coolaudio

Voltage Controlled Filter
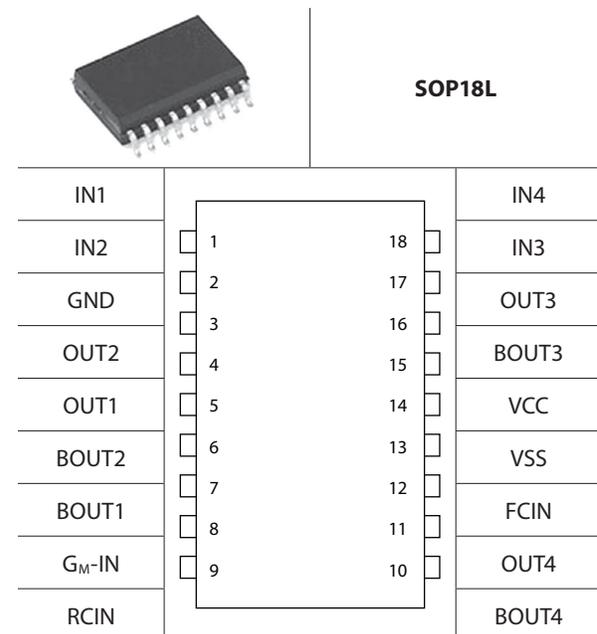
V3320

Overview

The V3320 is a high performance voltage controlled four-pole filter with voltage controllable resonance. A wide variety of filter responses, such as low pass, high pass, band pass and all pass can be achieved by connecting the four independent sections. A single input exponentially controls the frequency over greater than a ten octave range with little control voltage feed-through. Another input controls the resonance from zero to low distortion oscillation in a manner of modified linearity.

Every filter section includes a novel variable gain cell and a buffer. The variable gain cell features a better signal-to-noise ratio and low distortion.

Features

- ±15V Volt Supplies
- Low Cost
- Voltage Controllable Frequency: 12 octave range minimum
- Accurate Exponential Frequency Scale
- Accurate Linear Resonance Scale
- Low Control Voltage Feedthrough: -45 dB typical
- Filter Configurable into low pass, high pass, all pass, etc
- Large Output: .12 V.P.P. typical
- Low Noise: -86dB typical
- Low Distortion in Passband: 0.1% typical
- Low Warm Up Drift
- Configurable into Low Distortion Voltage Controlled Sine Wave Oscillator

Pin configuration

SOP18L

IN1		IN4
IN2	1 — 18	IN3
GND	2 — 17	OUT3
OUT2	3 — 16	BOUT3
OUT1	4 — 15	VCC
BOUT2	5 — 14	VSS
BOUT1	6 — 13	FCIN
G_M-IN	7 — 12	OUT4
RCIN	8 — 11	BOUT4
	9 — 10	

Typical Applications

- Voltage Controlled Filter

PIN Description

No.	Name	Functions Description	No.	Name	Functions Description
1	IN1	First Gain Cell Input	10	BOUT4	Fourth Buffer Output
2	IN2	Second Gain Cell Input	11	OUT4	Fourth Gain Cell Output
3	GND	GND	12	FCIN	Frequency Cntl Input
4	OUT2	Second Gain Cell Output	13	VSS	Negative Voltage
5	OUT1	First Gain Cell Output	14	VCC	Positive Voltage
6	BOUT2	Second Buffer Output	15	BOUT3	Third Buffer Output
7	BOUT1	First Buffer Output	16	OUT3	Third Gain Cell Output
8	G_M-IN	G_M Input	17	IN3	Third Gain Cell Input
9	RCIN	Resonance Cntl Input	18	IN4	Fourth Gain Cell Input

