APPLICATION MANUAL

FM IF IC
TK14583V

CONTENTS

MEETING YOUR NEEDS
TOKO, Inc.

FM IF IC
TK14583V

1. DESCRIPTION

TK14583V is the IF-IC developed for high speed communication, including mixer (∼500MHz) and IF (∼12MHz).

RSSI output is trimmed individually and very accurate and the stable temperature characteristic.

Mixer is high gain and wide dynamic range.

2. FEATURES

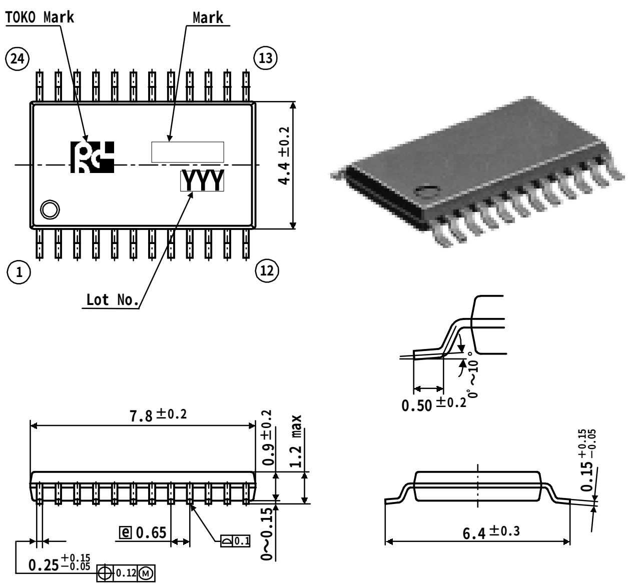
- Very Small Package TSSOP-24
- Iput Frequency MIXER ∼500MHz
  IF ∼12MHz
- Low Voltage Operation 2.5V∼
- High Speed Data Comparator ∼2Mbps
- Wide Band Amplifier ∼1MHz
- Battery Save Function
- Wide Band Demodulator ∼100kHz

3. APPLICATIONS

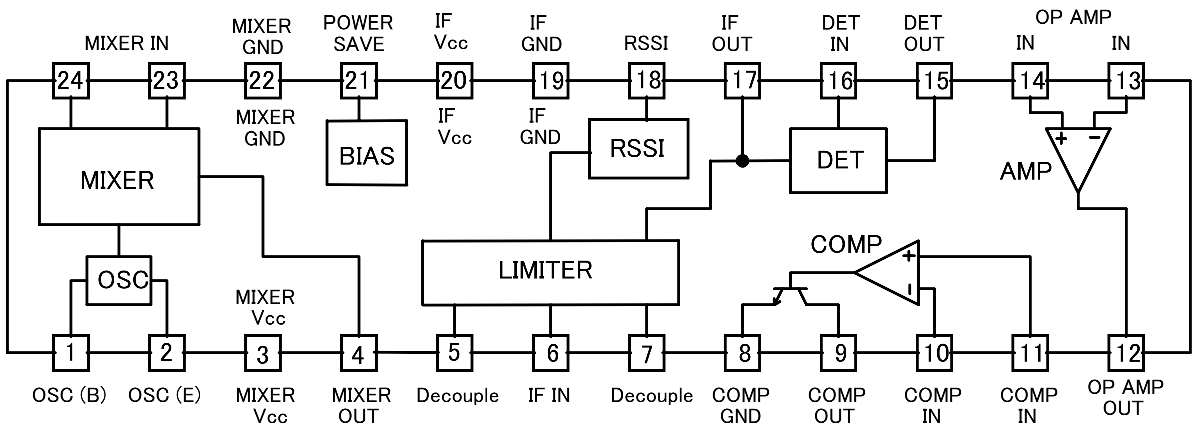
- Keyless Entry System
- Digital Cellular Phone
- Digital Cordless Phone
- DECT
- Wireless LAN

4. PACKAGE OUTLINE

- TSSOP-24



5. PIN CONFIGURATION / BLOCK DIAGRAM



6. ABSOLUTE MAXIMUM RATINGS

T_a=25°C

Rating	Symbol	Value	Unit	Condition
Supply Voltage	$V_{CC\ MAX}$	6.0	V	
Power Dissipation	P_D	230	mW	*
Storage Temperature Range	T_{stg}	-55 ~ +150	°C	
Operating Temperature Range	T_{OP}	-30 ~ +75	°C	
Operating Frequency	f_{MAX}	6 ~ 500 (Mixer) 6 ~ 12 (IF) ~ 0.1 (FM Demodulation)	MHz	
Operating Voltage Range	V_{OP}	2.5 ~ 5.5	V	

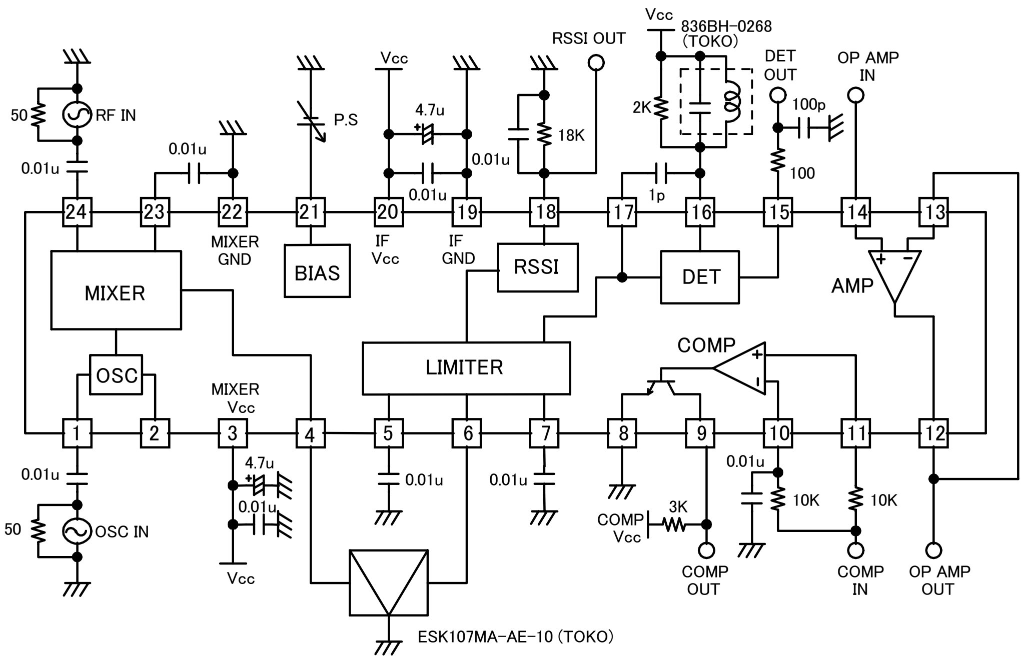
* P_D must be derated at rate of 1.84mW/°C for operation at T_a＝25°C.

7. ELECTRICAL CHARACTERISTICS

T_a = 25℃ , Vcc = 3V ,f_{in} = 250MHz , fm = 1kHz , Mod =±100kHz , f_{OSC} = 239.3MHz , V_{OSC} = -10dBm

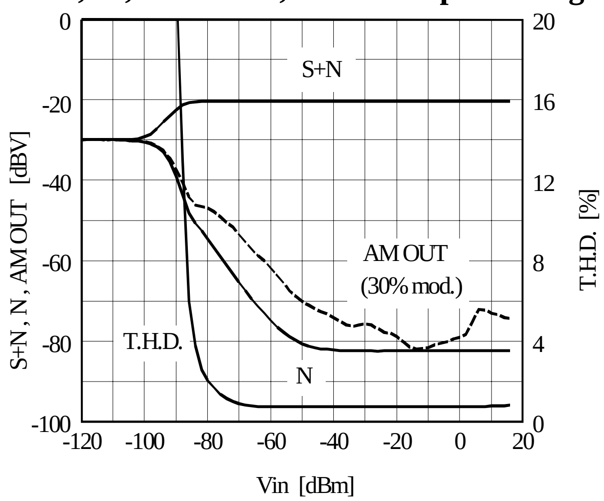
Characteristics	Symbol	Value			Unit	Condition
		MIN	TYP	MAX		
Supply Current 1	I_{CC} 1	3.5	5.6	7.8	mA	None input
Supply Current 2	I_{CC} 2	0	10	25	µA	PS=ON , None input
MIXER + IF						
Output Voltage 1	V_O1	60	100	180	mVrms	-30dBm input
Distortion	THD	0	1	3	%	-30dBm input
Signal to Noise Ratio	S/N	54	60	70	dB	-30dBm input
12dB SINAD	SINAD	-100	-91	-85	dBm	
MIXER						
Mixer Transfer Gain	G_M	23	29	35	dB	
Mixer 3rd Order Intercept	V_{ICP}	-10	-4	+2	dBm	
Mixer Input Resistance	R_{IM}	2.5	3.3	4.1	kΩ	
Mixer Output Impedance	Z_{OM}	250	330	410	Ω	
LIMITER						
Limiter Input Resistance	R_{IFIN}	250	330	410	Ω	
Gain	G	69	75	82	dB	
Output Voltage 2	V_O2	350	500	650	mV_{P-P}	
RSSI						
RSSI Output Voltage 1	V_{RSSI} 1	0.00	0.20	0.40	V	none input
RSSI Output Voltage 2	V_{RSSI} 2	0.45	0.60	0.75	V	-75dBm none-mod input
RSSI Output Voltage 3	V_{RSSI} 3	1.05	1.20	1.35	V	-50dBm none-mod input
RSSI Output Voltage 4	V_{RSSI} 4	1.35	1.55	1.80	V	-25dBm none-mod input
Comparator						
Duty Ratio	D_R	45	50	55	%	
Output Current	I_O	1	3	6	mA	
AMP						
Frequency Band Width	B	1.5	2.5	5.0	MHz	Gain = 1 , -3dB point
Output Amplitude	vo	1.0	1.5	2.8	V_{P-P}	Gain = 1 , fin = 50KHz , sin wave input

