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Preliminary Application Note

Usage and Applications of μPC8172TB/μPC8187TB 2.5 GHz Silicon Frequency Up-Converter IC for Mobile Communication

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The mark ★ shows major revised points.

CONTENTS

Precautions for design-ins

(1) Observe precautions for handling because of electro-static sensitive devices.

(2) Form a ground pattern as widely as possible to minimize ground impedance. All the ground pins must be connected as shortly as possible to decrease impedance difference (to prevent malfunction or undesired oscillation).

(3) The bypass capacitor should be attached to the V_{CC} pin.

(4) The RF output pin connects parallel inductors of an external LC matching circuit to V_{CC} to apply a bias and RF load.

(5) A DC cut capacitor must be each attached to the input pins and external adjustment of pin voltages is prohibited for input pins.

See the product's data sheet for more detailed caution points and descriptions of electrical specifications.
μPC8172TB Data Sheet (Document No.: P14729E)
μPC8187TB Data Sheet (Document No.: P15106E)

★ 1. PREFACE

In 1995, PDC (Personal Digital Cellular) services were launched in Japan, and PHS (Personal Handyphone System) services were started soon afterward. As of February 2001, Japan's cell phone subscriptions totaled about 59.5 million, indicating that almost half (47.2 percent) of the people in Japan has a call phone. PHS subscriptions alone totaled over 5.8 million, which represents about 4.6 percent of the nation's population.

Since mobile telephones use high frequencies, a frequency-raising function is needed for signal transmission. Methods for raising the frequency include direct modulation methods (such as the direct modulation method and the RF modulation method), in which a signal is increased to the transmission frequency and then the frequency is modulated, and indirect modulation methods (such as the up-converter method and the IF modulation method), in which the frequency of a pre-modulated signal is raised to obtain the transmission frequency. Frequency up-converters are used in all of these methods. NEC has developed silicon monolithic ICs as core products for frequency up-converters used with any of the above frequency modulation methods, and has added the new μPC8172TB and μPC8187TB to its product series. This Application Note describes usage and applications of these new products.

★ 2. PRODUCT OVERVIEW

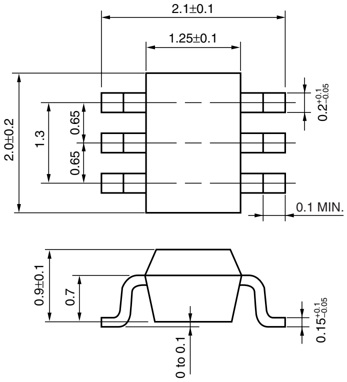
2.1 Product Overview

The μPC8172TB and μPC8187TB are process-renewal products that have the same circuit configuration as the existing μPC8106 and μPC8163TB respectively but are produced using the latest manufacturing process. These products are manufactured by using NEC's proprietary "UHS0" (Ultra High Speed Process) silicon bipolar process with f_{max} = 30 GHz.

The pin layout is the same as that of the existing product. The product series uses only 6-pin super minimold (2012 size) packages with C3A or C3G for the μPC8172TB or μPC8187TB marking respectively.

Figure 2-1 shows a package drawing of the 6-pin super minimold.

Figure 2-1. Package Drawing of 6-pin Super Minimold (Unit: mm)



2.2 Manufacturing Process

The μPC8172TB and μPC8187TB are manufactured by using NEC's proprietary "UHS0" silicon bipolar process. The features of this process are briefly described below.

<1> Realizes a high f_T (gain-bandwidth product) of 25 GHz by making the transistor base width approximately 1/3 that of the conventional "NESAT™ III" process.
<2> Realizes high gain creation by making the transistor's collector base capacitance less than 1/2 that of the conventional "NESAT III" process.

These features enable an IC having superior electrical characteristics to be created.

2.3 Differences with the Existing Product

Since the latest "UHS0" process, which produces superior electrical characteristics, is used for the μPC8172TB and μPC8187TB, the major characteristics are better than those of the existing product, which is produced using the conventional "NESAT III" process. In particular, use of the high f_T process has raised the operating frequency to a maximum of 2.5 GHz from the previous maximum of 2.0 GHz. Also, distortion characteristics, which are considered extremely important in the latest mobile communication terminals, are better than the existing product, with the equivalent circuit current. These improvements enable the μPC8172TB and μPC8187TB to be used not only for mobile communication terminals, but also for wireless LANs and a broad range of other applications. They also increase the degrees of freedom for chip set configurations.

