

V/F Converter

IR9331/IR9331N

T-73-13-03

# IR9331/IR9331N V/F Converter

## ■ Description

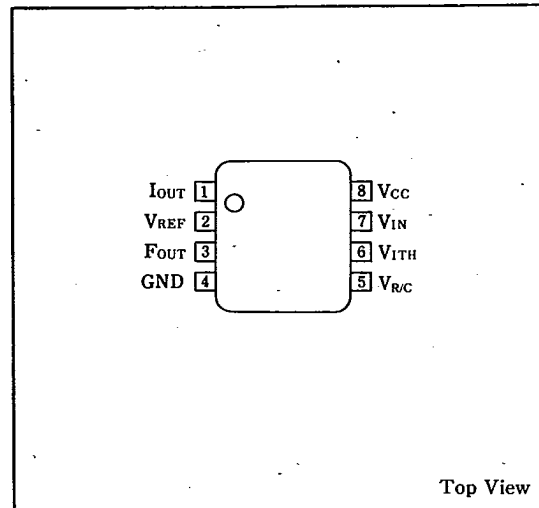
The IR9331/IR9331N is a voltage-to-frequency converters ideally suited for use in simple low-cost circuits for A/D conversion, precision F/V conversion, longterm intergration, linear frequency modulation or demodulation, and many other functions.

## ■ Features

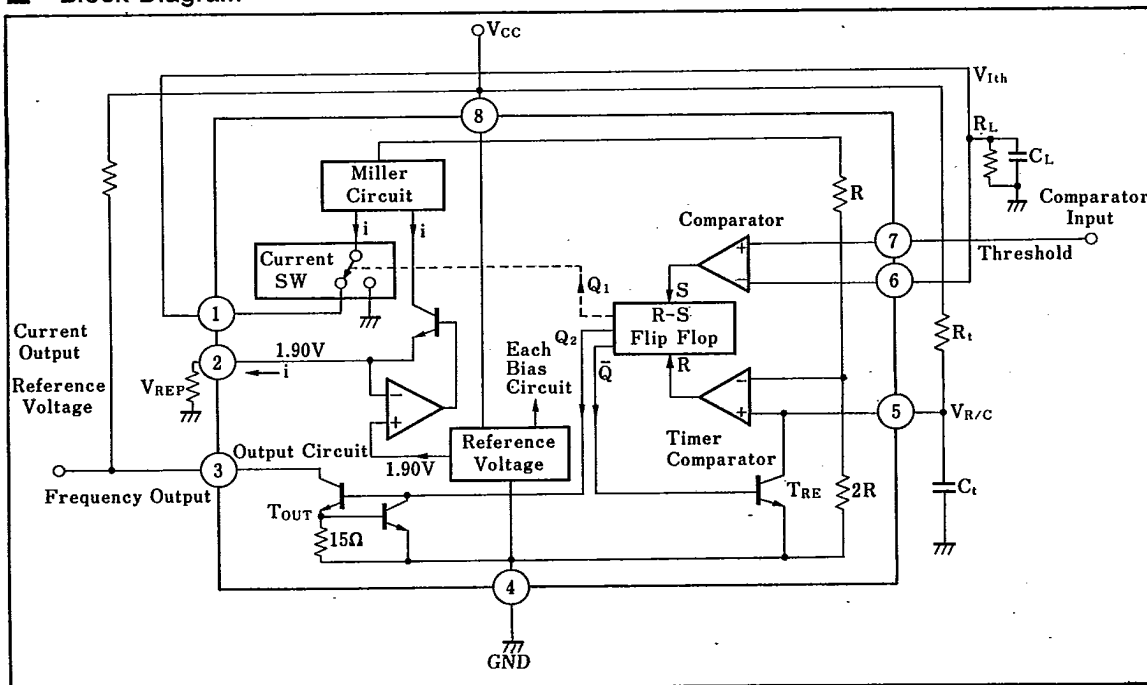
1. Guaranteed linearity 0.01%FS (MAX.)
2. Excellent temperature stability  
±30ppm/°C (TYP.)
3. Wide dynamic range 100dB at 10kHz FS\* (MIN.)
4. Wide range of FS frequency 1~100kHz
5. Wide range of supply voltage 4~40V
6. 8-pin dual-in-line package (IR9331)  
8-pin small-outline package (IR9331N)