8. TEST CIRCUIT

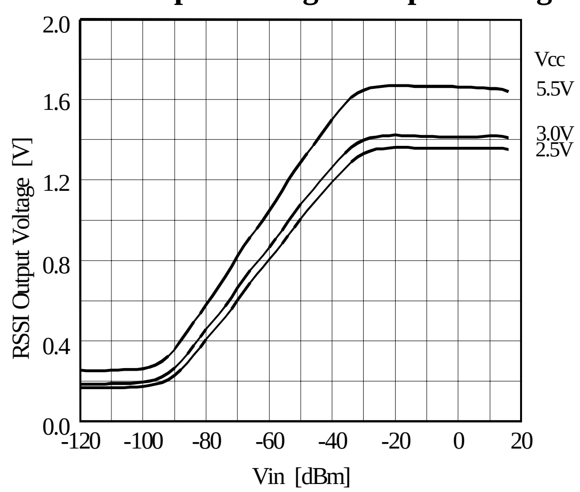


9. TYPICAL CHARACTERISTICS

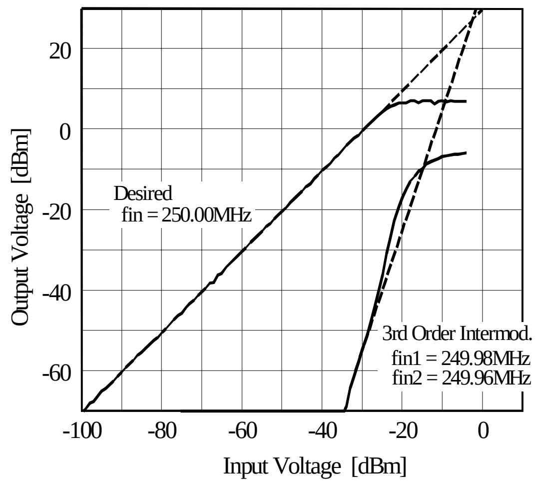
S+N , N , AM OUT , THD vs Input Voltage



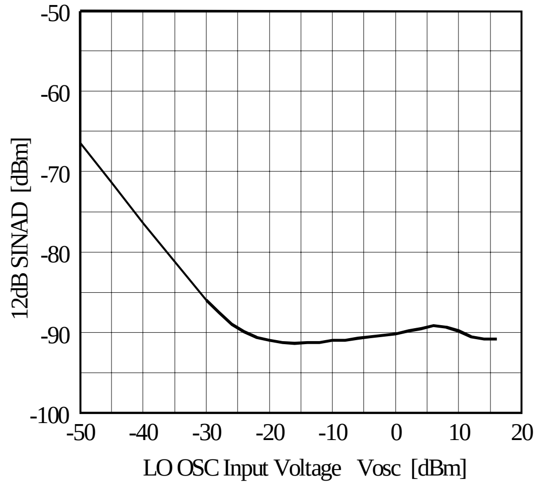
RSSI Output Voltage vs Input Voltage



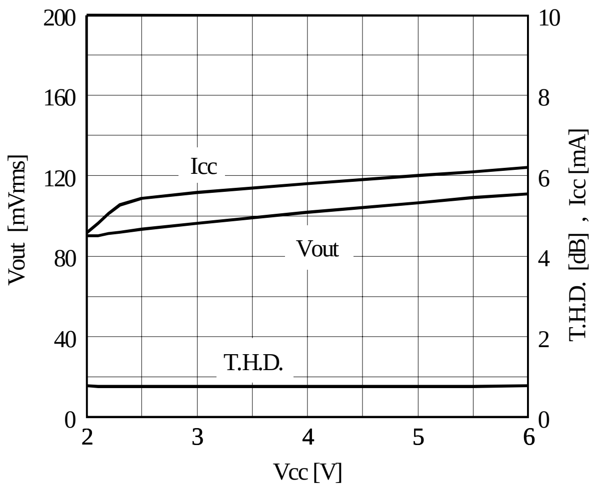
MIXER 3rd Order Product



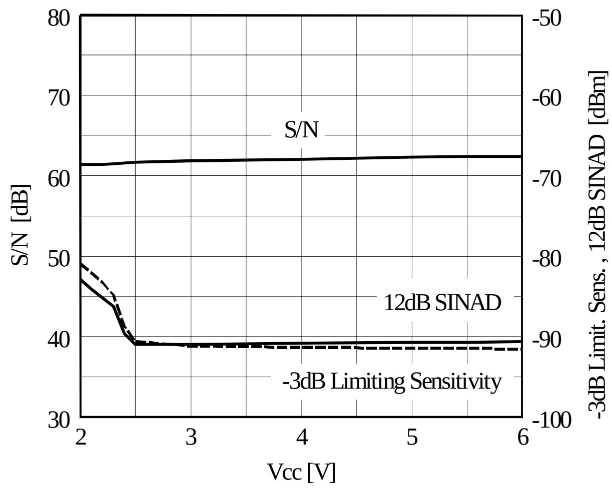
12dB SINAD vs LO OSC Input Voltage



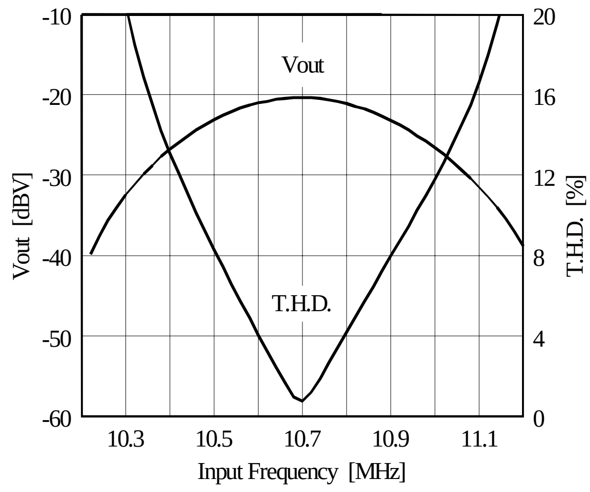
Icc , Vout , T.H.D vs Vcc



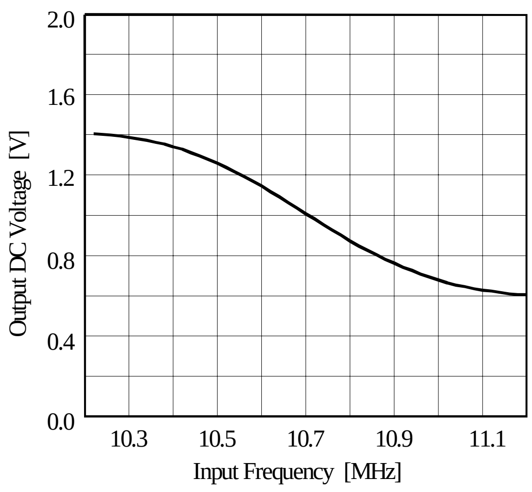
S/N , -3dB Limiting Sensitivity , 12dB SINAD vs Vcc



