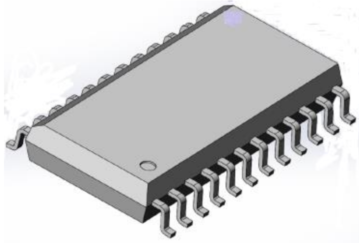
AS3394E µP CONTROLLABLE SYNTHESIZER VOICE

FEATURES

- Complete synthesizer Voice on a Chip
- Sample & Hold buffers on-chip for easy interface to a µP
- Fully temperature compensated VCO
- Independently selectable VCO waveforms
- Sub-oscillator output
- Separate saw-tooth output
- Separate VCO and filter sections allowing design flexibility
- Constant Loudness vs Resonance VCF
- Rich Sounding VCF Design
- Filter FM routing for more Timbres
- Low Noise, Low Feedthrough VCA

AS3394ED



SOIC-24 300mil, 1.27 mm

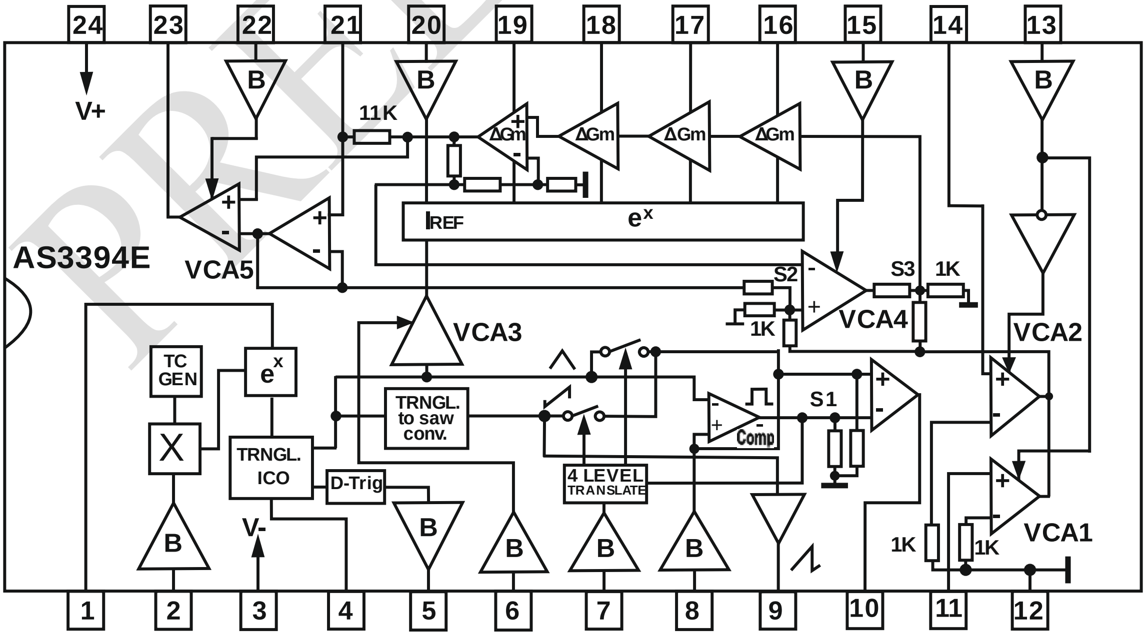
DESCRIPTION

The AS3394E is a complete analog music synthesizer voice-on-a-chip intended for software control by a microprocessor system. Included inside the compact 24 pin package is fully temperature compensated, wide range, voltage controlled oscillator providing sub-oscillator, triangle, saw-tooth, and pulse waveforms; a voltage controlled mixer for adjusting the balance between the internally generated VCO waveforms and any external signal; a dedicated four-pole low-pass voltage controlled filter with voltage controlled resonance; a modulation amount VCA for modulating the filter frequency by the triangle waveform output of the VCO; and a final VCA for allowing the output to be enveloped. Envelope control for both the VCF and final VCA may be provided by either a hardware envelope generator such as the AS3310 or through software.