Functional Block Diagram
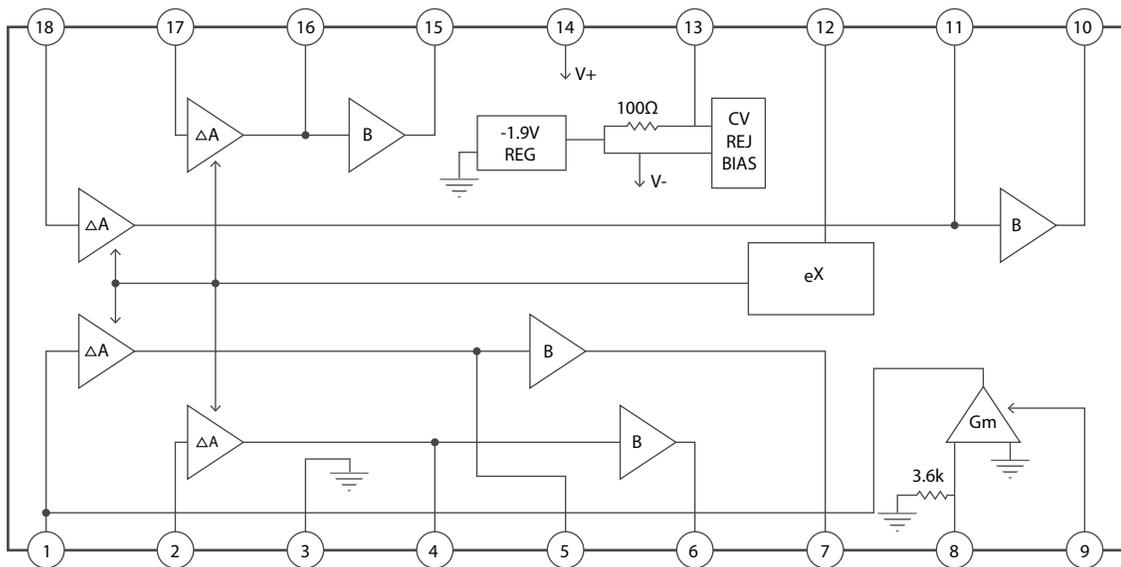
Figure 1. Functional Block

Absolute Maximum Ratings

Description	Symbol	Value range	Unit
Voltage Between VCC and VEE	$V_{VCC-VEE}$	−0.5~+22	V
Voltage Between VCC and Ground	$V_{VCC-GND}$	−0.5~+18	V
Voltage Between VEE and Ground	$V_{VEE-GND}$	−4~+0.5	V
Voltage Between Frequency Control and Ground	$V_{Freq\ Cntl-GND}$	−6~+6	V
Voltage Between Resonance Control and Ground	$V_{Res\ Cntl-GND}$	−18~+2	V
Current Through Any Pin	I	−40~+40	mA
Storage Temperature Range	T_{STG}	−55~+150	°C
Operating Free-air Temperature Range	T_A	−25~+75	°C

Note: Stresses greater than those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under "Recommended Operating Conditions" is not implied. Exposure to "Absolute Maximum Ratings" for extended periods may affect device reliability.

Electrical Characteristics

(VCC = 15 V, R_F = 100 K. A current limiting resistor is connected between -15 V and VSS, T_A = +20 °C. Actual circuit connection sees typical application circuit, unless otherwise noted)

Parameter	Symbol	Test Condition	Min.	Typ.	Max.	Unit
Pole Frequency Control Range	pfc	—	3500:01:00	10000:01:00	—	Hz
Positive Supply Voltage Range	VCC	—	9	—	18	V
Negative Supply Voltage Range	VSS	Current limiting resistor always required	-4	—	-18	V
Positive Supply Current	I_{VCC}	—	3.8	5	6.5	mA
Sensitivity of Pole Frequency Control Range Scale, Midrange	$S\text{-}_{FP}$	—	57.5	60	62.5	mv/decde
Tempco of Pole Frequency Control Range Scale	$TEMP\text{-}_{FP}$	—	3000	3300	3500	ppm
Exponential Error of Pole Frequency Control Range Scale	E_{FP}	$-25mV<V_C<155mV$	—	4	12	%
Gain of Variable Gain Cell	Gain	V_C=0V	0.7	0.9	1.3	—
Max Gain of Variable Gain Cell	$Gain\text{-}_{MAX}$	—	2.4	3	3.6	—
Tempco of Variable Gain Cell	$TEMP\text{-}_{Gain\ Cell}$	V_C=0V		500	1500	ppm
Output Impendence of Gain Cell	$Ro\text{-}_{Gain\ Cell}$	V_C=0V	0.5	1	2	MΩ
Pole Frequency Control Feed-through	$V_{FEED}\text{-}_{FP}$	—	—	60	200	mV