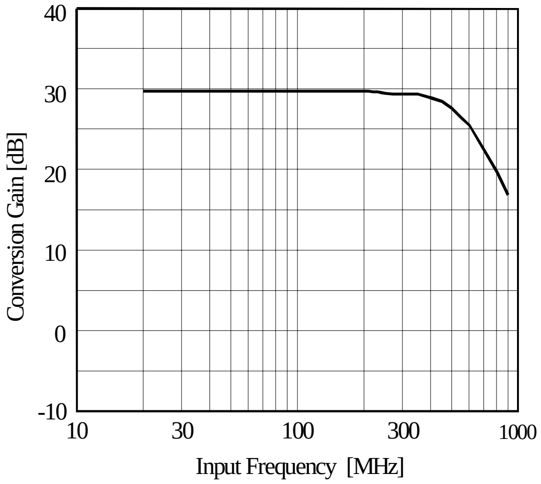
IF Detune Characteristics



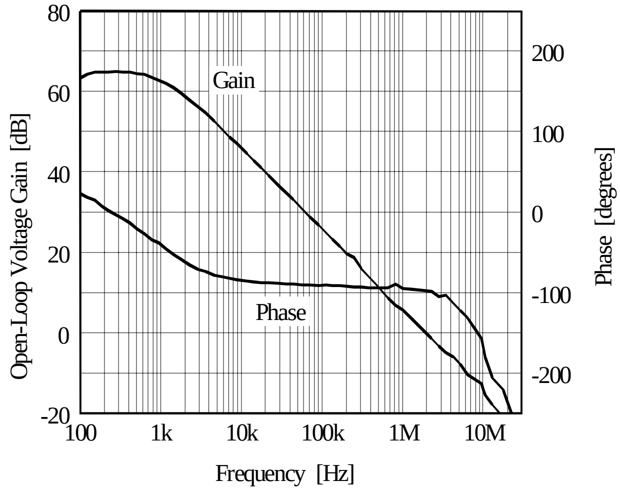
IF S Curve



MIXER
Conversion Gain vs Input Frequency

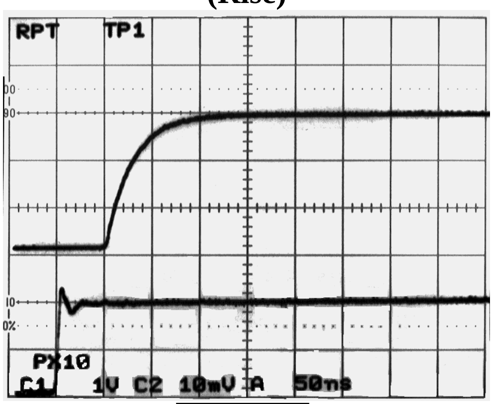


Op Amp Open-Loop Voltage Gain and Phase vs Frequency



Data Comparator Output Voltage Transient Response

(Rise)

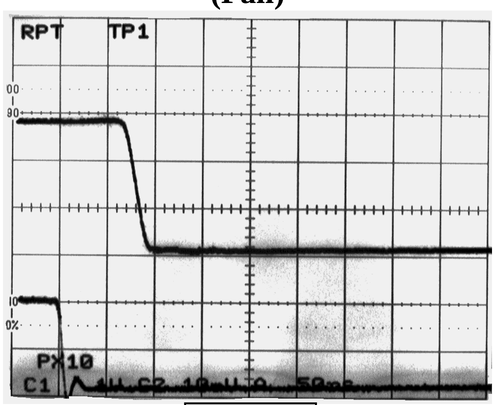


OUT

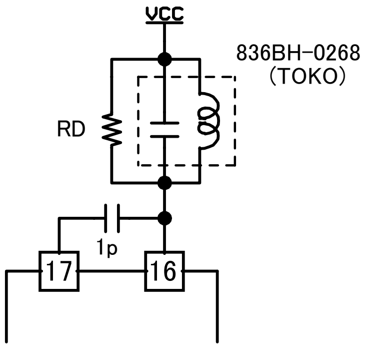
IN

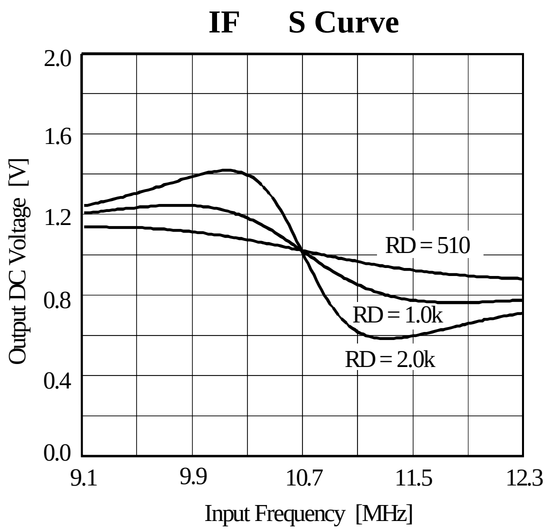
50nsec/div

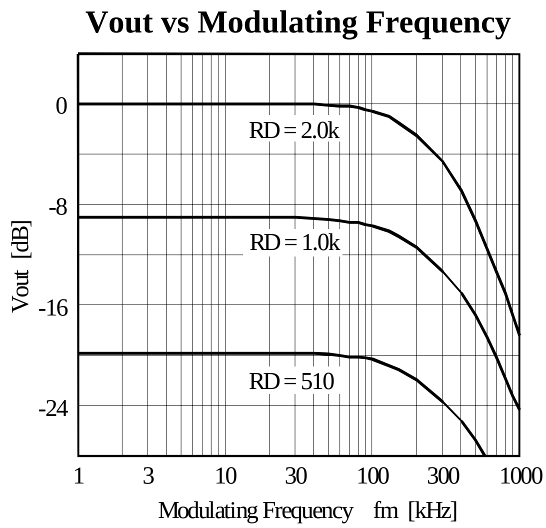
(Fall)



50nsec/div

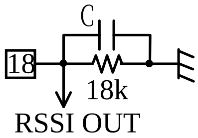

VCC
836BH-0268
（TOKO）
RD
1p
17
16


IF S Curve
2.0
1.6
1.2
0.8
0.4
0.0
Output DC Voltage [V]
9.1
9.9
10.7
11.5
12.3
Input Frequency [MHz]
RD = 510
RD = 1.0k
RD = 2.0k

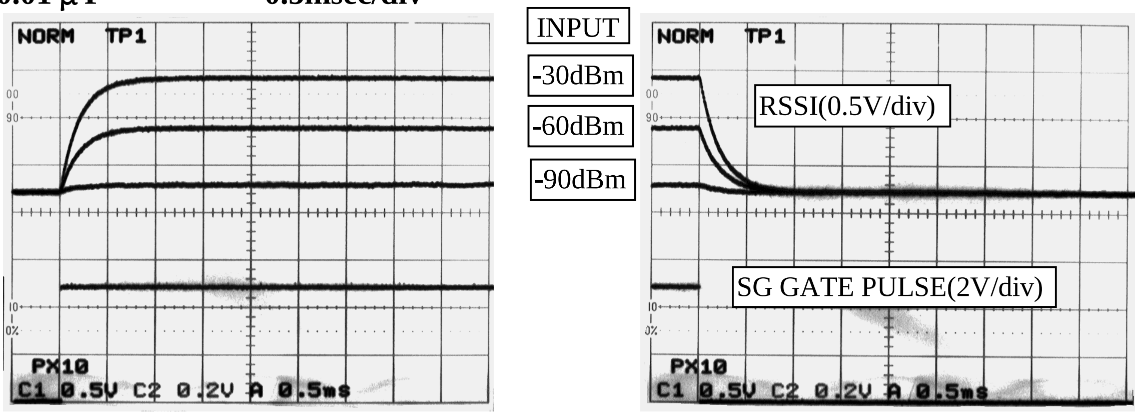

Vout vs Modulating Frequency
0
-8
-16
-24
Vout [dB]
1
3
10
30
100
300
1000
Modulating Frequency fm [kHz]
RD = 2.0k
RD = 1.0k
RD = 510

RSSI OUTPUT VOLTAGE TRANSIENT RESPONSE — MIXER INPUT ON/OFF

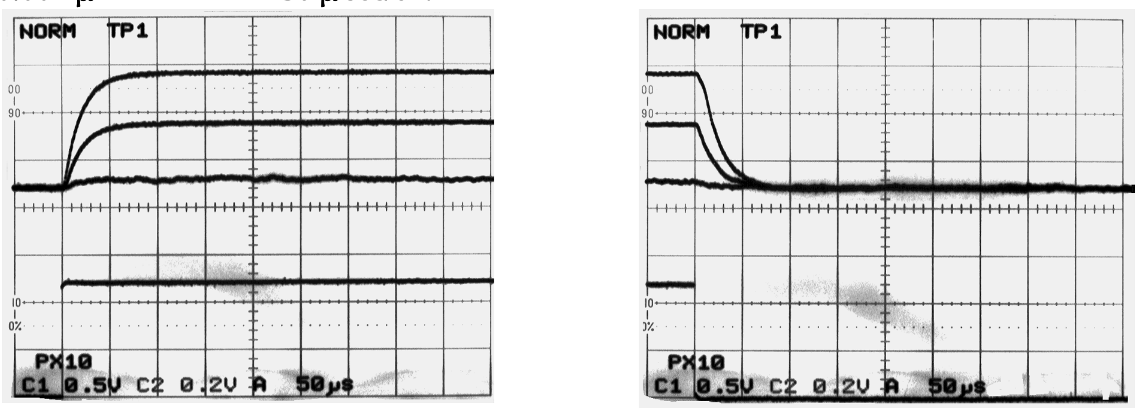
MIXER INPUT VOLTAGE
= -30 , -60 , -90 dBm