All eight control inputs are provided with internal very high input impedance, low bias current buffers. Thus interface to a microprocessor system may be accomplished simply with a single DAC, 4051-type CMOS multiplexer, and 8 hold capacitors.

Requiring a bare minimum of other external components, the AS3394E is ideal for low cost polyphonic or polytimbric musical instruments featuring rich, analog sound.

FUNCTIONAL BLOCK DIAGRAM



Pin Information

Pin No	Pin Name	Description	Pin №	Pin Name	Description
1	Iref	Reference Current	13	Mix_Bal	Mixer Balance CV
2	VCO_CF	VCO Input CF	14	VCA2	VCA2 Input 2
3	-Vee	Negative Supply Voltage	15	Filt_Res	Filter Resonance CV
4	Ct	Timing capacitor	16	C1	Filter capacitor 1
5	D-Trig Out	D-Trigger Output	17	C2	Filter capacitor 2
6	Mod_Amt	Filter VCA3 modulation control	18	C3	Filter capacitor 3
7	Wave_Sel	Wave Select CV Input	19	C4	Filter capacitor 4
8	PWM_CV	PWM CV	20	VCF _CV	Filter control voltage
9	Sawtooth Out	Sawtooth Output	21	Cs	Servo-capacitor
10	Wave_Out	Wave Output	22	VCA5_CV	VCA5 gain CV
11	VCA1	VCA1 Input 1	23	VCA5_Out	VCA5 Output
12	GND	Ground	24	+Vcc	Positive Supply Voltage

Electrical Characteristics

PARAMETER	MIN	TYPICAL	MAX	UNITS
VCO Specifications				
Frequency Range	12Hz	-	20KHz	
CV Input Range	-4.0	-	+4.0	Volts
CV Scale Factor	-0,65	-0,75	-0,85	V/Octave
Exponential Error (<8KHz)	-	0,3	1,0	%
Temperature Coefficient	-500	0	500	ppm
Reference Voltage (pin 1-3)	1,1	1,2	1,3	V
CV Input Current	-	0,3	3	nA
Frequency at CVin = 0.0V	330	500	750	Hz
Sub-oscillator output (D-Trigger RL=10kΩ):				
Maximum voltage output	1,8	2,0	2,2	V
Minimum voltage output	-2,2	-2,0	-1,8	V
Saw-tooth output :				
Maximum current output	40	50	60	μA
Minimum current output	-40	-50	-60	μA
WAVE OUTPUT				
Maximum current output	70	80	90	μA
Minimum current output	-70	-80	-90	μA
WAVE SHAPER				
Waveform Select Thresholds :				
- Pulse	-0,6	-1,0	-1,8	V
- Triangle	-0,2	-0,35	-0,5	V
- Triangle + Sawtooth	0,9	1,2	1,5	V
- Sawtooth	2,3	3,0	3,9	V
Wave Select Input Current	-	-50	-300	nA
PWM				
PWM Input Current	-	0,5	5,0	nA
Pulsewidth CV for 0% Pulse	0	-	0,2	V
Pulsewidth for 100% Pulse	1,9	-	2,2	V

