RF Power Detector/Controller

FEATURES

- Complete RF Detector/Controller Functionality
- 0.9GHz: Dynamic Range >50 dB: -47.1dBm ~+4.1dBm @50Ω
- Operating Frequency: 0.1GHz ~ 2.5GHz, Capable of Precise Control
- At 0.9GHz, Log Slope: 23.9mV/dB, Log Intercept: -58.3dBm
- Low Power Consumption: 22.7mW(2.8V); 53.5mW(5V)
- Shutdown Power Consumption: 10.1μW(2.8V); 62.0μW(5V)

APPLICATIONS

- Power Control for Single-band, Dual-band and Triple-band Mobile Phone (GSM, DCS, EDGE) Transmitters

PRODUCT DESCRIPTION

The MS2352 is a low-cost chip for precise control of RF power amplifiers, operating over a frequency range of 0.1GHz to 2.5GHz with a dynamic range exceeding 50dB.

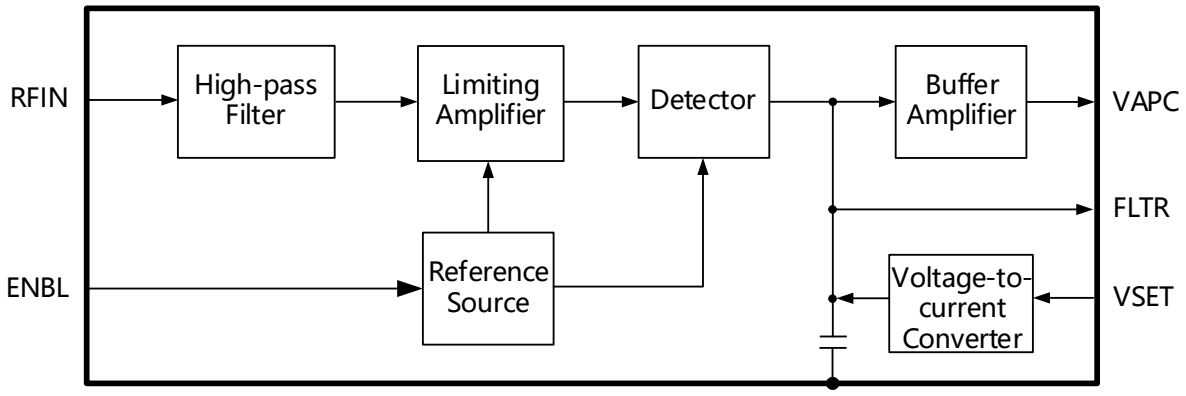
The VSET pin of the MS2352 can accept a set control voltage with an operating voltage range of 0.23V to 1.41V. To further simplify the application of the MS2352, the input resistance of the VSET pin is greater than 1MΩ.

The MS2352 uses internal AC coupling and provides an output voltage VAPC that can be directly connected to the gain control pin of most mobile phone power amplifiers. This output has a wide operating voltage range from 160mV to (V_{POS}-0.3)V and can support load currents up to 6mA.

ORDERING GUIDE

Part Number	Package	Marking
MS2352M	MSOP8	MS2352M

BLOCK DIAGRAM



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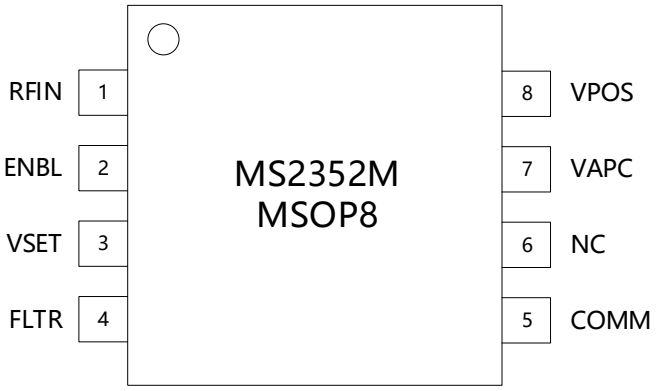
PIN CONFIGURATION



Pin	Name	Type	Description
1	RFIN	I	RF Input
2	ENBL	I	Connect to Supply for Normal Operation; Ground to Shut Down the Chip
3	VSET	I	Input Set Control Voltage
4	FLTR	I/O	Connect a Filter Capacitor between FLTR and Ground
5	COMM	-	Reference Ground
6	NC	-	No Connection
7	VAPC	O	Output, Control Voltage for Gain Control Element
8	VPOS	-	Power Supply

Note: Unused input pins should be left floating.

ABSOLUTE MAXIMUM RATINGS

Any exceeding absolute maximum rating application causes permanent damage to device. Because long-time absolute operation state affects device reliability. Absolute ratings just conclude from a series of extreme tests. It doesn't represent chip can operate normally in these extreme conditions.

