V_{OUT} and L. Thus, larger C_{OUT}, V_{OUT} and L lead to longer start-up time.

External protection

When a mechanical or thermal shock is applied to the piezo sounder it can produce high surge voltage which may cause permanent damage to the IC. If in your application the device is expected to face such shocks you can consider using external protection against this surge voltage.

An ideal solution for external protection is using Zener diodes since it has no effect on achieved output power. See figure 4 illustrating Zener protection when driving piezo sounder in differential load configuration. The Zener voltage should be chosen high enough to not limit selected output voltage (VOUT) level but also not being too far away to provide the best protection. In case driving piezo sounder up to maximum output voltage which can be $V_{OUT} = 30 + 5\% = 31.5V$ a suitable choice for a nominal Zener voltage is for example 32V.

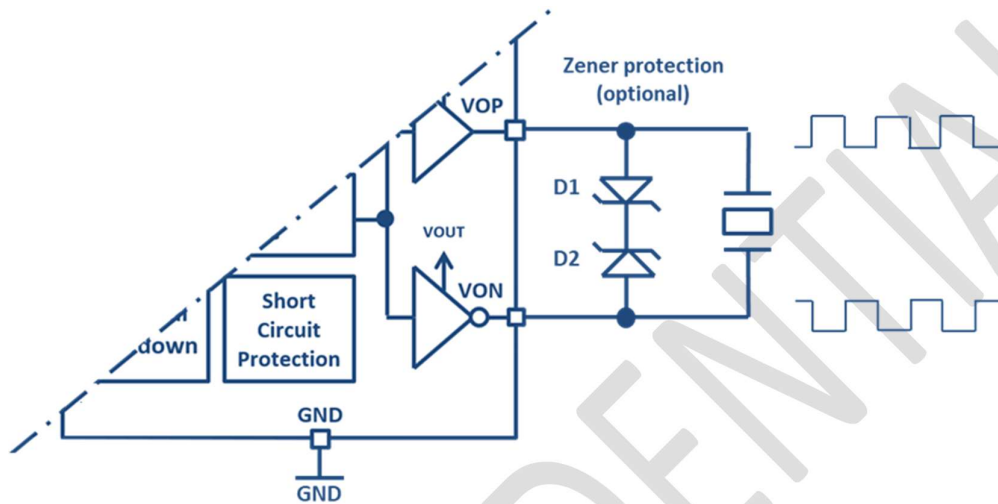


Figure 4. External Zener diode protection of piezo driver outputs

DETAILED OPERATION

◆ Operating modes

The MAS6254 has two operating modes, shutdown and active mode, which are selected by EN pin. The DIN pin serves as input for frequency signal which is driven to piezo transducer. By keeping EN low makes the device to enter shutdown. When at shutdown the device draws only a minimal leakage current. When using MAS6254 in self-drive configuration, it can be operated just via single EN control pin or just by connecting the supply power.

The DC/DC converter is activated at EN high signal. The output capacitor at VOUT pin is charged to selected output voltage level employing soft-start feature to keep inrush current at low level. The piezo driver outputs are kept disabled until the output voltage (VOUT) has risen to selected output voltage level. When activated, the piezo driver output VOP provides non-inverted and VON inverted signal relative to the DIN control signal polarity.

To return back to shutdown state it only requires setting the EN pin low. At shutdown both piezo driver outputs (VOP, VON) are pulled to GND (pull down resistance $\sim 1\text{M}\Omega$).