Continuation of Table

FILTER MODULATOR				
Max Modulation Depth	0,01X	-	2X	Freq.
CV for 0% Modulation	-0,3	-	0,1	V
CV for Max Modulation	3	-	4	V
CV Input Current	-	-0,5	-5	nA
FILTER INPUT MIXER				
External Input Level (VCA1, VCA2)	-	±40	-	mV @ 5% THD
External Input to Output Gain	3,6	4,5	5,6	mmho
CV Input Current	-	-0,3	-3	nA
External Input Bias Current	-	-0,3	-0,7	μA
CV Feedthrough	-30	0	30	μA
4-POLE LOW-PASS FILTER				
CV Input Range	-3		+4	V
CV Scale Factor	-0.33	-0.38	-0.43	V/Octave
Frequency @ CV = 0.0V	900	1300	1800	Hz
Frequency CV Input Current	-	-0,3	-3	nA
Resonance CV : No Resonance	0	-	0,3	V
Resonance CV: Oscillation	2	2,5	3	V
FINAL VCA				
Attenuation at CV = 0	80	90	-	dB
CV for Maximum Output	3,8	4	4,3	V
CV Scale Factor (20-100dB) 4)	-	20	-	dB/V
Triangle Wave Output Level	190	250	325	μA pp
Triangle + Sawtooth Output	255	330	430	μA pp
Sawtooth Output Level	150	200	260	μA pp
Square Wave Output Level	120	160	210	μA pp
All Waves On Output Level	300	400	520	μA pp
CV Feedthrough	-	±0,3	±3	μA
CV Input Current	-	0,3	3	nA
POWER SUPPLIES				
Positive Supply Range	+4,75	-	+8	V
Negative Supply Range	-4,75	-	-16	V
Positive Supply Current	13	16	21	mA
Negative Supply Current	-13	-16	-21	mA

1. Most of error occurs at frequency extremes. Typical value is at mid-range
2. When switching from the no waveforms condition.
3. Filter frequency C.V. = 0V.
4. This scale holds from max attenuation to approximately 20 dB of attenuation. Thereafter, scale is approximately linear.

APPLICATION HINTS

POWER SUPPLY

The AS3394E was designed to operate from +5V and -6.5V supplies. The non-standard negative supply was necessary not to compromise the VCO frequency resolution, which ranges from -4 to +4 volts, in favor of a -5V supply (this is because there needs to be 4 diode drops for the current mirrors). Any one of the readily available 3-terminal regulators may be used to supply the -6.5V negative supply. Since the stability and jitter of the VCO are directly affected by noise on the positive supply, a supply as stable and clean as possible should be use *(not the +5Vdigital supply)* Maximum supply allowable across the device is 25 volts.

VCO

The control scale of the VCO is temperature compensated with an internal +3300ppm tempco generator and multiplier. Thus, as chip temperature changes, the control voltage applied to the exponential generator changes proportional to temperature, effectively canceling the -3300ppm tempco of the control scale.
The resistor Rt from Pin 1 to the negative supply sets up an internal reference current for the exponential voltage-to-current converter. Its value and that of timing capacitor Ct determine the nominal initial frequency of the VCO at zero CV applied. The equation is:

Fout = (Vref)/(Vcc x Rt x Ct)

where Vref is the voltage across pins 1 and 3, nominally 1,2 volts. The other consideration is the current range of the V to I converter, which is optimized for a range of 300nA to 80μA. Using 80μA as an upper limit, the timing capacitor is chosen by:

Ct = (80μA)/(Fmax1 x Vcc)

where Fmax1 is the maximum frequency at the best accuracy (80μA).

In a typical application, suppose the best accuracy is in the range of 32Hz to 8KHz. Thus Fmax1 is 8KHz, and Ct is calculated to be 2nF. The middle of this range is 500Hz which is set to Fout. Therefore Rt calculates to 240K. Note that since the VCO input range is -4 to +4 volts with a scale factor of 0,75 V/Octave, the VCO will sweep from 12Hz to 20KHz.

A -5V negative supply can be used if the sweep range is reduced. In this case, Ct = 4nF and Rt = 65K.
Since the VCO was designed to be software adjusted, a simple multiplier was used with slight non-linearity at its two extremes. Therefore, for best results, it is recommended that the scale factor and scale linearity be auto-corrected through software means.

Output Saw-tooth Out (pin 9) - saw-tooth signal with an internal VCO frequency span of ± 50 μA. This output can be loaded on a 1 kΩ resistor and the saw-tooth signal can be fed directly to the Ext In1 or Ext In2 inputs, as well as used for other purposes. The maximum signal voltage at this output should not exceed ± 200 mV.