Parameter	Symbol	Range	Unit
Supply Voltage	V_{POS}	5.5	V
Output Voltage	V_{APC}	0 ~ V_{POS}	V
Input Control Voltage	V_{SET}		
Enable Voltage	V_{ENBL}		
RF Input Power	P_{RFIN}	17	dBm
Equivalent RF Input Voltage	V_{RFIN}	1.6	Vrms
Maximum Power Dissipation	P_D	60	mW
Storage Temperature	T_{STG}	-65 ~ +150	°C
Soldering Temperature (10s)	T_{SOLDER}	260	°C

ESD CAUTION

Static electricity can be generated in many places. The following precautions can be taken to effectively prevent the damage caused by electrostatic discharge:

1. The operator shall ground through the anti-static wristband.
2. The equipment shell must be grounded.
3. The tools used in the assembly process must be grounded.
4. Must use conductor packaging or anti-static materials packaging or transportation.

RECOMMENDED OPERATING CONDITIONS

Parameter	Symbol	Min	Typ	Max	Unit
Supply Voltage	V_{POS}	2.8	5	5.5	V
Operating Temperature	T_A	-30	25	85	°C

ELECTRICAL CHARACTERISTICS(2.8V)

Unless otherwise noted, V_{POS}=2.8V, T_A=25°C, Resistance at RFIN Pin: 52.3Ω.

Parameter	Condition	Min	Typ	Max	Unit
Overall Characteristics					
Operating Frequency	Meet All Specifications	0.1		2.5	GHz
Linearity Error	f=0.1GHz, 0.9GHz, 1.9GHz		±1		dB
	f=2.5GHz		±3		
Input Voltage	for ±1dB Error at 0.1GHz	-58.6		-9.2	dBV
Equivalent Input Power		-45.6		+3.8	dBm
Log Slope	0.1GHz		23.4		mV/dB
Log Intercept	0.1GHz		-71.8		dBV
Equivalent Log Intercept			-58.8		dBm
RF Input Pin RFIN					
Input Resistance	0.1GHz		2.7		kΩ
Input Capacitance	0.1GHz		1.5		pF
Output Pin VAPC					
Minimum Output Voltage	ENBL=H, V_{SET}≤200mV		0.16		V
	ENBL=H, V_{SET}=0, No Input at RFIN		0.06		V
	ENBL=L		2.2		μV
Maximum Output Voltage	R_L≥800Ω		2.5		V
Output Voltage Variation with Temperature	85℃,V_{POS}=3V, I_{OUT}=6mA		2.43		V
Limit Voltage	2.8V≤V_{POS}≤5.5V, R_L=∞		2.57		V
Output Current Drive	Current Source/Current Sink		6/300		mA/μA
Output Buffer Noise			19.4		nV/√Hz
Output Noise	RF Input 2GHz, 0dBm, f_{NOISE}=100kHz, C_{FLT}=220pF		82.7		nV/√Hz
Small Signal Bandwidth	0.2V-2.6V Swing		11.3		MHz
Slew Rate	10%-90%, 1.2V Step (V_{SET}), Open-loop		9.2		V/μs
Response Time	FLTR=open		100		ns

Parameter	Condition	Min	Typ	Max	Unit
Set Input Voltage Pin VSET					
Input Voltage	Corresponding to Center 50dB	0.23		1.41	V
Log Slope Increase			42.7		dB/V
Input Resistance			1		MΩ
Enable Pin ENBL					
Enable Threshold High		1.6		V_{POS}	V
Input Current when Enable High			16.7		μA
Enable Threshold Low				0.8	V
Enable Turn-on Time	Time from ENBL H to V_{APC} within 1% of Final Value, V_{SET}≤200mV, See Figure1		3.9		μs
Enable Turn-off Time	Time from ENBL L to V_{APC} within 1% of Final Value, V_{SET}≤200mV, See Figure1		14.6		μs
Power-on Time	Time from VPOS H to V_{APC} within 1% of Final Value, V_{SET}≤200mV, See Figure 2		3.7		μs
Power-off Time	Time from VPOS L to V_{APC} within 1% of Final Value, V_{SET}≤200mV, See Figure 2		450		ns
Supply Pin VPOS					
Supply Voltage		2.8		5.5	V
Quiescent Current	ENBL=H		8.1		mA
	ENBL=H, -30℃<T_A<+85℃		9.2		mA
Shutdown Current	ENBL=L		2.7		μA
	ENBL=L, -30℃<T_A<+85℃		6		μA

Table 1. Typical Characteristics at a Given Frequency at 25℃ (Mean and Variance)

	Log Slope (mV/dB)		Log Intercept (dBV)		±1dB Dynamic Range			
					Output Error Low Point (dBV)		Output Error High Point (dBV)	
Frequency (GHz)	Mean	Variance	Mean	Variance	Mean	Variance	Mean	Variance
0.1	23.6	0.2	-70.2	0.4	-58.6	0.2	-9.2	0.2
0.9	23.9	0.2	-70.2	0.4	-58.0	0.9	-9.0	0.2
1.9	23.9	0.1	-71.9	0.3	-61.0	0.6	-10.8	0.2
2.5	23.9	0.2	-71.7	0.5	-60.6	0.9	-10.5	0.1

ELECTRICAL CHARACTERISTICS(5V)

Unless otherwise noted, V_{POS}=5.0V, T_A=25°C, Resistance at RFIN pin: 52.3Ω.