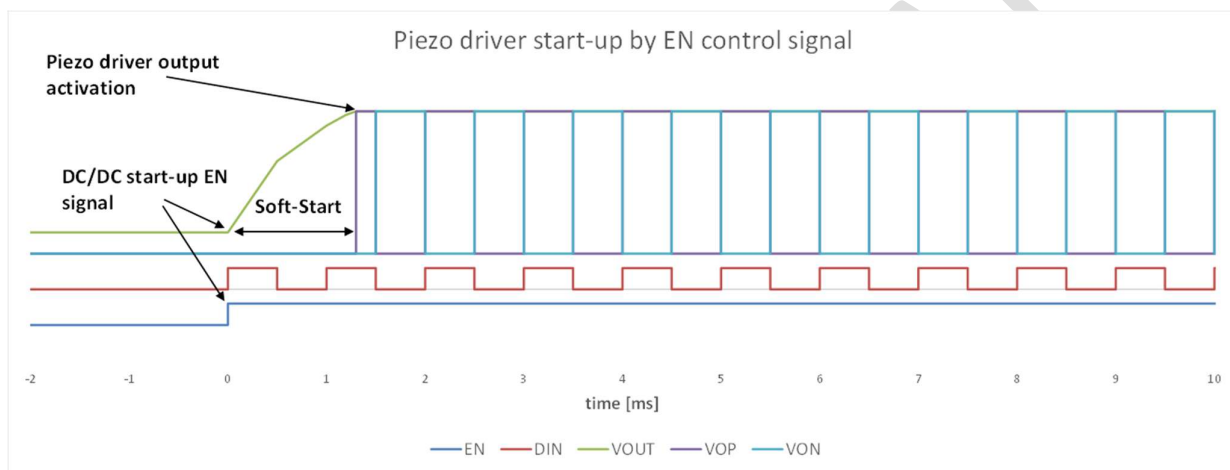


Figure 5. MAS6254AA1 piezo driver start-up by EN control signal

MAS6254AA2 version has push button type EN input. It means that first raising front at EN pin enables the device and next raising front disables the device.

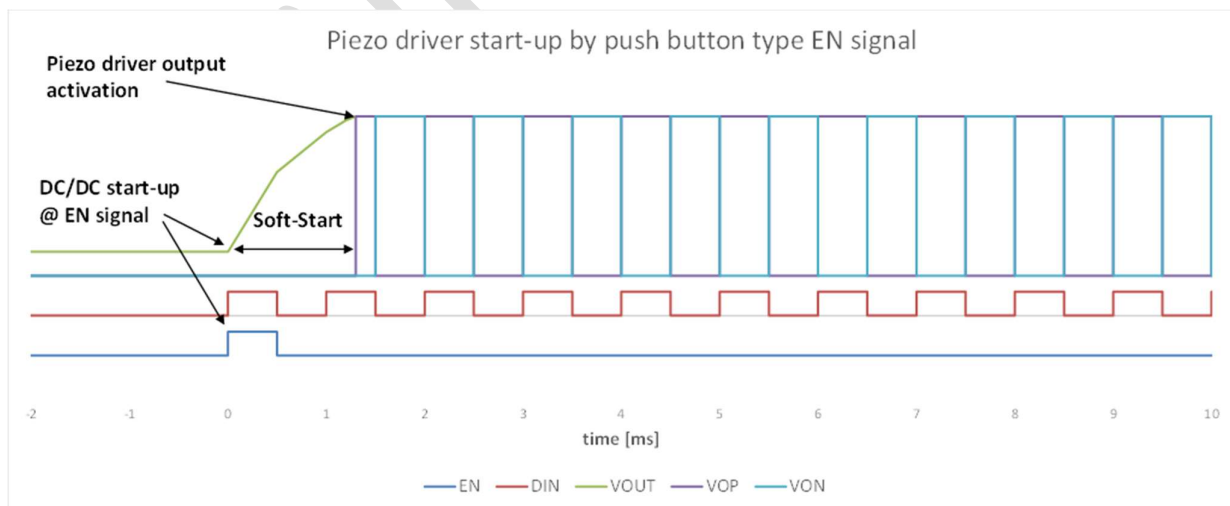


Figure 6. MAS6254AA2 piezo driver start-up by push button type EN signal

◆ Output voltage control modes

The MAS6254 supports multiple output voltage (V_{OUT}) options which are selectable either using pin control or I2C serial communication bus.

◆ Pin control mode

After power on reset (POR) the device is by default in pin control mode. In pin control mode the output voltage is selected by logic state of the SCL and SDA pins. See table 5 for the four output voltage options available in the pin control mode.

Note that it is possible to select output voltages even using down to 1.2V control voltage from a low supply voltage MCU since the logic high threshold of the SCL and SDA pins is min 0.9V. See Electrical characteristics table on page 3.

Table 5. Output voltage (V_{OUT}) options in pin control mode

SCL	SDA	V_{OUT} [V]
low	low	30
high	low	24
high	high	17.5
low	high	15

◆ I2C bus control mode

In I2C bus communication the MAS6254 operates as a slave device. To activate I2C bus control mode, you need to write an 8-bit output voltage control (OVC) data to the MAS6254 using I2C device address 0x76 (%1110110). This configures the device to I2C bus control mode and output voltage selection according to given OVC value. See table 6 for eight output voltage options that are available in the I2C bus control mode.

Since every power-on reset (POR) will reset the device to default pin control mode you need to write the OVC setting after every power-up (connection of supply voltage).