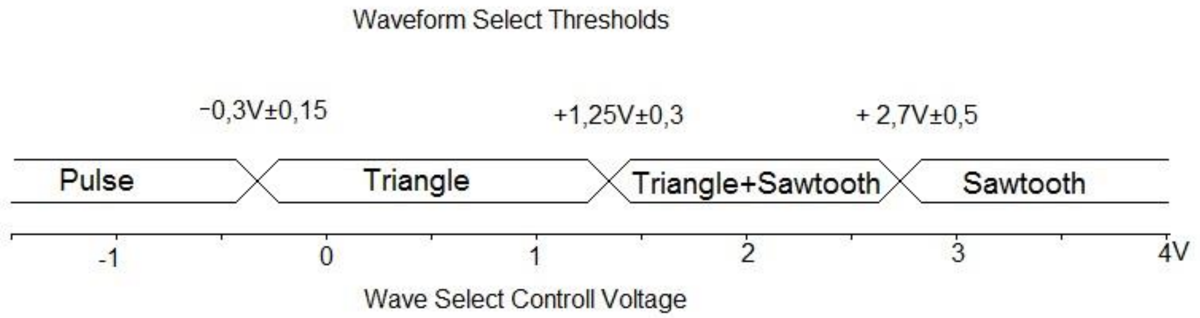
Output of a Sub-Oscillator (pin 5) - rectangular pulses with the frequency of the internal oscillator VCO divided by 2 (square wave one octave below the fundamental frequency). The output voltage swing is ± 2 V; this output can be loaded onto a resistor with a resistance of at least 10 kΩ. This signal can also be mixed with other used signals.

WAVEFORM SELECTION

By applying the control voltage in the range from -2 V to +4 V to the Wave Select CV input (pin 7), you can select the following waveforms at the Wave Out output: Pulsed (PWM), Triangular, Triangular + Saw-tooth and Saw-tooth. The specific value of the control voltage for selecting the waveform is given in the table of parameters.

The pulse width may be turned off simply by setting the Pulse Width control voltage slightly negative to ensure a pulse width of 0%. A unique circuit on-chip keeps the average DC level of the pulse waveform constant regardless of duty cycle, so that pulse width may be modulated without annoying control signal feedthrough.

The relative amplitudes of the three waveforms have been set as follows to give approximately equal loudness: The triangle is 27% larger than the saw-tooth, which is about 27% larger than the pulse wave.



EXTERNAL INPUT

External inputs VCA1 and VCA2 can receive any signals up to ± 40 mV. Normally, a resister divider is required to attenuated the input signal to this level. The resistance to ground should be 1k to keep the VCA balanced, and the input signal should be capacitively coupled to minimize control voltage feedthrough. A small adjustable offset of ±20mV may be applied to this input to further reduce CV feedthrough.

The control voltage range at the Mixer Balance CV pin 13 input is from -2 V to +2 V. The VCA1 and VCA2 amplifiers are controlled in antiphase, at -2 V VCA2 is fully switched on, at +2 V VCA1 is fully switched on. Signals from VCA1 and VCA2 inputs are nominally in equal balance- each being 6dB down from its maximum, when the control voltage is at zero volts. The control scale is roughly audio taper: the first 20dB of range is linear while the remaining 60dB is exponential. This external input is ideal for adding noise, a signal from a second VCO, or both.

VCF

Able to sweep over a minimum of 14 octaves, the filter is the classical wide range 4-pole low-pass type designed for musical instruments.

The control scale has twice the sensitivity as that for the VCO: it is 3/8V per octave. The first 3 stages of the filter are unity gain transconductors while the last stage provides a gain of 57 (and consequently has a transconductance of 1/57 of the first three). This requires three equal capacitor values, and the fourth is 1/57th of the other value.