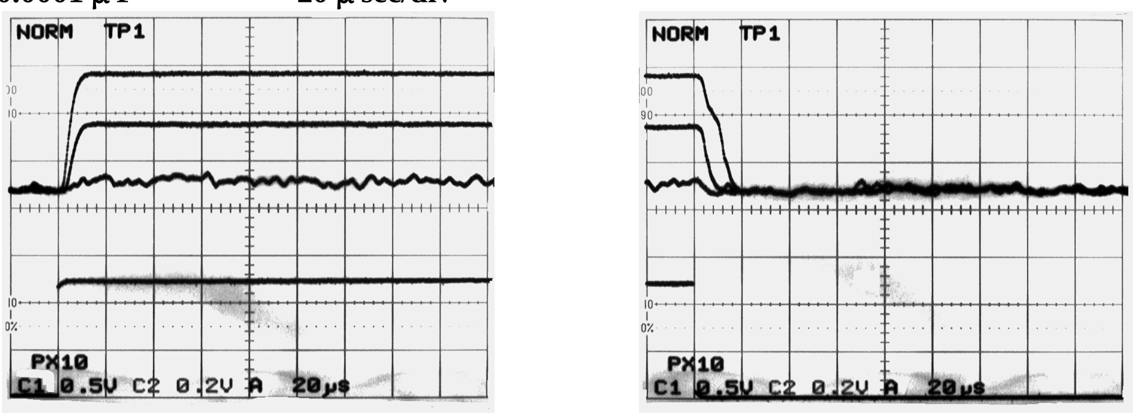
C = 0.01 μ F **0.5msec/div**



C = 0.001 μ F **50 μ sec/div**

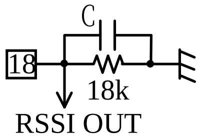


C = 0.0001 μ F **20 μ sec/div**

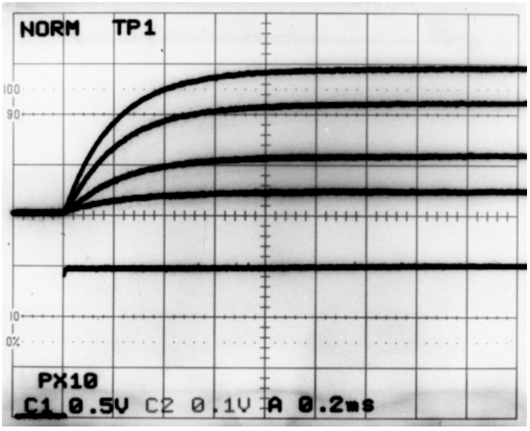


RSSI OUTPUT VOLTAGE TRANSIENT RESPONSE — POWER SAVE ON/OFF

MIXER INPUT VOLTAGE
= -25 , -50 , -75 , -100 dBm



C = 0.01 μ F 0.2msec/div

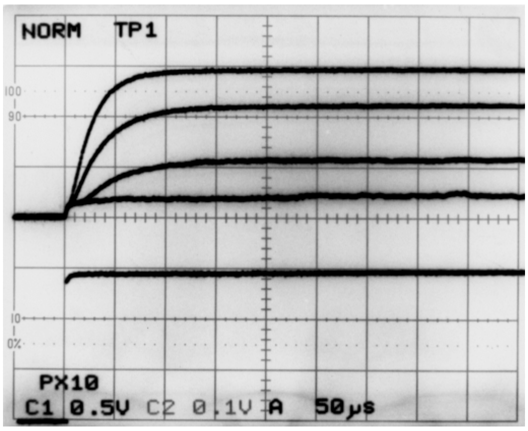


RSSI OUT (0.5V/div)

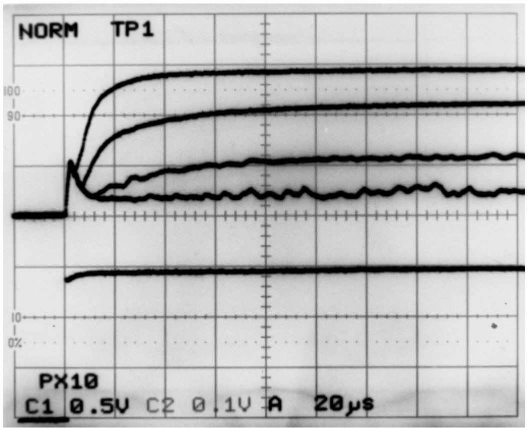
-25dBm in
-50dBm in
-75dBm in
-100dBm in

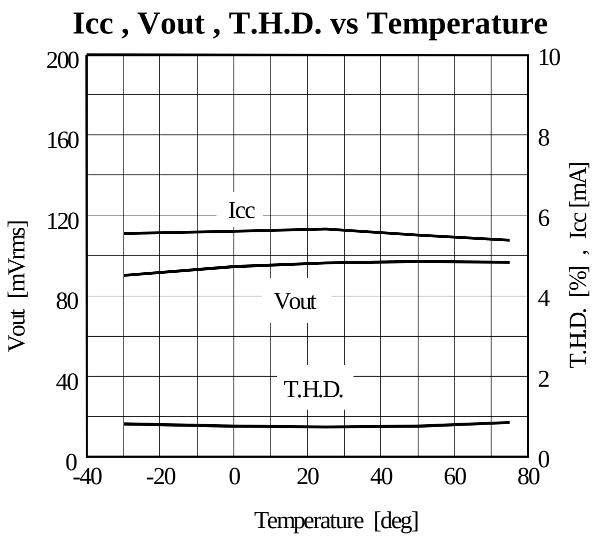
POWER SAVE (1V/div)