\* FS: Full Scale

## ■ Pin connections



## ■ Block Diagram



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### Absolute Maximum Ratings

(Ta=25°C)

Parameter	Symbol	Condition	Rating	Unit	
Supply voltage	V <sub>CC</sub>		40	V	
Input voltage	V <sub>RC</sub>		-0.2~V <sub>CC</sub>	V	
	V <sub>th</sub>				
	V <sub>IN</sub>				
Output short-circuit time	t <sub>SG</sub>	to GND	Infinity	s	
	t <sub>SV</sub>	to V <sub>CC</sub> , short-circuit 30mA(TYP.)	Infinity		
Power dissipation	P <sub>D</sub>	Ta≤25°C	IR9331	500	mW
			IR9331N	450	
P <sub>D</sub> derating ratio	ΔP <sub>D</sub> /°C	Ta>25°C	IR9331N	4.5	mW/°C
Operating temperature	T <sub>opr</sub>		-10~+70	°C	
Storage temperature	T <sub>stg</sub>		-55~+150	°C	

### Electrical Characteristics

(V<sub>CC</sub>=15V, Ta=25°C, Test circuit 1)

Parameter	Symbol	Condition	MIN.	TYP.	MAX.	Unit
VFC non linearity error*2	NL <sub>b</sub>	4.5V≤V <sub>CC</sub> ≤20V		±0.003	±0.01	%FS
	NL <sub>b'</sub>	T <sub>opr</sub> (-10~70°C)		±0.006	±0.02	
	NL <sub>a</sub>	V <sub>CC</sub> =15V, f <sub>OUT</sub> Test circuit 2*1		±0.10	±0.30	
Scale factor (gain)	SF	V <sub>IN</sub> =-10V, R <sub>S</sub> =14kΩ	0.90	1.00	1.10	kHz/V
Gain temperature coefficient	α SF	4.5V≤V <sub>CC</sub> ≤20V T <sub>opr</sub> (-10~+70°C)		±30		ppm/°C
Gain-power supply stability	SVR	4.5V≤V <sub>CC</sub> ≤10V		0.01	0.15	%V
	SVR'	10V≤V <sub>CC</sub> ≤40V		0.006	0.06	
Full scale frequency	F <sub>FS</sub>	V <sub>IN</sub> =-10V	10.0			kHz
Over range frequency	F <sub>over</sub>	V <sub>IN</sub> =-11V	10			%

#### Input comparator (terminal 6 and 7)

Offset voltage	V <sub>IO1</sub>			±3	±10	mV
	V <sub>IO2</sub>	T <sub>opr</sub> (-10~+70°C)		±4	±14	
Bias current	I <sub>B</sub>			-80	-300	nA
Offset current	I <sub>IO</sub>			±8	±100	nA
In-phase input range	V <sub>ICM</sub>	T <sub>opr</sub> (-10~+70°C)	-0.2		V <sub>CC</sub> -2.0	V

#### Timer (terminal 5)

Timer threshold voltage	V <sub>th</sub>		0.63	0.667	0.70	(×V <sub>CC</sub> )V
Input bias current	I <sub>15</sub>	V <sub>CC</sub> =15V, 0V≤V <sub>5</sub> ≤9.9V		±10		nA
	I <sub>15'</sub>	V <sub>CC</sub> =15V, V <sub>5</sub> =10V		200	1,000	
Saturation voltage (reset)	V <sub>SAT5</sub>	I=5mA		0.22	0.5	V

#### Power supply source (terminal 1)

Output current	I <sub>OUT</sub>	R <sub>S</sub> =14kΩ, V <sub>1</sub> =0V	116	136	156	μA
I <sub>OUT</sub> -Voltage fluctuation	I <sub>OV</sub>	0V≤V <sub>1</sub> ≤10V		0.7	1.5	μA
OFF-state leakage current	I <sub>OFF</sub>			0.02	10.0	nA
	I <sub>OFF'</sub>	Ta=70°C		2.0	50.0	
Operating current range	I <sub>opr</sub>			10~500		μA

#### Reference voltage (terminal 2)

Reference voltage	V <sub>REF</sub>		1.70	1.89	2.08	V <sub>DC</sub>
Temperature coefficient	α V <sub>REF</sub>			±60		ppm/°C
Time drift	α V <sub>REF</sub>	1,000 hours		±0.1		%