The frequency of the -12dB point on the cut-off slope is given by:

$$Pzcv = Gm/(2 \times pi \times Ceq) = (Iref)/(4 \times pi \times Ceq \times V_T)$$

where V_T = KT/q = 26mV at 20ºC. The reference current is set up internally an given a +3300 ppm to compensate for the V_T -3300ppm tempco. Thus this equation can be reduced to:

Pzcv = 4,3 x 10E-5/Ceq

Note that due to internal resistor tolerances, the 4,3E-5 term can vary 40% part-to-part.

Selection of the 4 filter capacitors is again determined by the maximum desired cut-off frequency and optimum operating range of the OTAs. The range has been optimized for an operating range of 5 umho to 5 mmho. Thus we can calculate C as follows:
C = 5E-3/(2 x pi x Fmax)

As an example, assume the highest cut-off frequency is 24KHz. C1-C3 becomes 33nF and C4 is 33nF/57 = 580pF. The frequency at zero control volts is approximately 1300Hz; 24KHz will be reached in 4,2 octaves, or at -1,6V. The filter can be opened up to >40KHz using these values, but CV feedthrough becomes excessive.

The resonance VCA feedback circuit has been designed so that as the resonance is increased the apparent loudness remains constant, providing a much richer resonant sound. Note, however, that the peak-to-peak level of a pule/square wave actually doubles as resonance is increased, due to the ringing on its fast edge transitions.

VCF MODULATION

The modulation VCA allows the VCO triangle wave to modulate the reference current of the VCF, and hence the cut-off frequency. The Modulation Amount control voltage (Pin 6) controls the 'depth': at maximum setting the VCF is swept from a very low value to twice the unmodulated frequency. Since the modulation is linear, the apparent filter frequency does not shift as modulation is increased.

One application of this control is to set the filter into oscillation for obtaining linear audio FM of one VCO by another (using the VCF as a VCO). However, an equally interesting application is to audio FM the filter while it is filtering normally. The result is strong timbral effects, especially with some resonance added.

FINAL VCA

The final VCA is a low noise, low control feedthrough design which substantially reduces fast envelope click and pop noises without the need for a trimmer. The output of the filter is essentially AC coupled to the VCA input by means of the bypass capacitor connected to Pin 21. Thus, its value along with the internal 11K resistor sets the low corner frequency; a value of 4,7µF results in a -3dB point of 3Hz. This pin may also be used to extract the filter output signal before it is passed through the VCA.
The final VCA control scale is approximately audio taper. The first 20dB of attenuation from a control voltage of +4V to +2,5V is linear. The next 60 to 80dB of attenuation is from +2,5V to 0V is exponential. This allows the natural sound of exponential decays to be produced with simple linear envelope control, which is much simpler to generate in software.
The signal output at Pin 23 is a current with a voltage compliance of Vee+1 to Vcc-1. This allows the outputs of multiple 3394s to be mixed together by connecting all Pin 23s together. The summed current can then be converted to a voltage simply by a resistor to ground, or an op-amp with feedback resistor. The major portion of the 40% tolerance on the maximum output swing (nominally ±210µA) is due to the monolithic diffused resistors setting the currents. Although the output variations part-to-part are typically much less than this *(about 5-10%, ed.)*, output levels as well as the filter initial frequency may be more closely matched by matching the resistance between the Vcc and Vee pins.