Table 6. Output voltage (V_{OUT}) options in I2C bus control mode

I2C bus control mode ⁽¹⁾ (8 settings)		Pin control mode ⁽²⁾ (4 settings)		Output voltage
OVC[7-0]		SCL	SDA	V_{OUT} [V]
XXXX X111	0xFF	low	low	30
XXXX X110	0xFE			27
XXXX X101	0xFD	high	low	24
XXXX X100	0xFC			20
XXXX X011 (value after POR)	0xFB	high	high	17.5
XXXX X010	0xFA	low	high	15
XXXX X001	0xF9			12
XXXX X000	0xF8			9

X = Don't care. However, due to pull-up resistors of I2C bus choosing X=1 minimizes current consumption in the serial communication.

Note 1: In I2C bus communication mode the output voltage control (OVC) setting is accessed using I2C device address 0x76 (%1110 110). There are eight different output voltage settings. In the 8-bit output voltage control (OVC) value only the three LSB most bits are significant.

Note 2: In pin control mode there are four different output voltage settings to choose from using logic state of the SCL and SDA pins.

See table 7 example of I2C bus communication to select $V_{OUT}=24$ output voltage option.

Table 7. I2C bus communication writing OVC value 0xFD02 ($V_{OUT}=24V$) to the MAS6254

Start	Addr Byte (0xEC / 0xED)		Ack	OVC Data (0xFD)	Ack	Stop
	Dev Addr (0x76)	Write bit (0) Read bit (1)				
S	1110 110	0	0	1111 1101	0	P

In the I2C bus protocol the data transfer starts with start (S) condition given by the master (MCU). This is followed by 7-bit device address (0x76) and 8th read(1)/write(0) selection bit which is 0 in case of data write. Then the receiver (MAS6254) acknowledges receiving the first eight bits by pulling data line low (0). After this master (MCU) sends the eight OVC data bits which the receiver acknowledges. Communication ends to stop command sent by the master (MCU).

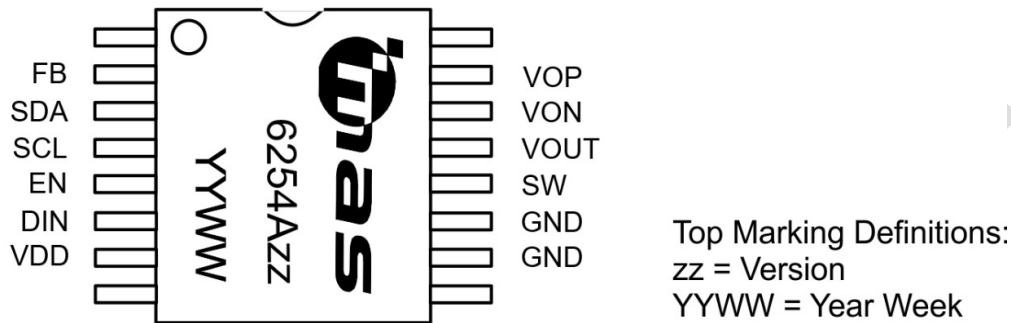
Important note: The MAS6254 responses also to I2C devices address 0x71 (%1110 001) but which is reserved for testing purpose only. It is strictly forbidden to write any data to this test purpose reserved I2C device address since that can lead to harmful device conditions in the application circuit.

PRINTED CIRCUIT BOARD (PCB) LAYOUT CONSIDERATIONS

In PCB layout design the input (C_{IN}) and output (C_{OUT}) capacitors should be placed as close to the MAS6254 as possible and minimizing parasitic inductance and resistance of the PCB traces.

The SW, VOUT and GND pin traces transfer the highest currents and they must be drawn wider. The VDD pin of the MAS6254 draws only rather low operating current and it can be drawn with a normal trace width. Since SW pin is switching at high frequency the parasitic capacitances of the trace should be minimized by placing inductor connector close to the SW pin.

PIN CONFIGURATION & TOP MARKING FOR PLASTIC TSSOP-16 PACKAGE



Note: TSSOP16 package is used only in first samples, production package is TBD.