#### Logic output (Terminal 3)

Saturation voltage	V <sub>SAT3</sub>	I=5mA		0.15	0.50	V
	V <sub>SAT3'</sub>	I=3mA		0.10	0.40	
OFF-state leakage current	I <sub>OFF3</sub>			0.05	1.0	μA

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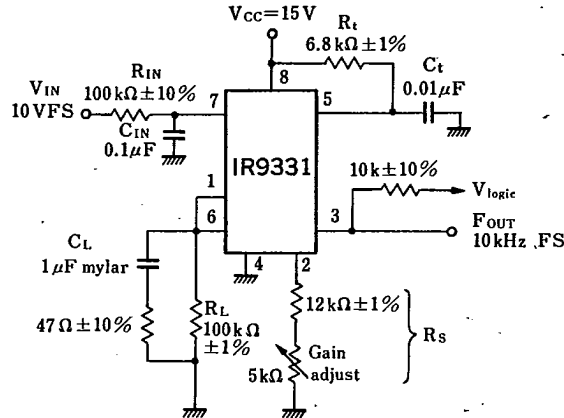
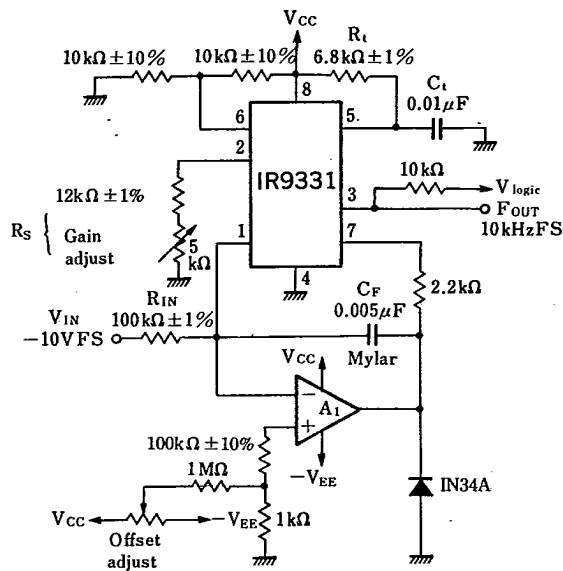
IR9331/IR9331N

Parameter	Symbol	Condition	MIN.	TYP.	MAX.	Unit
<b>Supply current (terminal 8)</b>						
Supply current	$I_{CC}$	$V_{CC}=5V$	1.5	3.0	6.0	mA
	$I_{CC}'$	$V_{CC}=40V$	2.0	4.0	8.0	

- \*1  $f_{OUT}=10Hz\sim 11kHz$ , this test alone is to be performed on test circuit 2.
- \*2 Non-linearity error is defined as the deviation from  $V_{IN} \times (10kHz/-10V_{DC})$  at  $f_{OUT}=1Hz\sim 11kHz$ .  
(Full scale adjustment at 10kHz, zero adjustment at 10kHz)

Test Circuit

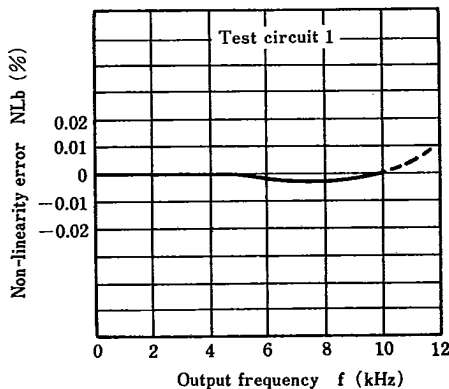
- (1) Test circuit (Precision V/F conversion circuit)      (2) Test circuit 2 (Simple V/F conversion circuit)



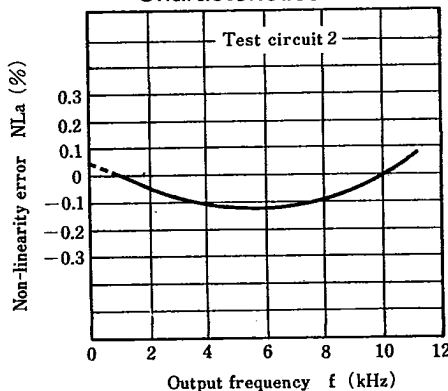
A1 : Use an operational amplifier that satisfies the following conditions:  
Input offset voltage below 1mV  
Input offset current below 2nA