Parameter	Symbol	Test Condition	Min.	Typ.	Max.	Unit
Pole Frequency Warm-up Drift	Drift-$_{FP}$	-25°C<TA<75°C	—	0.5	1.5	%
Gm of Resonance control Element	Gm-$_{RES}$	I_{CR}=100uA	0.8	1	1.2	mmhos
Amount of Resonance Obtainable Before Oscillation	Amount-$_{RES}$	—	20	30	—	dB
Resonance Control Feed-through	V$_{FEED}$-$_{RES}$	0<I_{CR}<100uA	—	0.2	1.5	V
Output Swing At Clipping	Output Swing	—	10	12	14	V.P.P
Output Noise re Max Output	V$_N$/ V.P.P	Low Pass and 20 Khz cut-off frequency	-76	-86	—	dB
Rejection in Band-reject	REJ-$_{BAND REJECT}$	—	73	83	—	dB
Distortion in Pass-band	THD-$_{PASS BAND}$	Output Signal is 3 dB below clipping point and Distortion is predominantly second harmonic	—	0.1	0.3	%
Distortion in Band-reject	THD-$_{BAND REJECT}$	Output Signal is 6 dB below clipping point and Distortion is predominantly second harmonic	—	0.3	1	%
Distortion of Sine Wave Oscillation	THD-$_{SINE}$	Sinewave is not clipped by first stage	—	0.5	1.5	%
Internal Reference Current	I$_{REF}$	—	45	63	85	uA
Input Bias Current of Frequency Control Input	I$_{BIAS}$-$_{FCIN}$	FCIN=0V	0.2	0.5	1.5	uA
Input Impedance to Resonance Signal Input	Rin-$_{RCIN}$	I_{RCIN}=150uA	2.7	3.6	4.5	KΩ
Buffer Slew Rate	SR-$_{BUFFER}$	—	1.5	3	-	V/us
Buffer Input Bias Current	I$_{BIAS}$-$_{BUFFER}$	IEE=8mA	±8	±30	±100	nA
Buffer Sink Capability	I-$_{SINK}$	—	0.4	0.5	0.63	mA
Buffer Output Impedance	Ro-$_{BUFFER}$	V$_C$=0V	75	100	200	Ω

Functional Description

1. Supplies

A shunt regulator is built-in to regulate the negative supply at -1.9 volts. The shunt regulator can reduce warm-up drift of the pole frequencies, at the same time, any negative supply greater than -4 volts can be used with the current limiting resistor. The value of current limiting resistor is given by the following expression:

$$R_{EE} = \frac{V_{SS} - 2.7 \text{ V}}{0.008}$$

Any positive supply between 9 volts and 18 volts can be applied to pin 14, but this will affect the output swing. The maximum possible peak to peak output swing is given by:

$$V_{OUT} \text{ (V.P.P.)} = V_{CC} - 3 \text{ V}$$

2. Operation of Each Filter stage

Each filter section contains a variable gain cell and a high impedance buffer. The variable gain cell is a current-in, current-out device, the output current IOUT is calculated as follows:

$$I_{OUT} = (I_{REF} - I_{IN}) \, A_{10} e^{-V_C/V_T}$$

Where $V_T = KT/q$, VC is the voltage applied to pin 12, and AIO is the current gain of the cell at $V_C = 0$, the IREF is given by:

$$I_{REF} = \frac{0.46 V_{CC} - 0.65 \text{ V}}{100K}$$

For normal operation of any filter type, each stage is set up with a feedback resistor and a pole capacitor. The feedback resistor, R_F, is connected between variable gain cell input and buffer output, and the pole capacitor, C_P, is connected to the output of the variable gain cell. Figure2 shows this setup, the output of the buffer will always adjust itself so that a current equal to I_{REF} flows into the input.
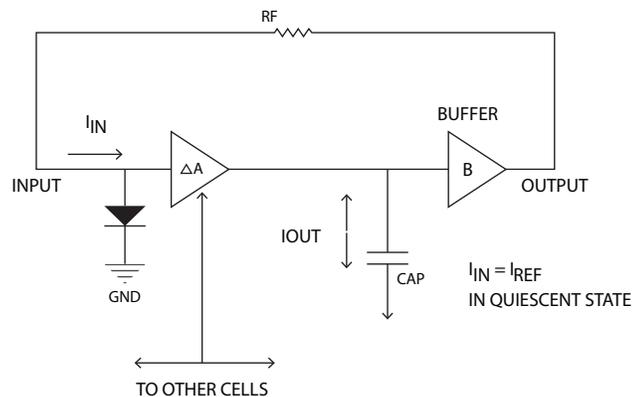
The quiescent output voltage of each buffer, V_{ODC}, should be set to $0.46V_{CC}$ for lowest control voltage feed-through and maximum peak-to-peak output signal, so the R_F in Figure2 can be calculated as follows:

$$R_F = \frac{V_{ODC} - 0.65\ V}{I_{REF}} = 100\ K\ nominal$$

The output impedance of variable gain cell is reflected to the input as an A.C. resistance (nominally 1M) in parallel with the feedback resistor regardless of control voltage value. The total equivalent feedback resistance, R_{EQ}, determines the pole frequency of each filter section.