Table 2-1 lists NEC's line-up of high-frequency up-converter ICs.

Table 2-1. NEC's Line-up of Frequency Up-Converter ICs

Part Number	Supply Voltage V_{CC} (V)	Circuit Current I_{CC} (mA)	RF output Frequency f_{RFout} (GHz)	Conversion Gain 1 CG1 (dB)	Conversion Gain 2 CG2 (dB)	Conversion Gain 3 CG3 (dB)
μPC8106T	2.7 to 5.5	9	0.4 to 2.0	10	7	–
μPC8106TB				9		
μPC8109T	2.7 to 5.5	5	0.4 to 2.0	7	5	–
μPC8109TB				6	4	
μPC8163TB	2.7 to 3.3	16.5	0.8 to 2.0	9	5.5	–
μPC8172TB	2.7 to 3.3	9	0.8 to 2.5	9.5	8.5	8.0
μPC8187TB	2.7 to 3.3	15	0.8 to 2.5	11	11	10

Part Number	Maximum Output Power 1 $P_{O(sat)}$1 (dBm)	Maximum Output Power 2 $P_{O(sat)}$2 (dBm)	Maximum Output Power 3 $P_{O(sat)}$3 (dBm)	Output $IP_3$1 $OIP_3$1 (dBm)	Output $IP_3$2 $OIP_3$2 (dBm)	Output $IP_3$3 $OIP_3$3 (dBm)	Process
μPC8106T	−2	−4	–	+5.5	+2.0	–	NESAT III
μPC8106TB							
μPC8109T	−6	−8	–	+1.5	−1.0	–	
μPC8109TB	−5.5	−7.5					
μPC8163TB	+0.5	−2	–	+9.5	+6.0	–	
μPC8172TB	+0.5	0	−0.5	+7.5	+6.0	+4.0	UHS0
μPC8187TB	+4	+2.5	+1	+10	+10	+8.5	

T_A = +25°C, $V_{CC} = V_{RFout}$ = 3.0 V, $Z_S = Z_L$ = 50 Ω (μPC8106T/TB, μPC8109T/TB, μPC8172TB: V_{PS} = 3.0 V)

In the various characteristics above, 1, 2, and 3 have the following meanings. 1: f_{RFout} = 0.9 GHz (0.83 GHz for the μPC8163TB, μPC8187TB), 2: f_{RFout} = 1.9 GHz, 3: f_{RFout} = 2.4 GHz

The above values are typical values for major characteristics. See each product's data sheet for detailed ratings, characteristic curves, etc.

★ 3. INTERNAL CIRCUIT CONFIGURATION

The μPC8172TB is a double-balanced mixer + bias circuit IC. The μPC8187TB has the same circuit configuration as other up-converter ICs (apart from the absence of a power-save control circuit), but features a high IP_3 due to optimization of the current distribution and adjustment of the CG and IIP_3. Figure 3-1 shows the internal equivalent circuit diagram.

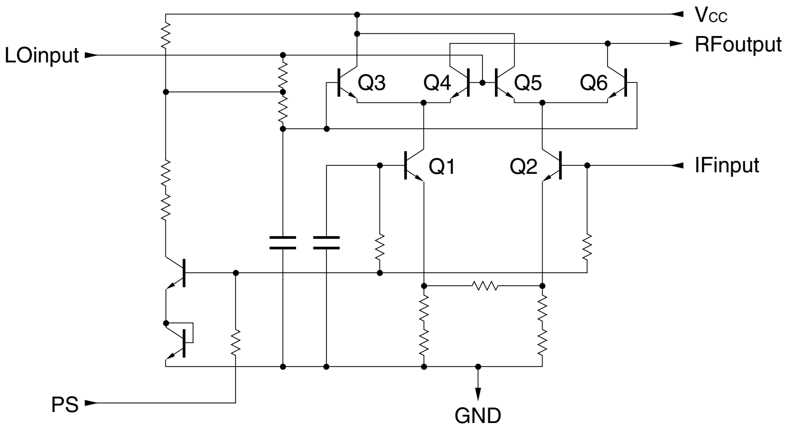
This IC includes bypass capacitors for double balanced mixer type complementary IF inputs in order to improve the AC characteristics of the 50 MHz to 400 MHz IF frequency range. This lowers the conversion gain when the IF input frequency is lower than the minimum frequency. When the IF input frequency is higher than the maximum frequency, the conversion gain is lowered according to the frequency characteristics of the internal transistors.