Electrical Characteristics Curves (Unless otherwise specified,  $V_{CC}=15V, T_a=25^\circ C$ )

Non-linearity error—Output frequency Characteristics

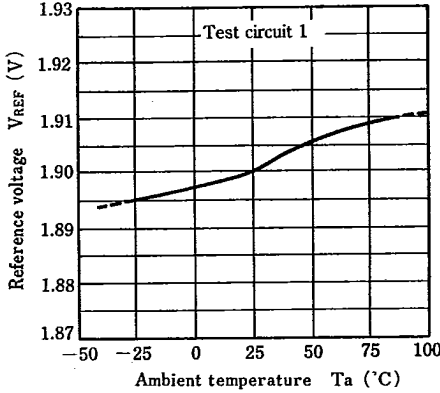


Non-linearity error—Output frequency Characteristics

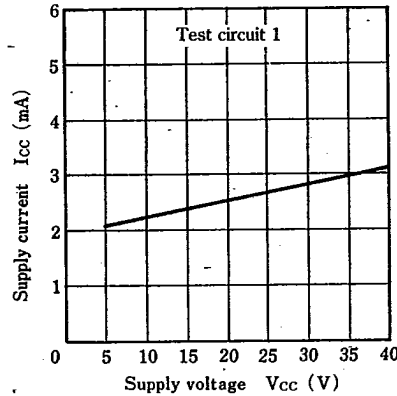


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Reference voltage—Ambient temperature Characteristics



Supply current—Supply voltage Characteristics



**Description of Operation**

The IR9331 is organized mainly as an input comparator, R-S flip-flop, timer comparator, current supply, current switch 1.9V reference voltage supply and output circuit. To briefly explain the circuit operation, the feed-back of this circuit is organized in supply, current switch 1.9V reference voltage supply and output circuit. To briefly explain the circuit V<sub>IN</sub> is higher, C<sub>L</sub> will be discharged through R<sub>L</sub> in a relatively short time to settle for a lower frequency. That is to say that it operates as a highly accurate loose coupling oscillator that produces frequencies linearly in proportion to the input voltage.

Following is a detailed description.

Suppose that the voltage V<sub>Ith</sub> (terminal 6) becomes as satisfies V<sub>Ith</sub> < V<sub>IN</sub>. The input comparator compares V<sub>Ith</sub> and V<sub>IN</sub> to set the R-S flip-flop. The Q<sub>1</sub> output of F.F closes the current switch and starts charging C<sub>L</sub> with the current i. At the same time the Q<sub>2</sub> output turns on the frequency output transistor (T<sub>OUT</sub>) while the Q̄ turns off the reset transistor (T<sub>RE</sub>). From this moment on C<sub>T</sub> will continue to get charged logarithmically toward V<sub>CC</sub>. When the voltage of C<sub>T</sub> has come up to 2/3 V<sub>CC</sub>, the timer comparator applies reset output to F.F. The time taken so far is about 1.1R<sub>t</sub>C<sub>t</sub> (1.1=ln0.333...)

Even if the timer comparator generate reset output, the F.F will remain set so long as V<sub>Ith</sub> ≤ V<sub>IN</sub>, in which it will continue being charged well beyond 2/3 V<sub>CC</sub> until it gets to the state where V<sub>Ith</sub> > V<sub>IN</sub>. This condition arises on power-up or when an excessively higher signal gets in to have the output frequency 0. It will, however, go back to normal if V<sub>IN</sub> restores within the operating range.

F.F will not be reset until the reset output is produced and a condition is reached as satisfies V<sub>Ith</sub>

V<sub>IN</sub>. The current switch opens to have C<sub>L</sub> start discharging (until it reaches a point where V<sub>Ith</sub> > V<sub>IN</sub>). Simultaneously with the resetting of F.F, T<sub>RE</sub> turns on to have C<sub>T</sub> discharge itself. Also T<sub>OUT</sub> turns off. The number of the repetition of this cycle above over and over again in a second is the frequency as defined.