$$R_{EQ} = \frac{R_F * 1\ M\Omega}{F_R + 1\ M\Omega}$$

And

$$f_p = \frac{A_{IO}}{2\pi R_{EQ}C_p}\ e^{-V_c/V_T}$$

3.   Pole Frequency Control
The voltage applied to pin 12 controls the current gain of each filter section, because the exponential scale need to meet the standard 18 mV/octave(60 mV/decade), an input attenuator network may be required in most case. An increasing positive control voltage will cause a drop of the pole frequency. If you want to get a thousand-to-one control range, the voltage applied to pin 12 should be maintained between -25 mV and 155 mV.

4.   Resonance Control
The traditional transconductance type of amplifier can control the amount of resonance. Pin 8 is a separate signal voltage input and pin 9 is a separate control current input with a modified linear scale. A current output of amplifier is internally connected to the input of stage one. The input impedance of the amplifier is 3.6 K $\pm900\ \Omega$, and the input refers to ground, so a coupling capacitor is needed to be connected to the filter output.

Control of the transconductance is accomplished with a current input. Since the control input is a low impedance summing node, which is a potential near ground, the control current may be derived by an input resistor, R_{RC}, from the resonance control voltage, at the same time, this resistor should meet the requirement that the maximum available resonance control voltage produces the maximum desired control current.

5.   Stage Buffers
For any sections, each buffer can source up to 10 mA and sink a nominal 500 uA, when any D.C. load greater than ±200 uA to ±300 uA, the performance of the filter will drop, especially the loads on each buffer differ by more than this amount, so the maximum recommended D.C. loads are 1 mA source, 250 uA sink, and a 150 uA load difference between buffers. The maximum recommended A.C. loads are ±250 uA.

The D.C. level of the filter output has been set to $0.46V_{CC}$ (6.9 volts for $V_{CC} = 15$ V), the coupling capacitor will be needed at the filter output or the following input of the device.

6.   Filter Responses
In the typical application circuit, Figures 3, 4, 5 and 6 show four filter responses: low pass, high pass, band pass and all pass. All filter responses have the function of voltage controlled resonance, Since the configuration of the resonance feedback, the resonance frequency of the high pass will be about 2.4 times higher than low pass, however, the resonance frequency of the band pass and all pass will be 0.42 times lower than low pass.
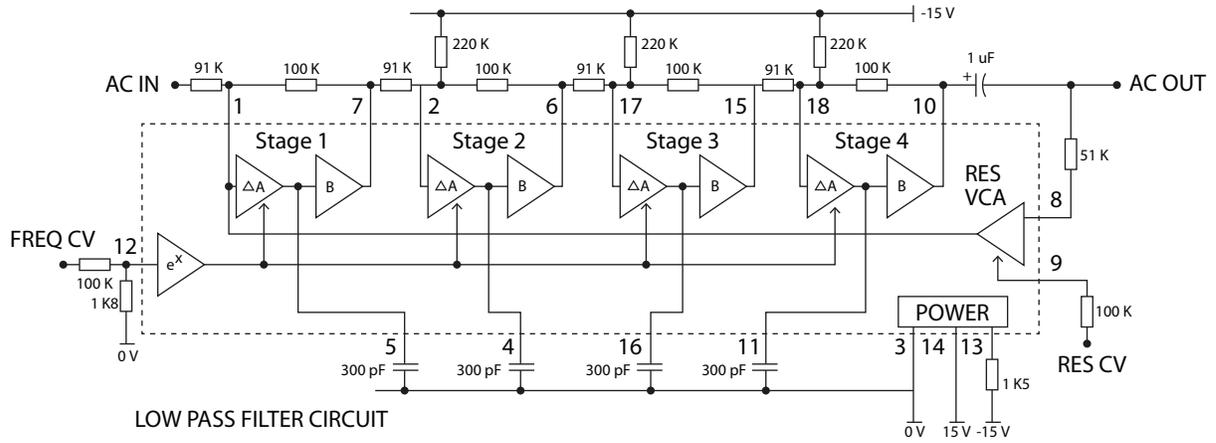
Typical Application Circuit
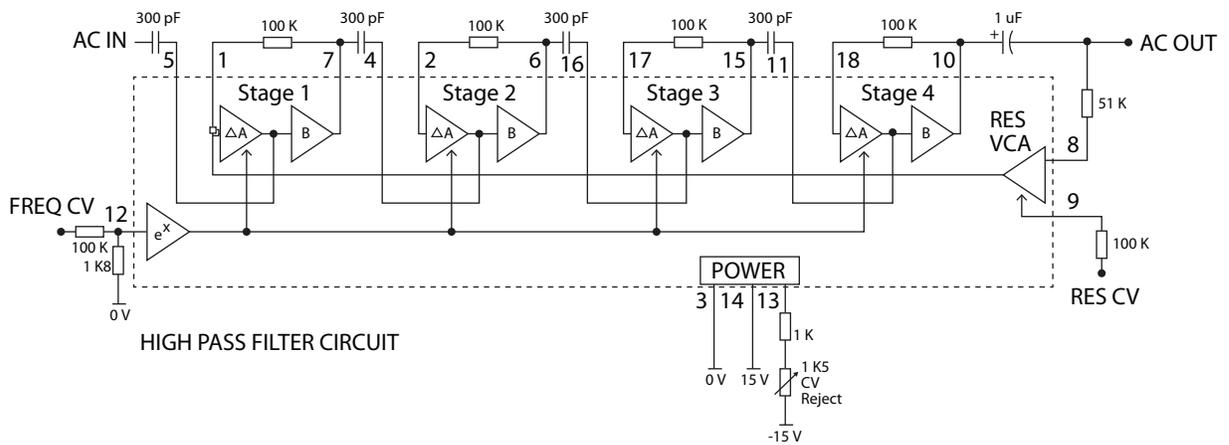