Parameter	Condition	Min	Typ	Max	Unit
Overall Characteristics					
Operating Frequency	Meet All Specifications	0.1		2.5	GHz
Linearity Error	f=0.1GHz,0.9GHz,1.9GHz		±1		dB
	f=2.5GHz		±3		
Input Voltage	for ±1dB Error at 0.1GHz	-58.2		-9.4	dBV
Equivalent Input Power		-45.2		+3.6	dBm
Log Slope	0.1GHz		23.5		mV/dB
Log Intercept	0.1GHz		-71.4		dBV
Equivalent Log Intercept			-58.4		dBm
RF Input Pin RFIN					
Input Resistance	0.1GHz		2.7		kΩ
Input Capacitance	0.1GHz		1.5		pF
Output Pin VAPC					
Minimum Output Voltage	ENBL=H, V_{SET}≤200mV		0.16		V
	ENBL=H, V_{SET}=0, No Input at RFIN		0.06		V
	ENBL=L		2.3		μV
Maximum Output Voltage	R_L≥800Ω		4.8		V
Output Voltage Variation with Temperature	85℃, V_{POS}=3V, I_{OUT}=6mA		2.43		V
Limit Voltage	2.8V≤V_{POS}≤5.5V, R_L=∞		2.57		V
Output Current Drive	Current Source/Current Sink		6/300		mA/μA
Output Buffer Noise			21.0		nV/√Hz
Output Noise	RF Input 2GHz, 0dBm, f_{NOISE}=100kHz, C_{FLT}=220pF		85		nV/√Hz
Small Signal Bandwidth	0.2V-2.6V Swing 10%-90%, 1.2V Step (V_{SET}), Open-loop FLTR=open		12		MHz
Slew Rate			9.7		V/μs
Response Time			228		ns

Parameter	Condition	Min	Typ	Max	Unit
Set Input Voltage Pin VSET					
Input Voltage	Corresponding to Center 50dB	0.23		1.41	V
Log Slope Increase			42.5		dB/V
Input Resistance			1		MΩ
Enable Pin ENBL					
Enable Threshold High		1.6		V_{POS}	V
Input Current when Enable High			55		μA
Input Current when Enable High				0.8	V
Enable Turn-on Time	Time from ENBL H to V_{APC} within 1% of Final Value, V_{SET}≤200mV, See Figure 1		9.6		μs
Enable Turn-off Time	Time from ENBL L to V_{APC} within 1% of Final Value, V_{SET}≤200mV, See Figure 1		41		μs
Power-on Time	Time from VPOS H to V_{APC} within 1% of Final Value, V_{SET}≤200mV, See Figure 2		2.7		μs
Power-off Time	Time from VPOS L to V_{APC} within 1% of Final Value, V_{SET}≤200mV, See Figure 2		500		ns
Supply Pin VPOS					
Supply Voltage		2.8		5.5	V
Quiescent Current	ENBL=H		10.7		mA
	ENBL=H, -30℃~+85℃		12.7		mA
Shutdown Current	ENBL=L		12.4		μA
	ENBL=L, -30℃~+85℃		15.5		μA

Table 2. Typical Characteristics at a Given Frequency at 25℃ (Mean and Variance)

	Log Slope (mV/dB)		Log Intercept (dBV)		±1dB Dynamic Range			
					Output Error Low Point (dBV)		Output Error High Point (dBV)	
Frequency (GHz)	Mean	Variance	Mean	Variance	Mean	Variance	Mean	Variance
0.1	23.5	0.2	-71.4	0.5	-58.2	1.1	-9.4	0.2
0.9	23.8	0.1	-71.3	0.5	-60.1	0.7	-8.9	0.2
1.9	23.6	0.1	-73.2	0.5	-62.1	0.7	-10.5	0.1
2.5	23.6	0.1	-73.3	0.6	-61.5	1.0	-10.6	0.2