How to work out the output frequency

$$f_{OUT} = \frac{1}{T_1 + T_2}, \quad i = V_{REF}/R_S$$

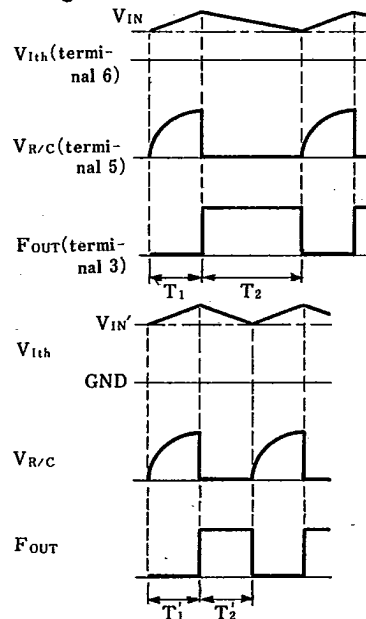
$$T_1 = -R_t C_t \ln(1/3) \approx 1.1 R_t C_t \quad \text{Charging time for } C_L$$

$$T_2 = \frac{(i - V_{IN}/R_L) R_L}{V_{IN}} T_1 \quad \text{Charging time for } C_T$$

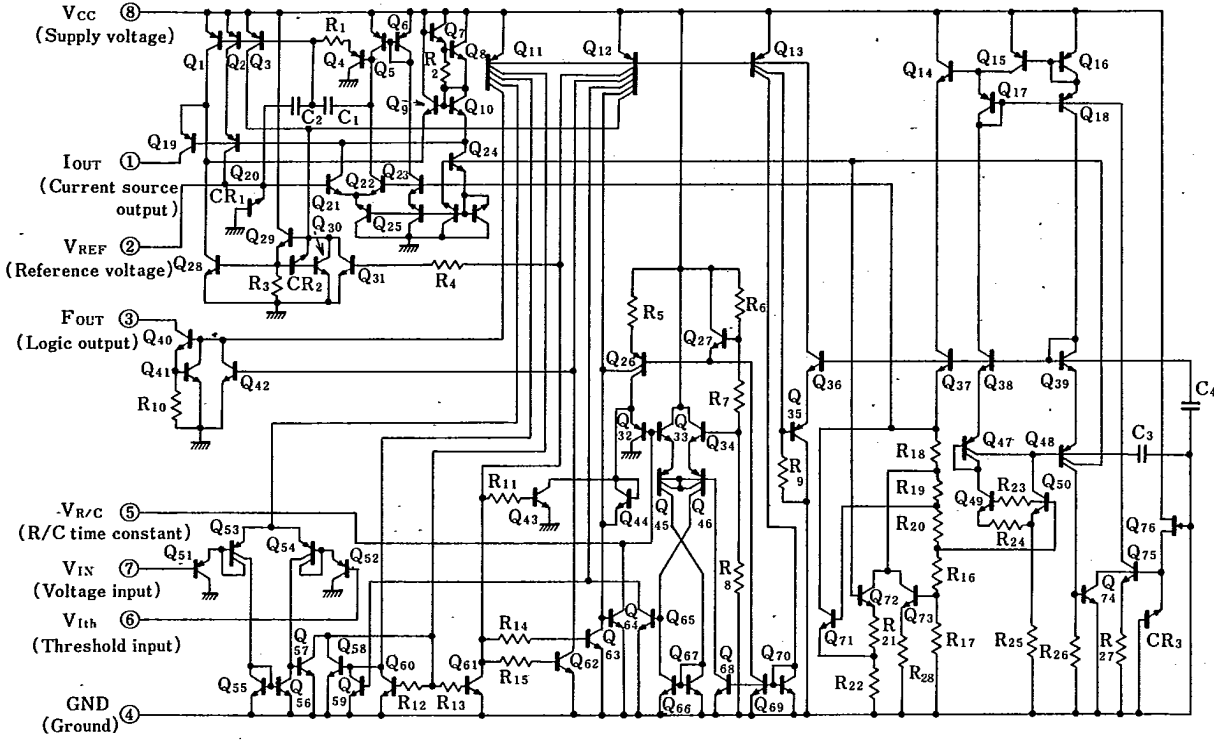
$$f_{OUT} = \frac{V_{IN}}{i R_L T_1} = \frac{V_{IN}}{V_{REF}} \cdot \frac{R_S}{R_L} \cdot \frac{1}{1.1 R_t C_t}$$