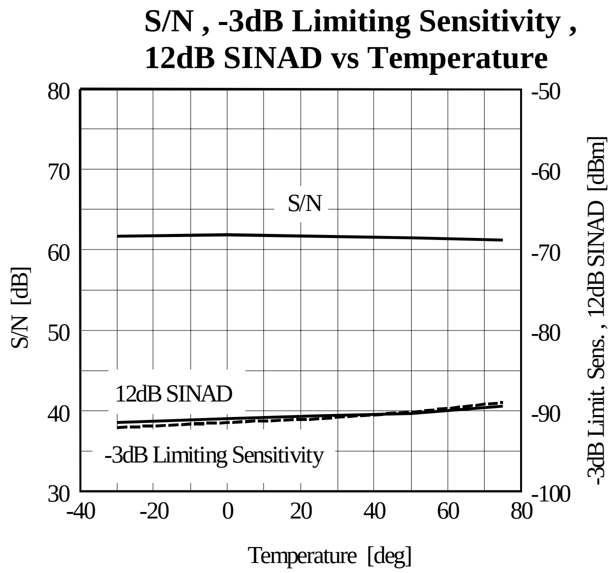
C = 0.001 μ F 50 μ sec/div

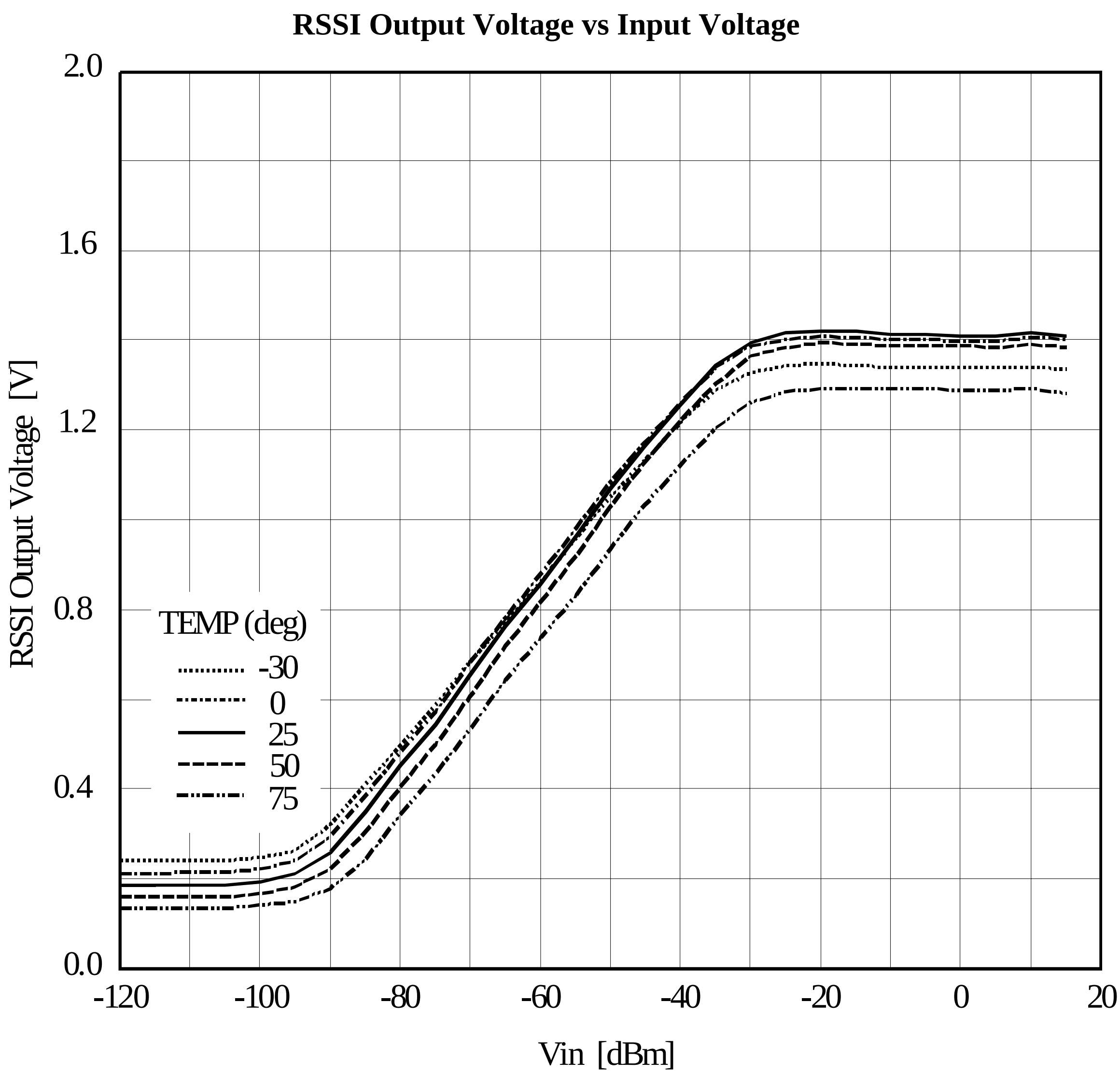


C = 100 pF 20 μ sec/div

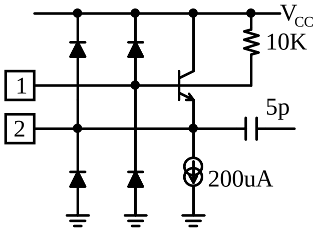
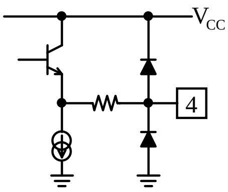
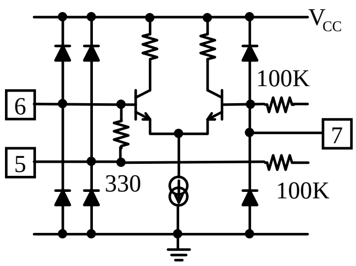
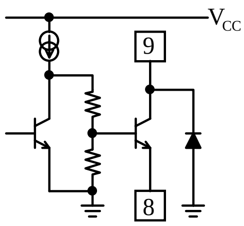
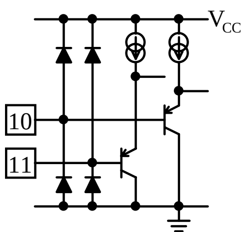
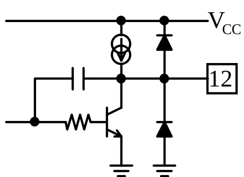


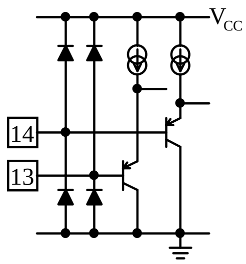
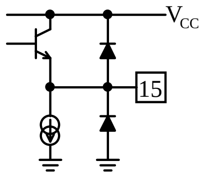
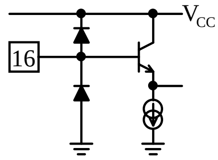
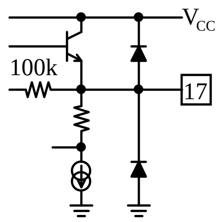
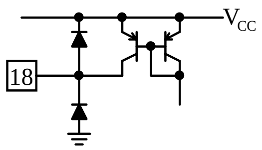
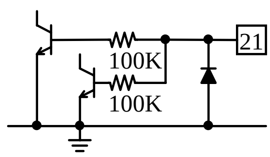
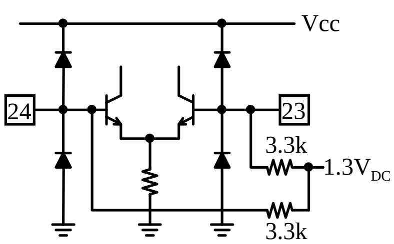

Icc , Vout , T.H.D. vs Temperature
200
160
120
80
40
0
10
8
6
4
2
0
-40
-20
0
20
40
60
80
Icc
Vout
T.H.D.
Vout [mVrms]
T.H.D. [%] , Icc [mA]
Temperature [deg]


S/N , -3dB Limiting Sensitivity ,
12dB SINAD vs Temperature
80
70
60
50
40
30
-50
-60
-70
-80
-90
-100
-40
-20
0
20
40
60
80
S/N
12dB SINAD
-3dB Limiting Sensitivity
S/N [dB]
-3dB Limit. Sens. , 12dB SINAD [dBm]
Temperature [deg]


RSSI Output Voltage vs Input Voltage
2.0
1.6
1.2
0.8
0.4
0.0
-120
-100
-80
-60
-40
-20
0
20
TEMP (deg)
-30
0
25
50
75
RSSI Output Voltage [V]
Vin [dBm]

10. PIN DESCRIPTION

Pin No.	Symbol	Voltage	Internal Equivalent Circuit	Description
1 2	OSC (B) OSC (E)	2.98V 2.2V		Corpitze Type Oscillator
3	MIXER VCC	3.0V		Supply Voltage (Mixer)
4	MIXER OUT	1.4V		Mixer Output
5 6 7	DECOUPLE IF IN DECOUPLE	2.0V 2.0V 2.0V		5,7 : Limiting Amplifier Decoupling 6 : Limiting Amplifier Input
8 9	COMP GND COMP OUT	0V		8 : Data Comparator GND 9 : Data Comparator Output
10 11	COMP IN COMP IN			10,11 : Data Comparator Input
12	OP AMP OUT			OP Amplifier Output

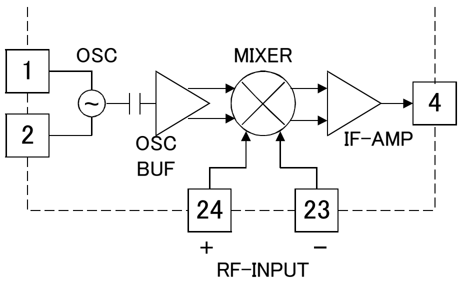
13 14	OP AMP IN OP AMP IN			13,14 : OP Amplifier Input
15	DET OUT	1.1V		Detector Output
16	DET IN	3V		Detector Input
17	IF OUT	2.0V		IF Limiter Output
18	RSSI			RSSI Output
19	IF GND	0V		GND (IF)
20	IF Vcc	3V		Supply Voltage (IF)
21	POWER SAVE	Vs		Vs = 1.5V～Vcc : Power Save Off Vs＜0.3V : Power Save On
22	MIXER GND	0V		GND (Mixer)
23 24	MIXER IN MIXER IN	1.3V 1.3V		Mixer Input

11. APPLICATIONS INFORMATION

1)Mixer, Oscillator

Mixer is composed by Gilbert multiplier and oscillator, oscillator buffer amplifier, IF amplifier.
And it is high transfer gain (26dB) and wide dynamic range.
Mixer circuit and IF stage are independent completely.
Pin 3 is an independent supply voltage terminal of mixer. In case Pin 3 is not terminated power supply voltage, mixer doesn't operate, and current consumption of mixer is zero.

Figure-1 internal equivalent circuit of Mixer

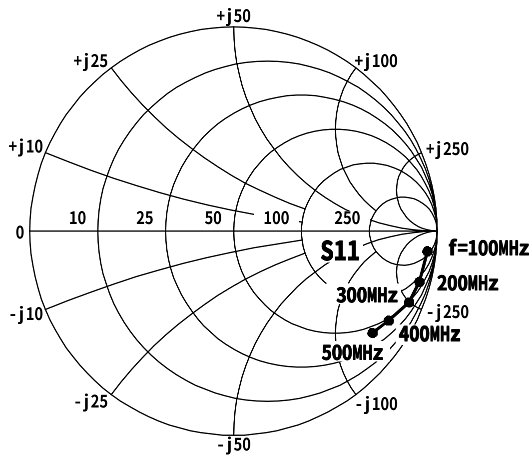


As RF input is the balance input, it is easy to match the SAW filter etc.
The oscillator output signal leaks to RF input terminal scarcely, because it is inputted to buffer amplifier and afterwards it becomes balance output and it is injected to multiplier.
In case RF input is the balance input, a leakage to RF input terminal from oscillator can be reduced furthermore because it is cancelled at RF input section.
In case RF input is the imbalance input, earth some of Pin 23 and 24 in a condenser.

Figure-2 Mixer input S11 vs frequency

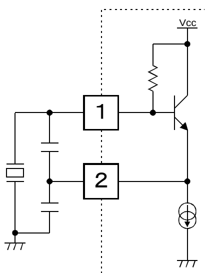
Frequency [MHz]	S11 |S11|	S11 ∠Φ	Zin [Ω]
100	0.955	-7.7	229-j665
200	0.946	-15.0	78.1-j364
250	0.929	-18.6	67.5-j290
300	0.923	-22.1	54.8-j244
315	0.910	-23.4	54.0-j229
400	0.879	-29.2	48.7-j180
500	0.845	-35.7	41.4-j145

※ cancelled the stray capacity of test board.