PIN DESCRIPTION

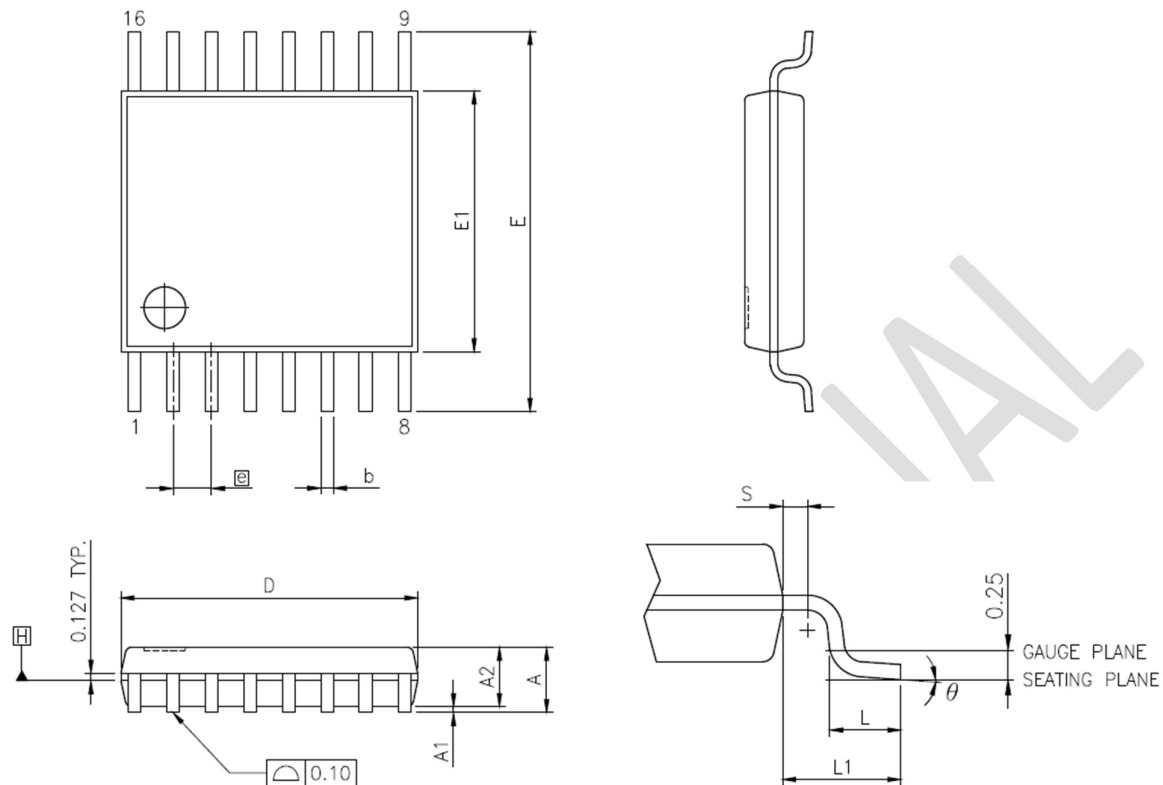
Pin Name	Pin	Type	Function	Note
	1		Not connected	
FB	2	AI	Self-drive mode feedback input	FB=GND in External drive mode
SDA	3	DIO	Serial data pin of I2C bus communication / SDA control input	
SCL	4	DI	Serial clock pin of I2C bus communication / SCL control input	
EN	5	DI	Device enable input	
DIN	6	DIO	Audio frequency input for External drive mode	DIN=GND in Self-drive mode
VDD	7	P	Positive supply voltage input	
	8		Not connected	
	9		Not connected	
GND	10,11	G	Supply ground pin	
SW	12	AO	Boost DC/DC converter switch	
VOUT	13	AO	Boost DC/DC converter voltage output	
VON	14	AO	Inverted piezo driver output	
VOP	15	AO	Non-inverted piezo driver output	
	16		Not connected	

A = Analog, D = Digital, P = Power, G = Ground, I = Input, O = Output

Note 1: Digital inputs or serial bus communication can be driven from 1.2V up to 5.5V level logic outputs.

Note 2: Output voltage selection is done via SDA and SCL pins either based on pin state or via I2C bus communication

PACKAGE (TSSOP-16) OUTLINES



Dimension	Min	Nom	Max	Unit
A			1.2	mm
A1	0.05		0.15	mm
A2	0.80	1.00	1.05	mm
b	0.19		0.30	mm
D	4.90	5.00	5.10	mm
E1	4.30	4.40	4.50	mm
E		6.40 BSC		mm
e		0.65 BSC		mm
L1		1.00 REF		mm
L	0.45	0.60	0.75	mm
S	0.20			mm
θ	0		8	°

Dimensions do not include mold flash, protrusions, or gate burrs.
All dimensions are in accordance with JEDEC standard MO-153.

ORDERING INFORMATION

Product Code	Product	Package	Comments
MAS6254AA1ST208	Piezo Driver with Boost Converter	TSSOP-16, Pb-free, RoHS compliant, Tube (only for first samples)	Logic level enable: EN=low, Shutdown mode EN=high, Active mode
MAS6254AA2ST208	Piezo Driver with Boost Converter	TSSOP-16, Pb-free, RoHS compliant, Tube (only for first samples)	Push button enable (EN): one raising front enables next raising front disables

Note: TSSOP16 package is used only in first samples, production package is TBD.

LOCAL DISTRIBUTOR

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