TEST CIRCUIT

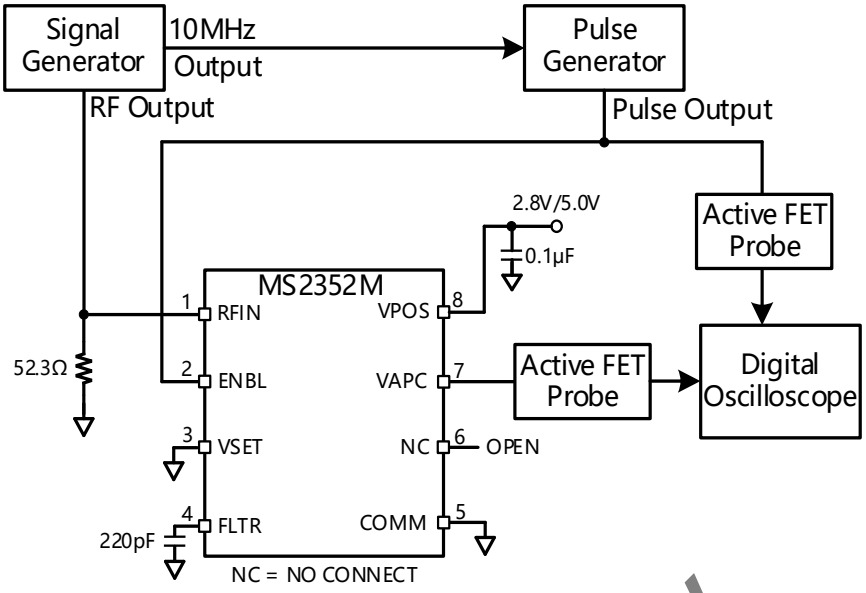


Figure 1. ENBL Response Time Test Diagram

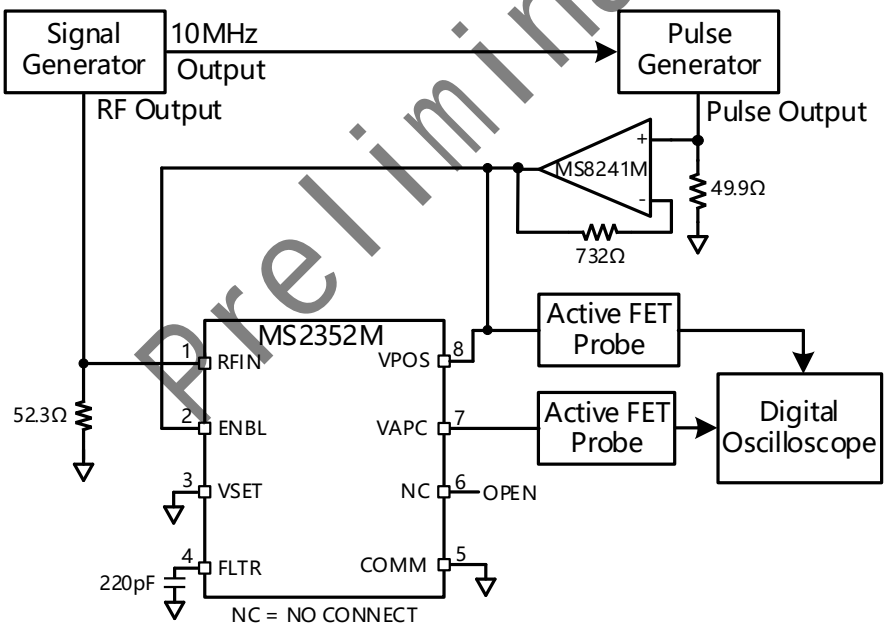


Figure 2. Chip Power-on and Power-off Response Time

TYPICAL PERFORMANCE CURVES

Unless otherwise noted, V_{POS}=5.0V.