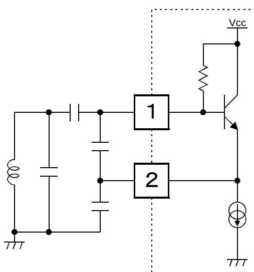


Oscillator can be composed the general corpitze type oscillator that is collector earthing. The operating current of oscillator is 200uA.
As the oscillator output signal is injected to the multiplier through the buffer amplifier, mixer is difficult to be have an effect on the fluctuation of oscillating level.
In case the level of Pin 1 is higher than –20dBm, the transfer gain of mixer is stable, but it is better that the level of Pin 1 is higher than –15dBm in consideration of the dispersion etc.
Follow explains about some use examples.

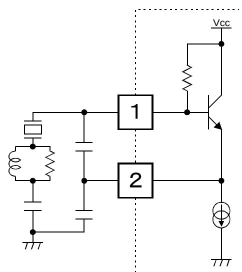
Figure-3 ex. constitution of oscillator



Crystal Resonator Oscillation



LC Oscillation

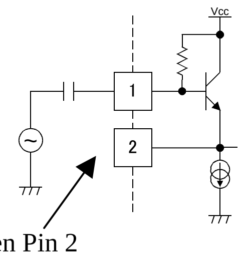


SAW Resonator Oscillation

External Injection

In case no use internal oscillator and use external oscillator, inject the oscillating signal to Pin 1 by condenser connection, and Pin 2 must be opened.
In this case, oscillator that sees the side of multiplier is operated as emitter-follower.

Figure-4 ex. External Injection



Overtone Oscillation

In case that operate overtone oscillation above 30MHz by using crystal resonator, to restrict the fundamental mode, construct the circuit as figure-5.
In case operating frequency is higher, it is feared that Gm of oscillator is insufficient and the oscillating intensity is down. In this case, it is possible to improve by connecting with an external resistor between Pin 2 and GND to increase the operating current.

ex. Overtone Oscillation

Figure-5

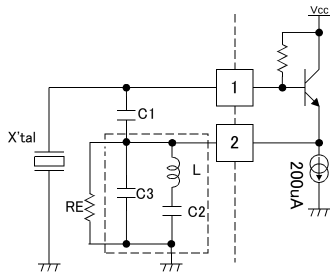
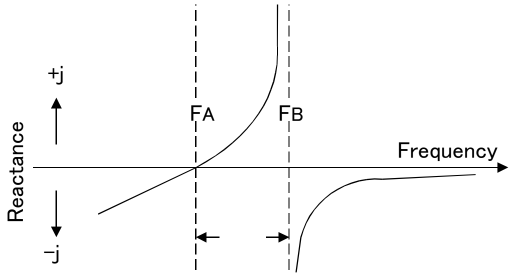


Figure-6



The constant of circuit in a dotted line of figure-5 is established that the condition of oscillation is met the 3rd overtone frequency only.
Figure-6 shows the characteristics of two terminals impedance versus frequency of this circuit. The condition of oscillation is the capacitive at overtone frequency and the inductive at near fundamental frequency.
Therefore, in case it is established that the fundamental frequency is included between FA and FB and that overtone frequency is above FB, the condition of oscillation is met.
Follow shows the calculation of 3 times overtone.

As $F(osc) > F_A$、 $3 \times F(osc) > F_B$ $\qquad FA = \frac{1}{2\pi\sqrt{LC2}}$ $\qquad FB = FA\sqrt{1+\frac{C2}{C3}}$

F(osc) is the fundamental frequency of crystal resonator. 3× F(osc) is the 3rd overtone frequency of crystal resonator.

And it is established that the series value of the equivalent capacitance of circuit in a dotted line of figure-5 and capacitance of C1 is the load capacitance of crystal resonator.
In case the operating current of oscillator is insufficient, increase Gm of oscillator by an external resistor RE.
In this case, the increased operating current (Ie) of oscillator is calculated by follows.

$$Ie(mA) = \frac{Vcc(V) - 0.7}{RE(K\Omega)}$$

SAW Resonator

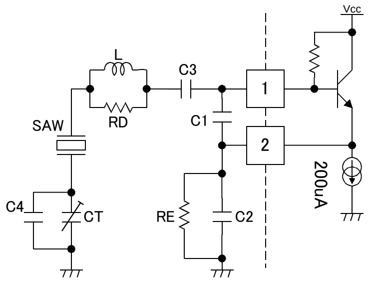
In case using SAW resonator, the many circuits are adjustable because the accuracy of oscillation frequency is bad in comparison with crystal resonator. Figure-7 shows the example of circuit.

A coil in series with a resonator is used the characteristics that self-resonance frequency is high and Q is high.

And a resistor in parallel with a coil is connected to reduce the peak level of self-resonance point. As this resistance is the lower, the oscillation is the more stable but the more difficult to oscillate, select a proper resistor.

Figure-7 ex. SAW resonator application

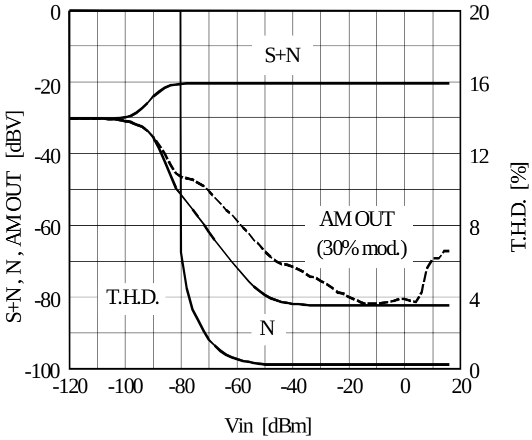
Vcc = 3.0V
Oscillating Frequency = 433MHz



component	constant	
C 1	4pF	
C 2	4pF	
C 3	1000pF	
C 4	5pF	
C T	10pFmax	
L	27nH	LL1608-FH27NJ (TOKO)
R E	3.3KΩ	Vcc=3.0V
R D	5KΩ	

Note) In case change the power supply voltage, change the value of RE as the operating current is same it in the case of Vcc = 3.0V.

Follow shows the characteristics of FM demodulation in this case of SAW oscillation.



Detector output vs Mixer input level

fin = 444.04MHz
fosc = 433.34MHz

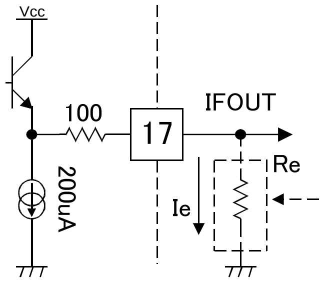
2) IF Limiter Amplifier , RSSI

The IF limiter amplifier is composed of five differential gain stage. The total gain of IF limiter amplifier is 80dB. The output signal of IF limiter amplifier is output at Pin 10 through emitter-follower output stage. IF limiter amplifier output level is $0.5V_{P\text{-}P}$.

The operating current of emitter-follower of IF limiter amplifier output is 200uA. In case that the capacitive load is heavy, it is feared that the negative half cycle of output waveform is distorted. In this case, it is possible to improve by connecting with an external resistor between Pin 17 and GND to increase the operating current. The increased operating current by an external resistor is calculated as follows (see Figure-8).

The increased operating current Ie(mA)＝(Vcc－1.0)／Re(kΩ)

Figure-8



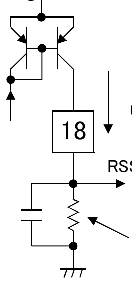
RSSI output is the current output. It is converted the voltage by an external resistor between Pin 18 and GND. The time constant of RSSI output is determined by the product of an external converting resistance and parallel capacitance. The time constant is longer, RSSI output is harder to be influence by the disturbance or the ingredient of amplitude modulation, but RSSI output response is slower. Determine the external resistance and capacitance with the purpose.

It is possible to change the inclination of RSSI curve characteristic by changing an external resistance. In this case, the maximum range of converted RSSI output voltage is GND level to about Vcc-0.2V (the supply voltage minus the collector saturation voltage of output transistor).

Moreover, it is possible to change the temperature characteristic of RSSI output voltage by changing the temperature characteristic of external resistor. Normally, the temperature characteristic of RSSI output voltage is very stable by using the carbon resistor or metal film resistor that temperature characteristic is 0～200ppm/℃.

This product is very accurate, because RSSI characteristic is trimmed individually.

Figure-9 RSSI output stage



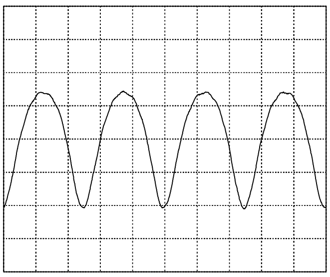
AM demodulation by using the RSSI output

Although the distortion of RSSI output is bad because it is logarithmic detection of envelope to IF input, it is possible to demodulate AM simply by using the RSSI output. In this case, the input dynamic range that can demodulate AM is the inside of linear of RSSI curve characteristic.

This method doesn’t have a feedback loop to control the gain, because it is no necessary AGC amplifier like the popular AM demodulation. Therefore, it is very useful application for some uses, because it doesn’t have the response time problem basically.