The RF output pin is an open collector, and since there is no on-chip component that limits the lower limit of the frequency range, the user should provide an external narrow-band matching circuit for the internal transistors' frequency characteristic range (800 MHz to 2.5 GHz) to set the desired bandwidth.

Since this mixer has been designed as a product for frequency up-converters, the user's determination of the desired bandwidth should be made according to the following conditions. Note with caution that this mixer's design and operation as a frequency down-converter are not guaranteed (other frequency down-converter mixer ICs are available).

- Frequency condition: $| f_{RFout} - f_{LOin} | = f_{IFin}$, f_{RFout}, $f_{LOin} > f_{IFin}$

Figure 3-1. Internal Equivalent Circuit Diagram



4. EXTERNAL CIRCUIT CONFIGURATIONS

4.1 Impedance Matching at RF Output

Since this IC has an open-collector output, configure an LC matching circuit for RF impedance using an external component. The matching circuit should include a parallel inductor to the V_{CC} side and a series capacitor toward the next stage. As mentioned earlier, the bias of the output pin's collector uses the method applying the V_{CC} pin's voltage via the inductor used for RF matching. In other words, the inductor that is connected to the output pin has two effects: its RF effect (frequency matching) and its DC effect (application of bias). This is why a small DC resistance and high-frequency type inductor should be used.

The LC matching circuit constants used in the test circuits shown in the data sheet are for the NEC evaluation board. This evaluation board is used only for simple evaluations; devices evaluated using this board are not immediately suitable for application in systems. The patterns used for evaluation does not allow parts to be mounted near the IC, so the pattern size is larger. Accordingly, these are not the recommended patterns or the recommended circuit constants.

The matching LC value is determined so as to produce narrow-band power gain that suits the used frequency bandwidth referencing the IC's own S-parameters. Select a value that reduces the S_{22} value of the RF output pin to about –20 dBm during maximum gain within the used frequency bandwidth. Examples of RF matching circuit configurations are the high-pass type at 900 MHz and the low-pass type at 1.9 GHz and 2.4 GHz. Figure 4-1 shows examples of external circuit configurations.

4.2 Input Impedance Matching

The IF and LO inputs in this IC are base inputs with parallel connections to bias resistors. Although their characteristic impedance is not 50 Ω, the test circuits in the data sheet show a signal generator with a 50 Ω signal source impedance. Accordingly, the data sheet's electrical specifications include loss due to this mismatched impedance. If impedance matching is implemented in the actual circuit, the elimination of this loss raises the IC's input level, which lowers the required input level.

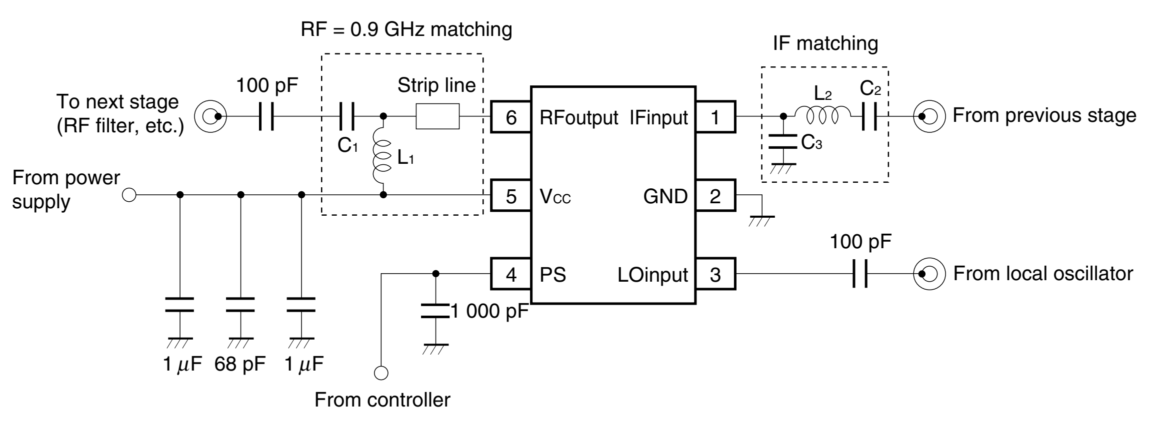
Figure 4-2 shows S parameter values for the RF, IF, and LO ports when matching is not implemented.