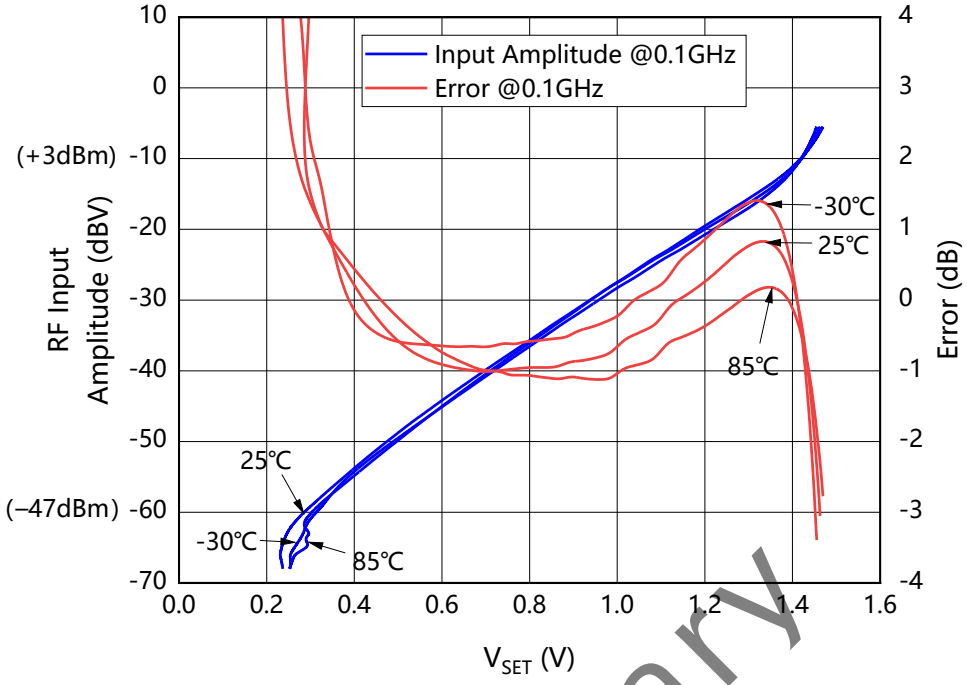


Figure 3. Input Amplitude and Error VS. V_{SET} (0.1GHz)

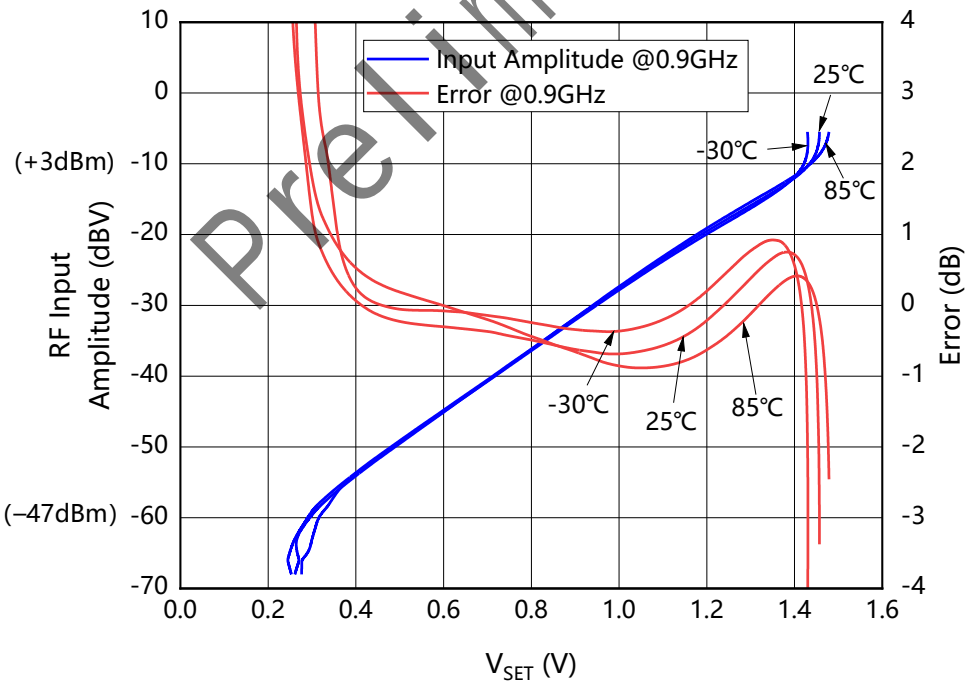


Figure 4. Input Amplitude and Error VS. V_{SET} (0.9GHz)