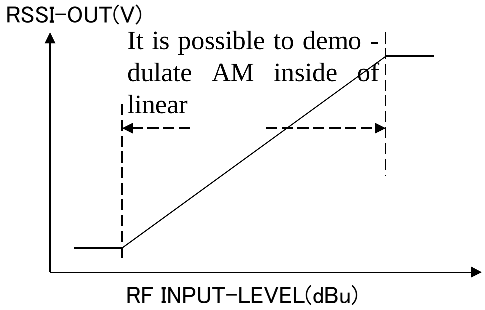
Figure-10 shows the AM demodulated waveform.

Figure-10 AM demodulated waveform



Operating Condition
Vcc=3V、fin=250MHz ,
fm=40kHz ,
Mod=±80% ,
Vin=-50dBm
fosc=239.3MHz ,
Vosc=-10dBm

100mV/div
10usec/div



3) FM Detector

It is included the quadrature FM detector used Gilbert multiplier.

It is suitable for high speed data communication because it is the wide band that the demodulation bandwidth is over 100kHz.

Between Pin 17 (IF limiter output) and Pin 16 (detector input) is connected with the phase shifter, any phase shifter available. It is possible to use of the LC resonance circuit, the ceramic discriminator, the delay line and etc.

Figure-11 shows the internal equivalent circuit of the detector.

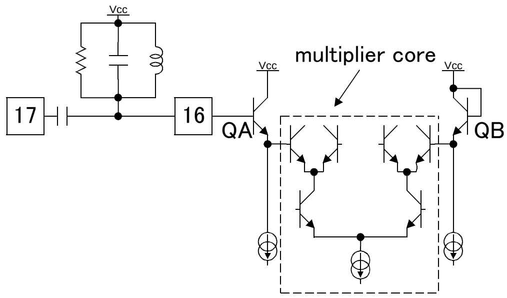
The signal from the phase shifter is put in the multiplier in a dotted line through emitter-follower stage QA. The notice to use is Pin 16 have to be impress the bias voltage from external source, because Pin 16 is connected with the base of QA only.

As the base of QB of the opposite side is connected with the supply voltage, Pin 16 has to be biased the equivalent voltage.

In case of using LC resonance circuit, it is not problem see figure-12, but in case of using ceramic discriminator, it is necessary to notice.

If it is a difference of the base voltages, the DC voltages of the multiplier doesn't balance, it is occurred the alteration of DC zero point or the growing worse of the distortion of demodulation output.

Figure-11

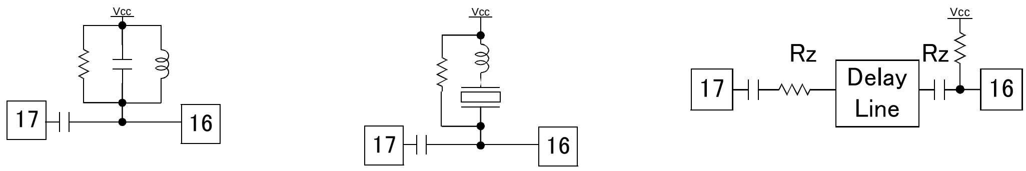


It is ideal that Pin 16 input level is saturated at the multiplier, if this level is lower, it is easy to disperse the modulation output. Therefore, to be stable operation, it is ideal that Pin 16 input level is higher than 100mV$_{P\text{-}P}$.

The following figure shows the examples of phase shifter.

Figure-12 the examples of phase shifter

Rz is a characteristic impedance



LC resonance circuit ceramic discriminator delay line

4) OP Amplifier , Comparator

This product contains a general high speed op amplifier and data comparator for the base band processing.

As the input stage of each circuits is composed of PNP transistor, it is possible to operate the minimum voltage 0.2V to the supply voltage minus 0.9V (see figure-13).

Moreover, as the HFE of this PNP transistor is over 100, the bias current is below 0.01uA that below 10% of the general products used lateral PNP transistor at input stage.

Figure-14 shows op amplifier output stage.

The maximum of output current is shows. The maximum output amplitude is between Vcc-0.2V and 0.2V.

Figure-13 input stage

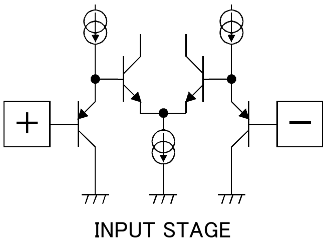


Figure-14 OP amplifier output stage

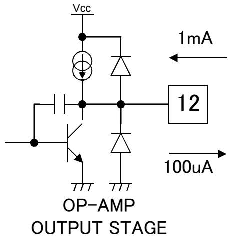


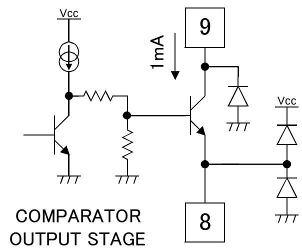
Figure-15 the internal equivalent circuit of comparator output stage. As comparator output is an open collector, it is suitable for the many interface level. This open collector output is connected with an electrostatic discharge protection diode at GND side only, but not connected with it at a power supply side in consideration of operating the voltage over the supply voltage of this IC.

In case that the collector pull up resistor is small, in consideration of operating of high current, the emitter of output transistor is output at Pin 8 independently in order to protect the interference to other circuit.

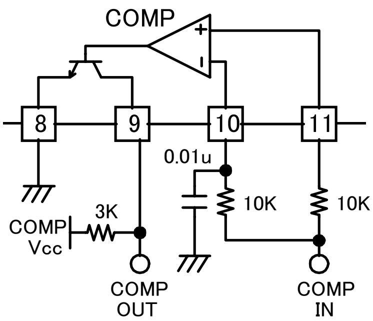
Pin 8 is not connected with the substrate and other GND of internal IC. Therefore, in case of operating comparator, this terminal must be connect to GND.

In case that make the comparator operate high speed, don’t be close the pattern of Pin 8 and 9 (comparator output stage) to the pattern of Pin 6 (IF input). In case that these pattern is close each other, it is feared that the switching waveform of comparator output has an effect on IF input and that it add the noise of the cross over distortion to the near zero cross of demodulated waveform.

Figure-15 comparator output stage



Please the reference terminal of comparator input is used the side of minus terminal (Pin 10) certainly. In case the reference terminal is used the side of plus terminal (Pin 11), it is feared that the comparator output oscillates.



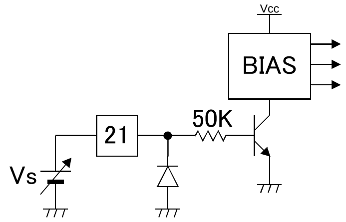
5) Power Save Function

Pin 21 is the control terminal for power save (battery save) function. It is possible to switch ON/OFF the operation of whole IC by controlling of DC voltage at this terminal. Figure-16 shows the internal equivalent circuit of near Pin 21.

As it switch the bias circuit of whole IC by the transistor, in case of shutting down mode, it is possible to cut the supply current down to zero. As an input terminal is connected with an electrostatic discharge protection diode at GND side only, it is possible to control the voltage over supply voltage. It is possible to shut down by disconnecting Pin 21, but it is not recommended, because Pin 21 is the high impedance and it is feared to malfunction by the disturbance.

In case of using Pin 21 is disconnected, it is ideal to connect with a suitable capacitor between Pin 21 and GND.

Figure-16



6) The attention of pattern layout

This product is considered to operate stably as mixer circuit and IF stage are independent completely.
But this product must be pay attention to follow (①～③) to operate stably because operating frequency is high.
And the standard application board of this product is shown to page 20.

① Mixer Vcc terminal and IF Vcc terminal is earthed in the shortest distance to each GND terminal by the condenser individually.

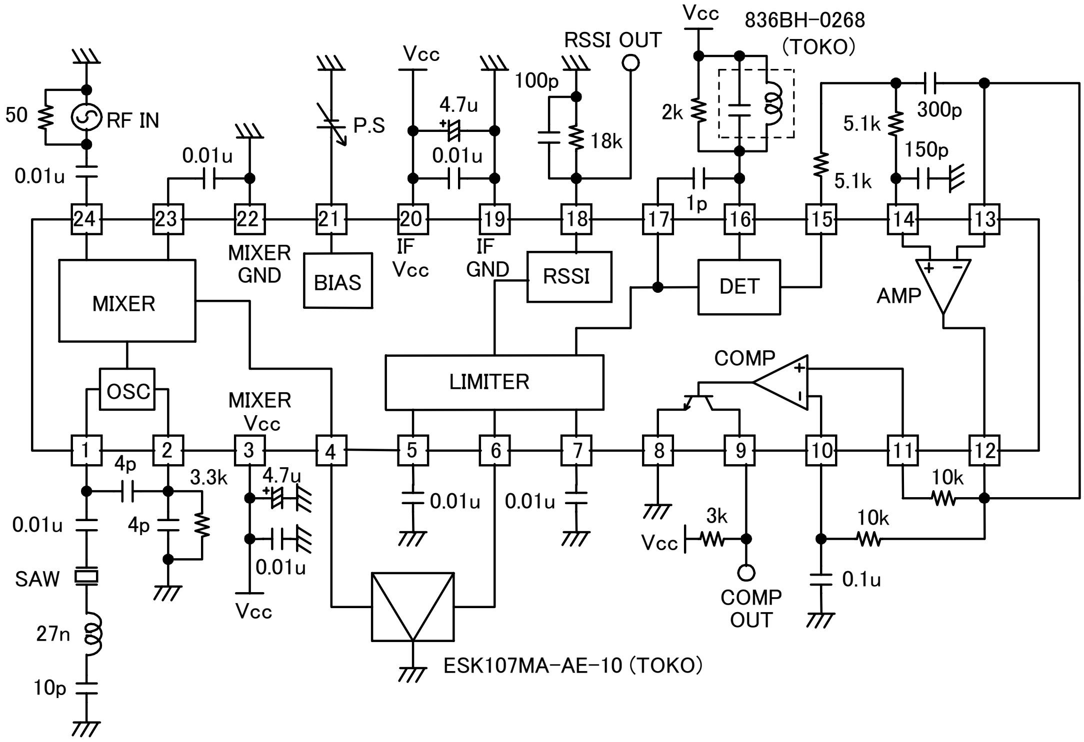
Mixer Vcc Terminal（Pin 3） → Mixer GND Terminal（Pin 22）
IF Vcc Terminal （Pin 20） → IF GND Terminal（Pin 19）