Figure 3. Low Pass Filter Circuit

Figure 4. High Pass Filter Circuit
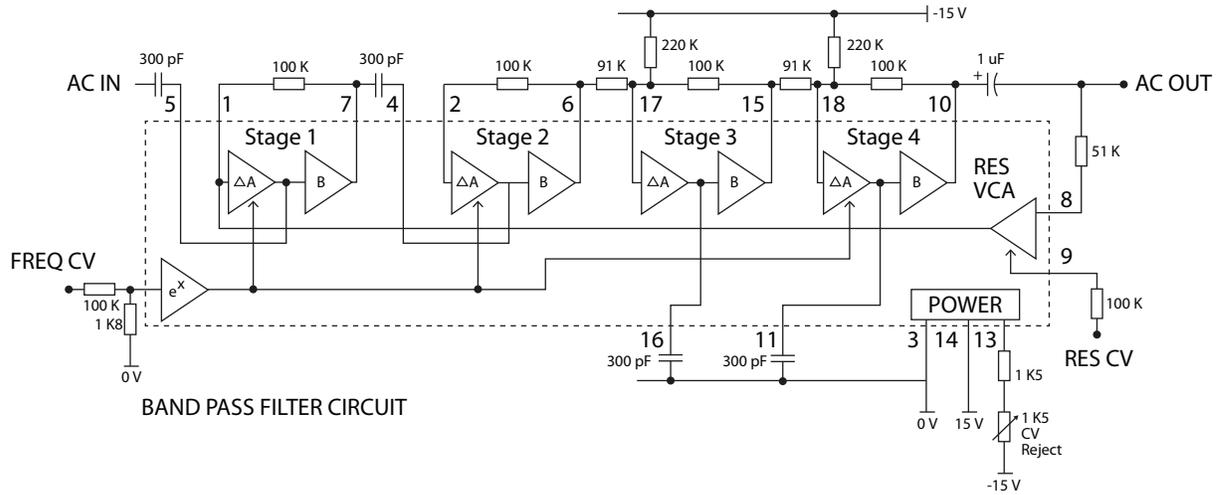
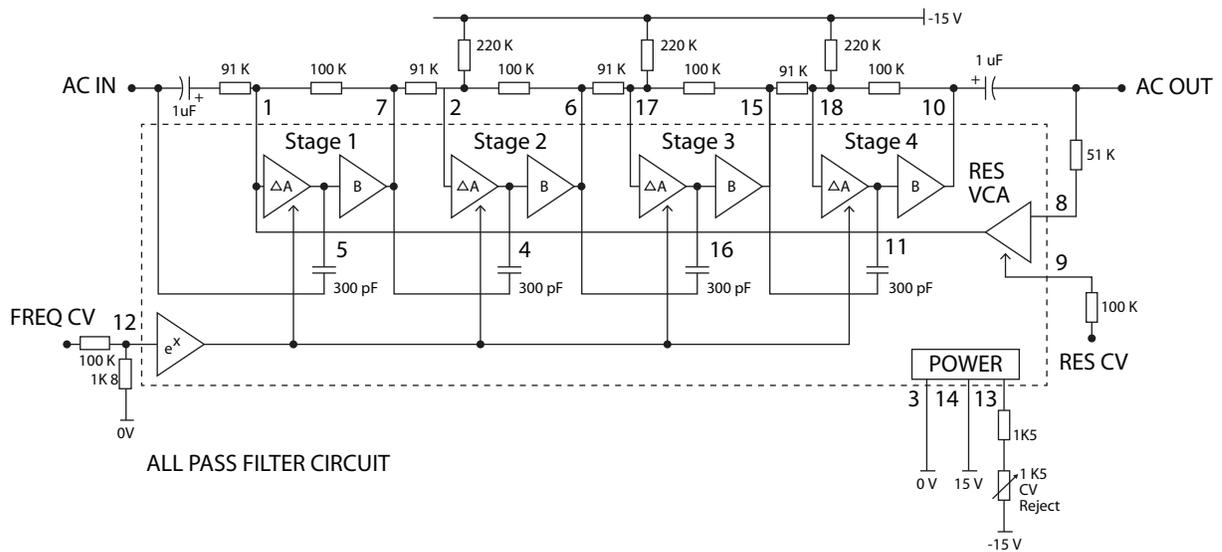**Typical Application Circuit**