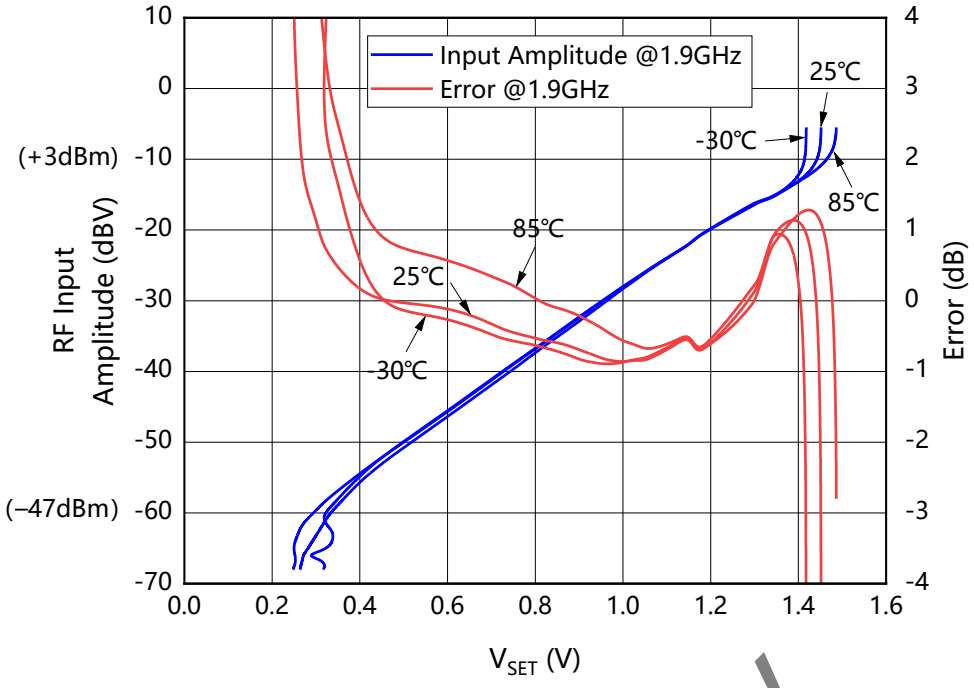


Figure 5. Input Amplitude and Error VS. V_{SET} (1.9GHz)

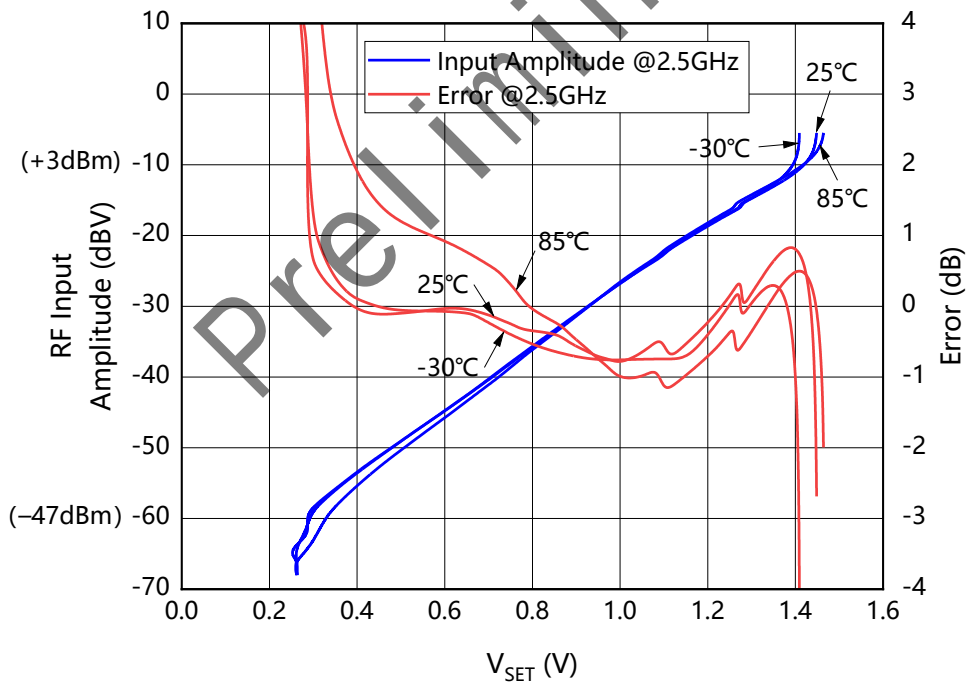


Figure 6. Input Amplitude and Error VS. V_{SET} (2.5GHz)

FUNCTIONAL DESCRIPTION

For ease of understanding and calculation, the logarithmic amplifier is often expressed as follows:

$$V_{OUT}=V_{SLP}\times\log_{10}\left(\frac{V_{IN}}{V_Z}\right) \quad (1)$$

V_{SLP} —— Log Slope

V_Z —— Voltage Intercept

V_{IN} —— Input Voltage

V_{OUT} —— Output Voltage

Converting input voltage to power, the above equation can be further rewritten as:

$$V_{OUT}=V_{DB}\times(P_{IN}-P_Z) \quad (2)$$

Where V_{DB} is the log slope (mV/dB), P_{IN} is the input power(@50Ω, dBm), P_Z is the log intercept (dBm). V_{DB} and P_Z are constants, the output voltage V_{OUT} is linearly related to the input signal power P_{IN}. This equation is also the basis for calculating the theoretical output.

In practice, the error is defined as the difference between the actual output and the theoretical output:

$$ERROR(dB)=\frac{V_{OUT}-V_{DB}\times(P_{IN}-P_Z)}{V_{DB}} \quad (3)$$

Over a wide dynamic range, the MS2352 has two key functions: power detection and control. The control function is shown in Figure 7. The overall loop in this figure is a negative feedback loop. When the voltage V_{SET} within the operating range is applied to the VSET pin (usually generated by an external DAC), through this negative feedback loop, the RF power amplifier PA finally outputs a corresponding voltage V_{PA}, bringing the entire loop into balance and satisfying Equation 4.

$$P_{PA}=\frac{1}{m^2}(k\times V_{SET}+P_Z) \quad (4)$$

In the above equation, k is the slope (dB/V), V_{SET} is the set input voltage (V), P_{PA} is the output power of the PA (@50Ω, dBm), P_Z is the log intercept (dBm), and m is the coupling coefficient. K, P_Z and m are all constants, and the PA output power P_{PA} is linearly related to the set input voltage V_{SET}.