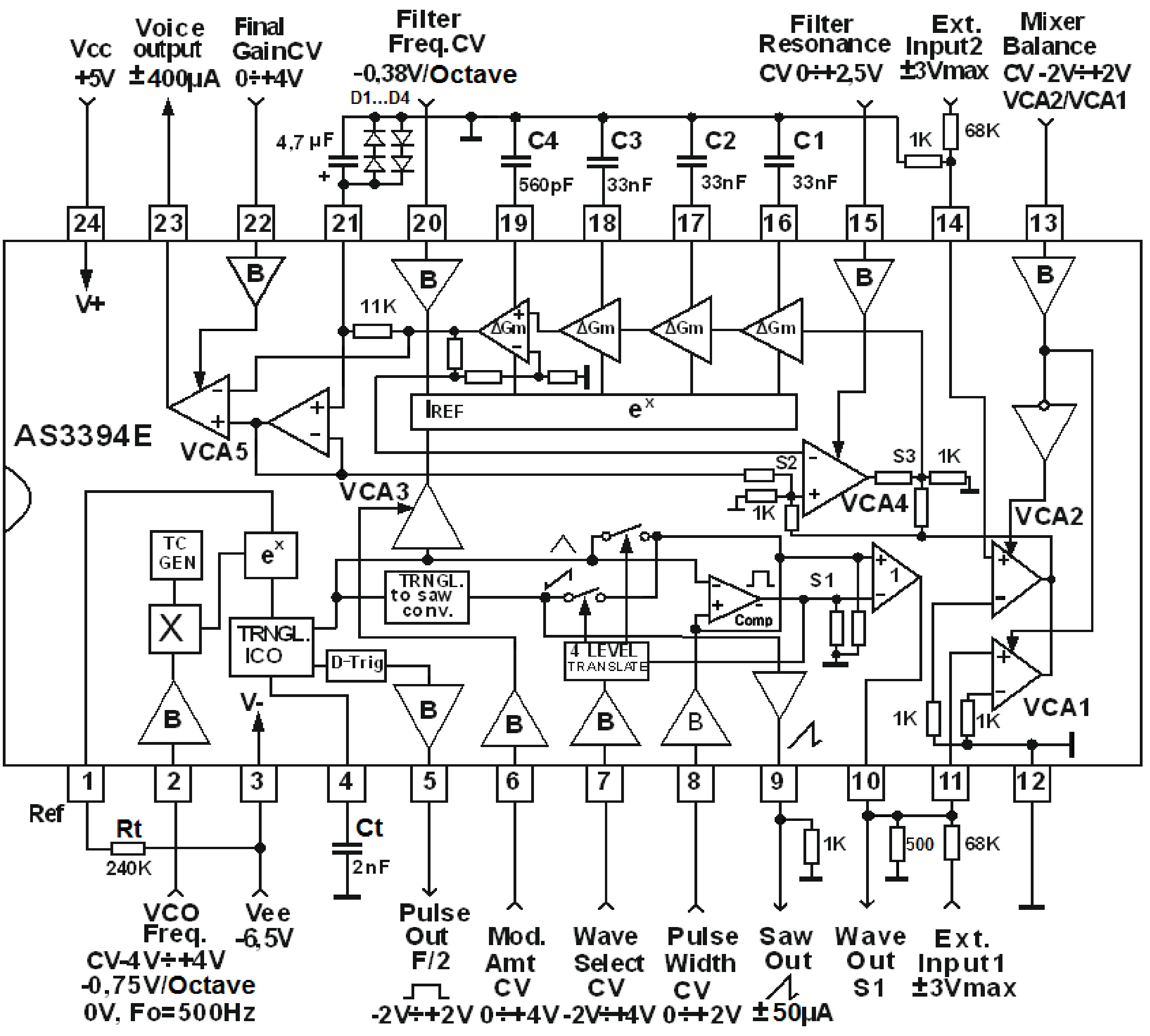
INPUT CONTROL VOLTAGE BUFFERS

With the exception of Waveform Select whose control voltage is not critical, the input bias current to all control inputs is typically less than 1 nA, and have maximum values of 3 and 5 nA. Hold capacitor values can be in the range of 2 to 20 nF before causing multiplexing problems and DAC output instability. The amount of droop is given by:

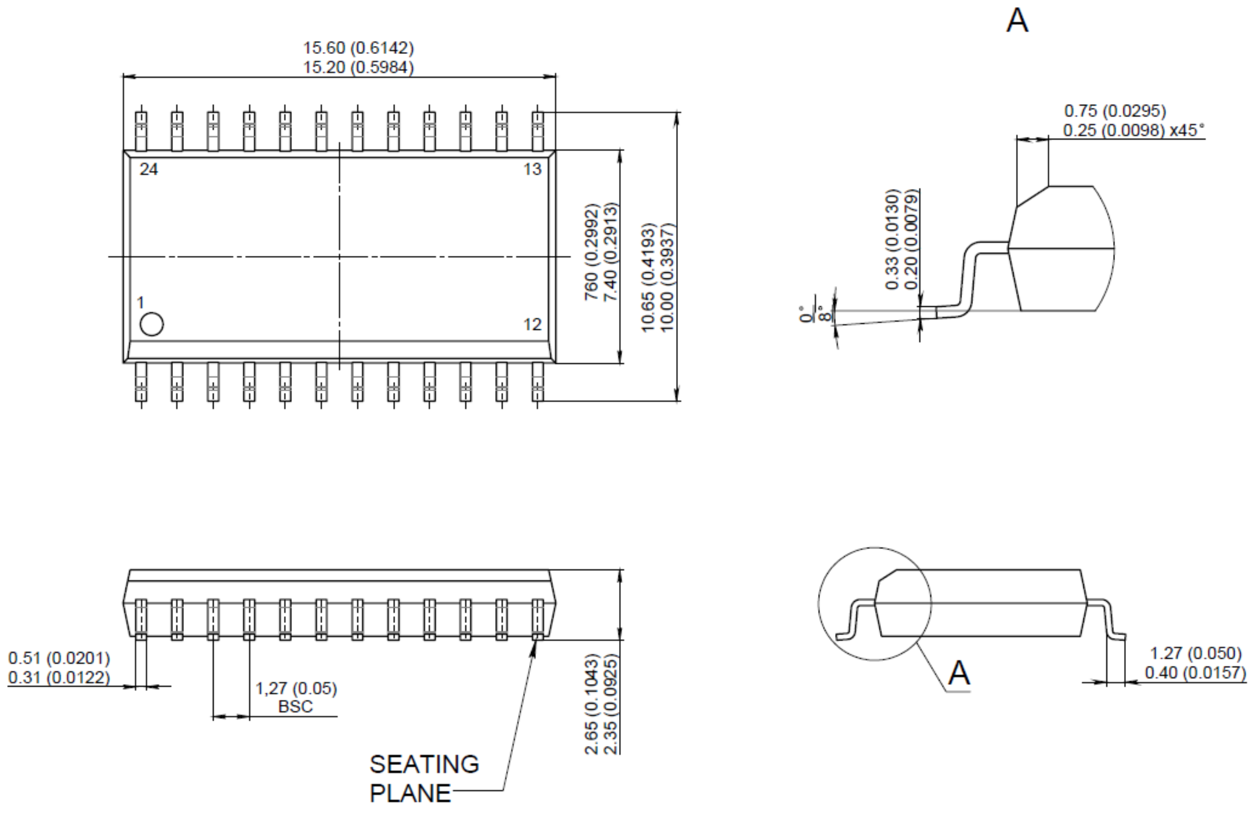
Vdroop = (Ibias – Tupdate) / Chold

With a hold capacitor of 10nF and update time of 10 ms, maximum droop would be 5 mV or between 0,06 and 0,12% of full scale. Typically, the droop is a factor of 10 less than these worst case values.

AS3394E µP controllable voice block and external connections



24-Lead Standard Small Outline Package (SOIC_W)
Wide Body
Dimensions shown in millimeters and (inches)



Revision history

Date	Revision	Changes
11-Mar-2019	**1**	Short version 1
03-Apr-2019	**2**	Added a diagramm in the section WAVEFORM SELECTION