② The pattern of phase shifter of demodulator is shortest distance.

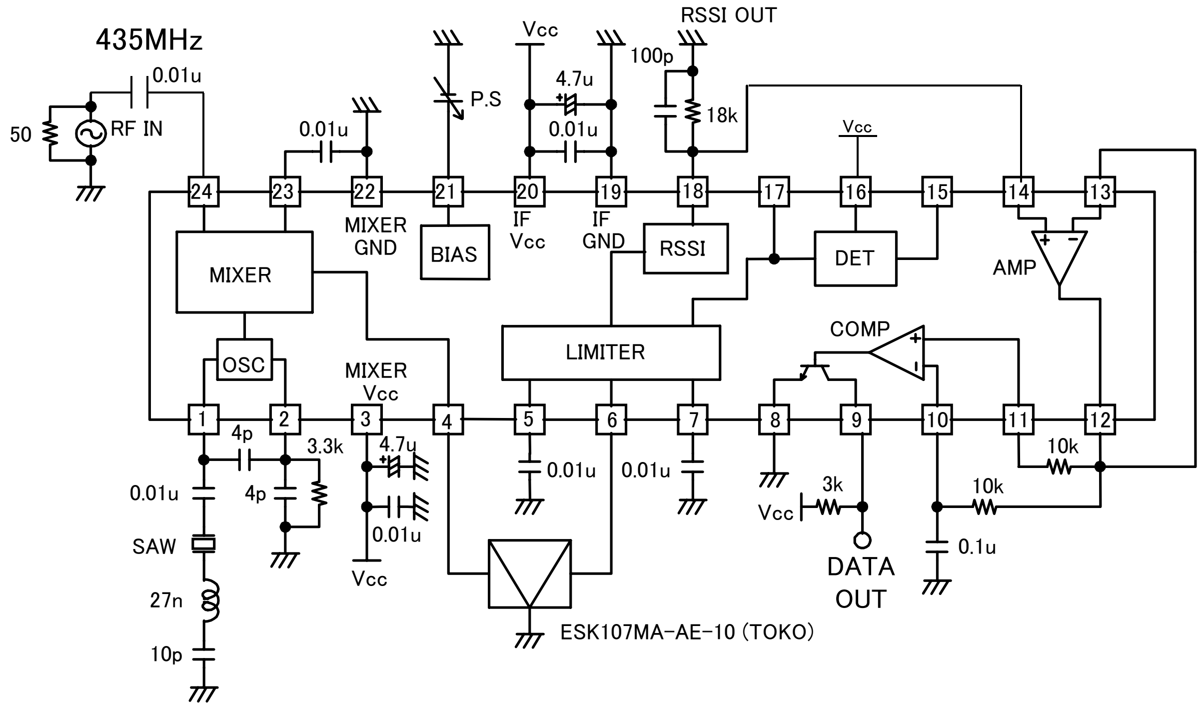
③ In case the signal is returned to mixer from demodulator, the stability is worst. It is ideal that these peripheral components are provided with different side of both side board and that reverse side is GND pattern.

12. APPLICATIONS CIRCUIT

ex. 430MHz band FM demodulation

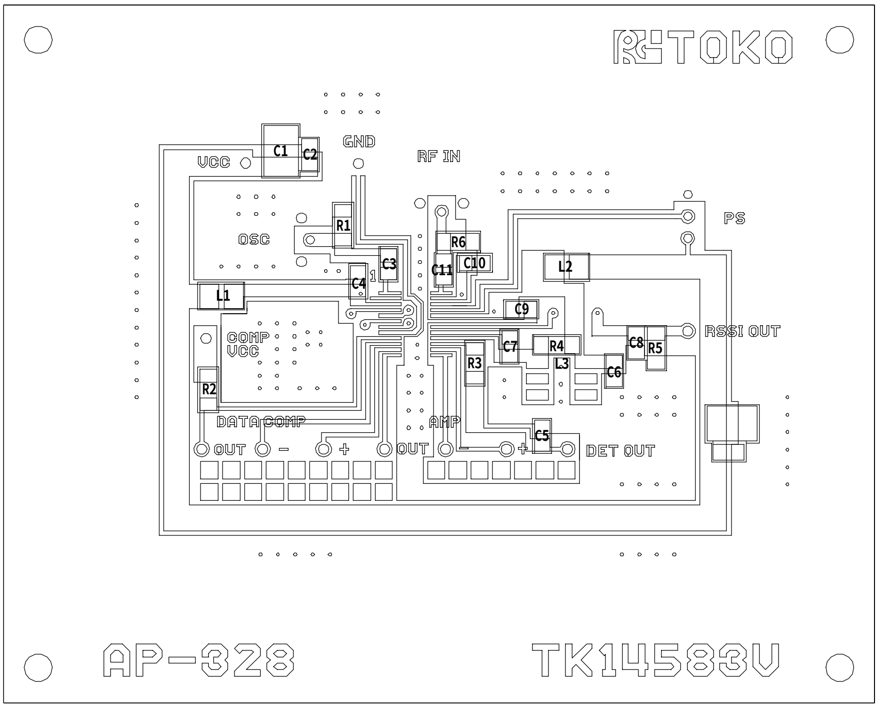


ex. 430MHz band AM demodulation

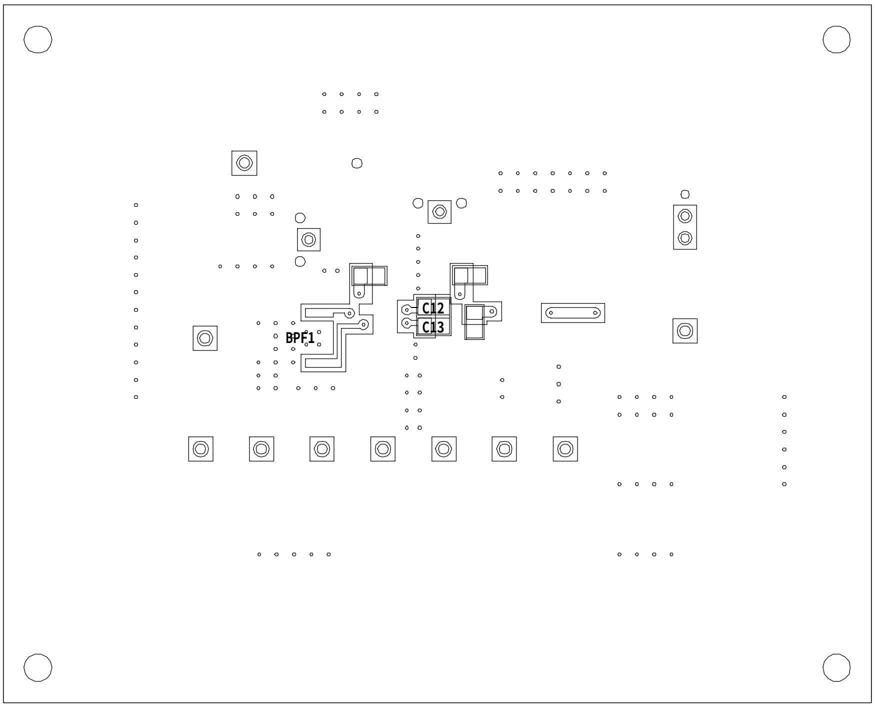


13. TEST BOARD

(THE SURFACE)



(THE REVERSE)



C2=C3=C4=C6=C8=C9=C10=C11=C12=C13=0.01uF , C1=4.7uF , C5=100pF , C7=1pF ,
R1=R6=51Ω , R2=3kΩ , R3=100 , R4=2kΩ , R5=18kΩ , L1=L2=10uH ,
L3=836BH-0268 (TOKO) , BPF=ESK107MA-AE-10(TOKO)

14. NOTES

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