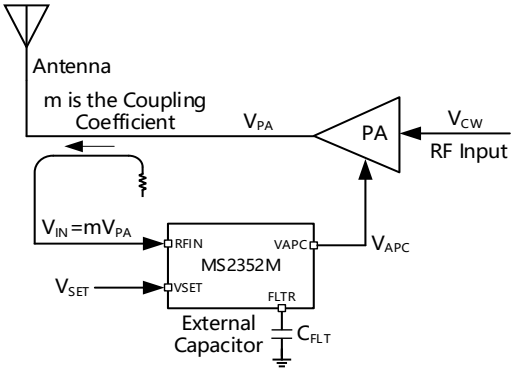


Figure 7. Control Function Loop Diagram

TYPICAL APPLICATIONS

CONTROLLER MODE

Figure 8 shows a typical application diagram for controller mode, including the basic connections of the MS2352 in controller mode. The supply voltage V_S in the diagram operates in the range of 2.8V~5.5V, and a 0.1μF decoupling capacitor should be connected next to the VPOS pin. In normal operation mode, the ENBL pin is connected to the supply voltage V_S; when ENBL is grounded, the chip shuts down. In the power control loop, the output power of the power amplifier PA is coupled to the RFIN pin via a directional coupler. Additionally, a 52.3Ω resistor to ground should be connected to this pin for broadband matching. The FLTR pin requires an external capacitor C_{FLT} to maintain loop stability, and typically C_{FLT} ranges from 150pF~300pF.

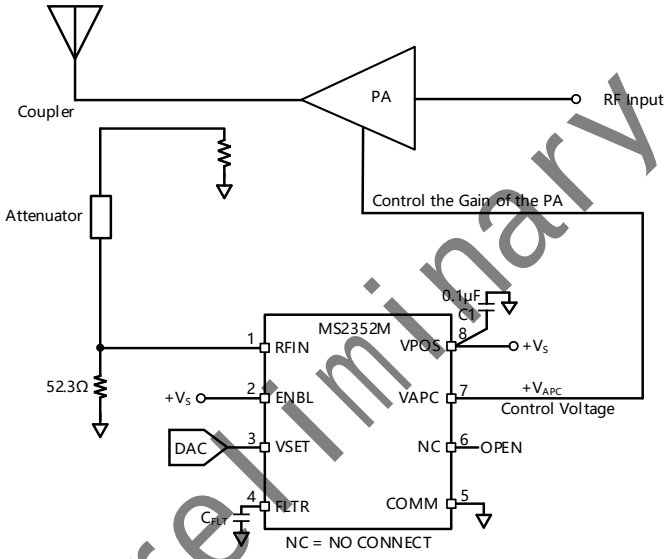


Figure 8. Typical Application Diagram for Controller Mode

The VSET pin requires an external DAC to set the input voltage V_{SET} for the MS2352. The VAPC pin connects to the gain control terminal of the PA to control the PA output power. When any imbalance occurs between the input level at the RFIN pin and the set voltage V_{SET}, the MS2352 output V_{APC} controls the PA output power to correct it. The V_{APC} voltage operating range is 160mV~(V_S-0.3)V, and it can support load currents up to 6mA. The RF input power at the RFIN pin is linearly related to the set input voltage V_{SET} (as shown in Figures 3, 4, 5, and 6). At an operating frequency of 0.9GHz, when V_{SET}=1V, the input signal power at the RFIN pin is -14dBm (@50Ω). Correspondingly, due to the attenuation of the directional coupler, the PA output power should be greater than -14dBm. Figures 3, 4, 5, and 6 show that the linear dynamic range of the MS2352 can reach 50dB. Corresponding to the 50dB dynamic range, the linear control range of the voltage V_{SET} is 0.23V~1.41V, with a corresponding line slope of 23.9mV/dB (approximately 41.8dB/V).

QUASI-MEASUREMENT MODE

Figure 9 shows the connection diagram for quasi-measurement mode. This mode consists of the MS2352 chip and an operational amplifier MS8091S, simulating the negative feedback loop of controller mode to establish the relationship between the input power P_{IN} at RFIN and the voltage V_{SET}. In this mode, the RF input power P_{IN} needs to be swept and the output voltage V_{SET} measured; this is the simplest method to verify the linear relationship between P_{IN} and V_{SET}. When operating in this mode, a filter capacitor C_{FLT} (0.01μF or larger) must be connected to the FLTR pin to ensure loop stability.