**Timing Chart**



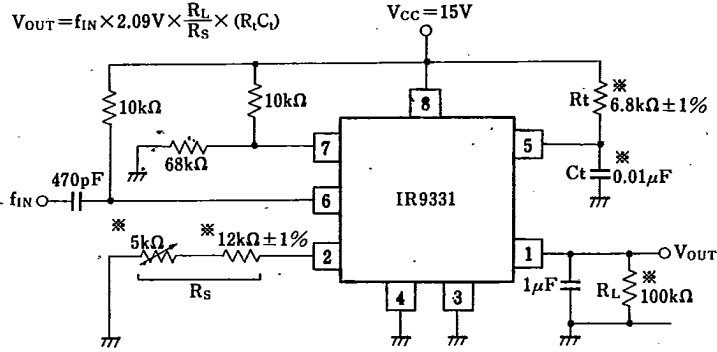
■ Equivalent Circuit



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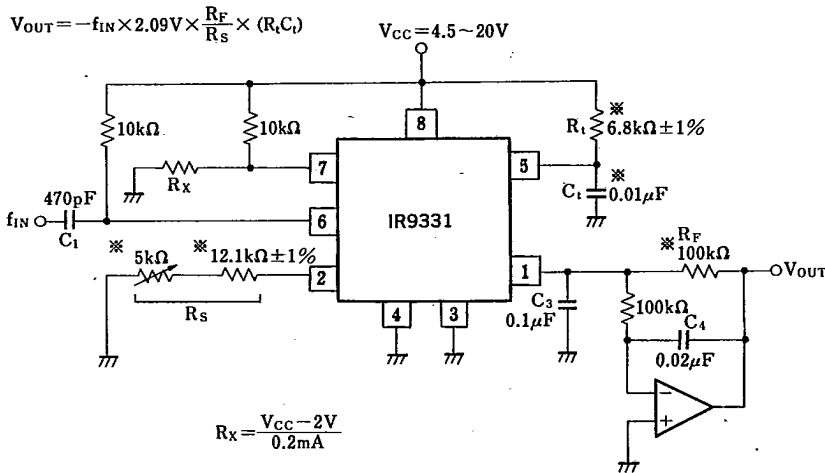
Application Circuit Example

(1) Simple F/V conversion



Full-scale : 10kHz  
Non-linearity : ±0.06%

(2) High grade F/V conversion

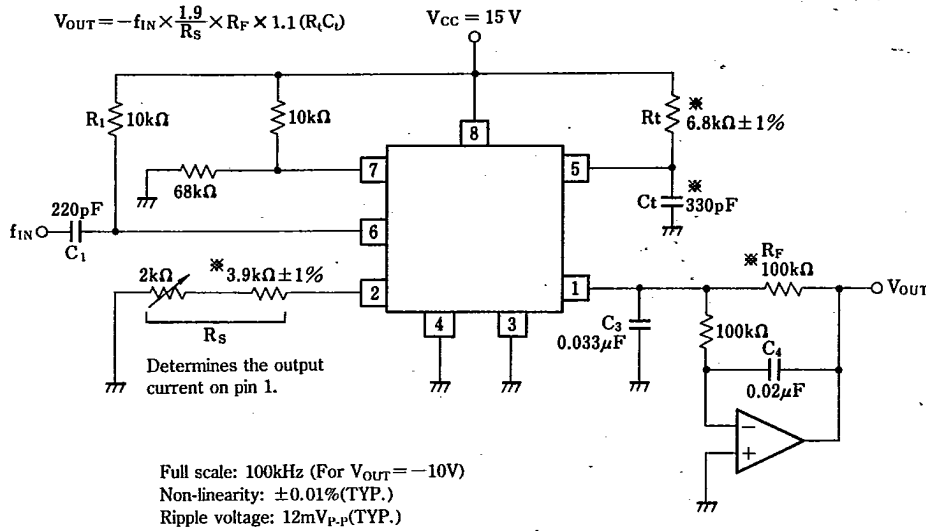


$$R_x = \frac{V_{CC} - 2V}{0.2mA}$$

Full-scale : 10kHz  
Non-linearity : ±0.01%

※ Use resistors with reduced coefficient of temperature.

(3) High grade F/V conversion



(4) High grade F/V conversion (100kHz full-scale)