Figure 5. Band Pass Filter Circuit

Figure 6. All Pass Filter Circuit

Package Information

SOP18L
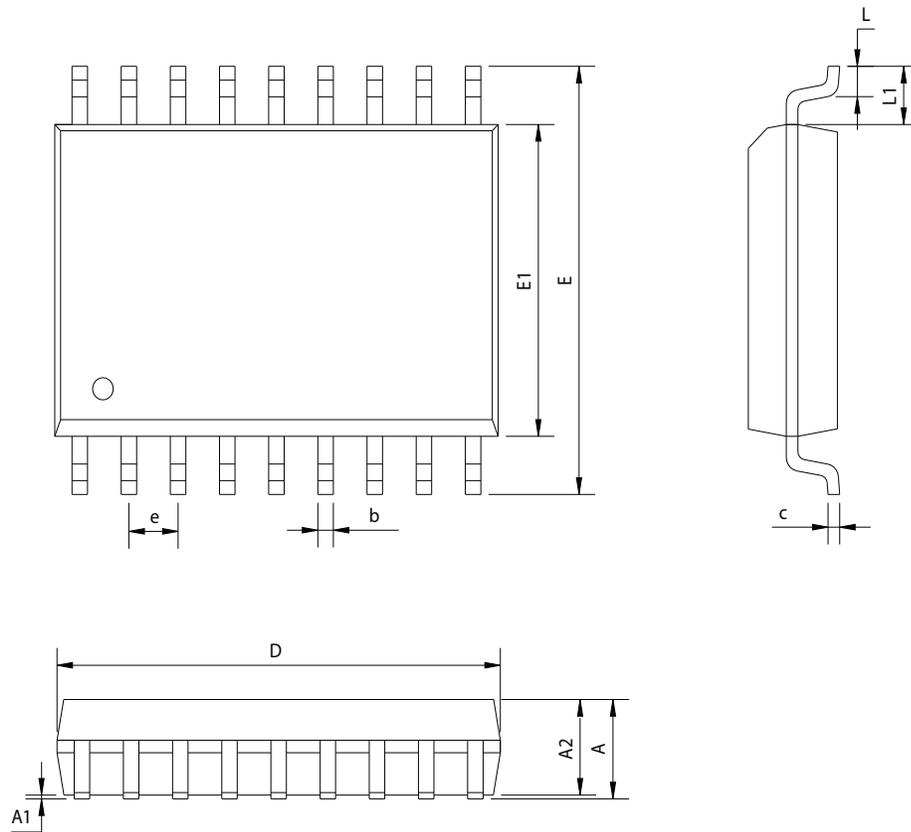
SYMBOL	mm	
	min	max
A	—	2.65
A1	0.10	0.30
A2	2.20	2.40
b	0.35	0.45
c	0.20	0.30
D	11.25	11.65
E	10.10	10.50
E1	7.30	7.70
e	1.27BSC	
L	0.50	1.00
L1	1.40BSC	