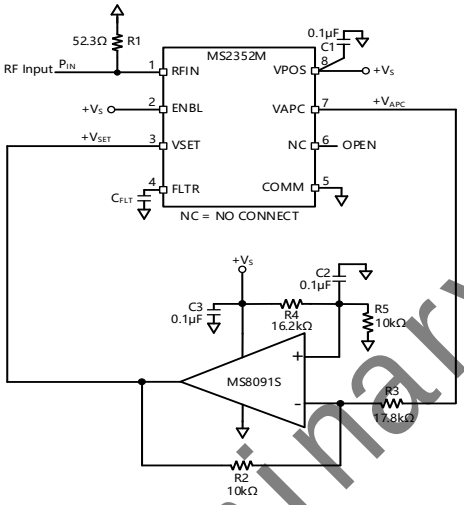


Figure 9. Connection Diagram for Quasi-Measurement Mode

INPUT COUPLING OPTIONS

The MS2352 has an internal input coupling capacitor and does not require an external AC coupling capacitor. Figure 10 shows the matching networks for broadband, narrowband, and attenuator applications. The component parameters in the figure can be matched using a Smith chart to determine optimal values based on actual requirements.

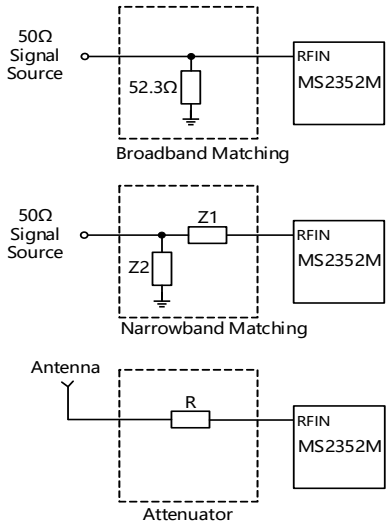
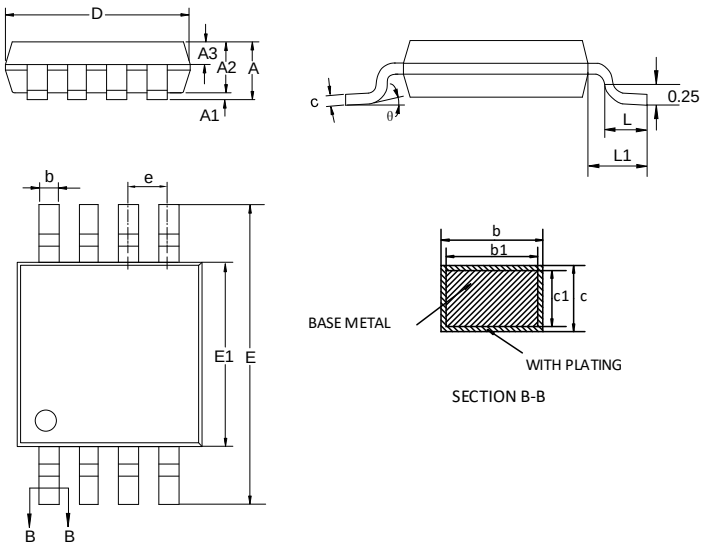


Figure 10. Input Matching and Connection Methods

PACKAGE OUTLINE DIMENSIONS

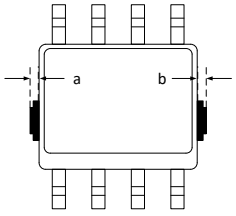
MSOP8



Symbol	Dimensions in Millimeters		
	Min	Typ	Max
A	-	-	1.10
A1	0.05	-	0.15
A2	0.75	0.85	0.95
A3	0.30	0.35	0.40
b	0.28	-	0.36
b1	0.27	0.30	0.33
c	0.15	-	0.19
c1	0.14	0.15	0.16
D	2.90	3.00	3.10
E	4.70	4.90	5.10
E1	2.90	3.00	3.10
e	0.65BSC		
L	0.40	-	0.70
L1	0.95REF		
θ	0°	-	8°

Note: In addition to the package size, a and b are allowed to have the maximum size of 0.15mm for waste glue simultaneously.

The diagram is as follows: taking SOP8 package as an example.



MARKING and PACKAGING SPECIFICATION

1. Marking Drawing Description

Product Name: MS2352M

Product Code: XXXXXXX

2. Marking Drawing Demand

Laser printing, contents in the middle, font type Arial.

3. Packaging Specification

Device	Package	Piece/Reel	Reel/Box	Piece/Box	Box/Carton	Piece/Carton
MS2352M	MSOP8	3000	1	3000	8	24000

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+86-571-89966911

Rm701, No.9 Building,
High-Tech Software
Zone, No. 1 WeiYe Road,
Puyan Street, Binjiang
District, Hangzhou

http:// www.relmon.com