4.3 Bypass Capacitor

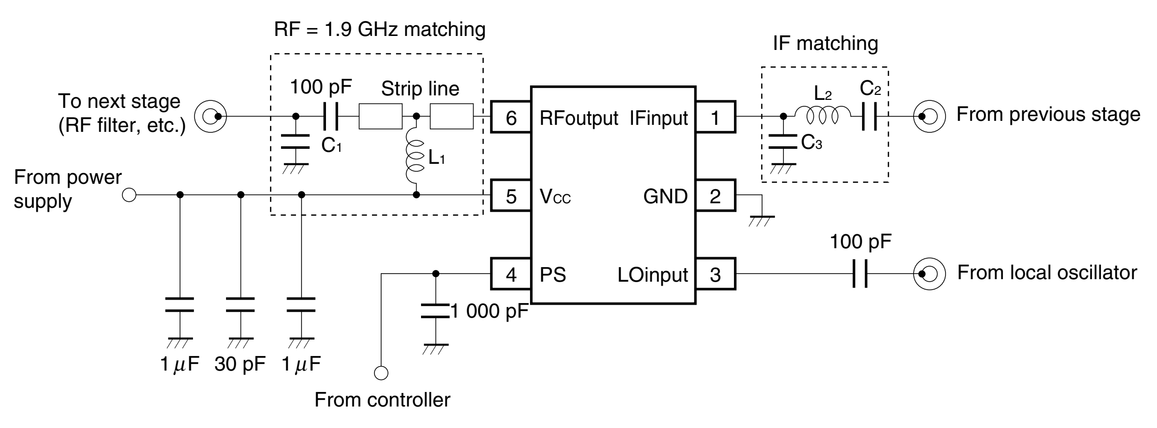
Like other ICs, this IC needs an RF bypass to GND for its V_{CC} pin, so an external capacitor should be connected to the V_{CC} pin as the bypass.

Figure 4-1. Examples of External Circuit Configurations (μPC8172TB) (1/2)

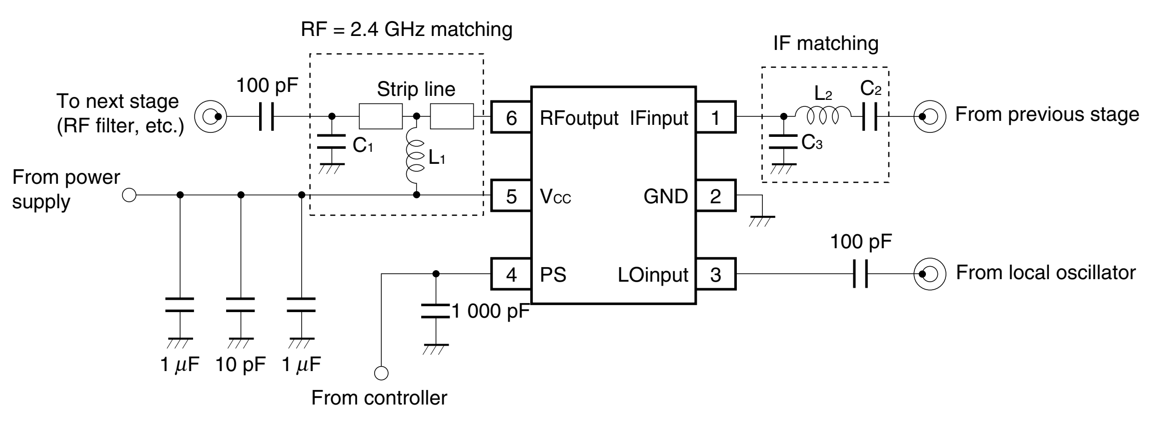
When f_{RFout} = 0.9 GHz matching



When f_{RFout} = 1.9 GHz matching



When f_{RFout} = 2.4 GHz matching



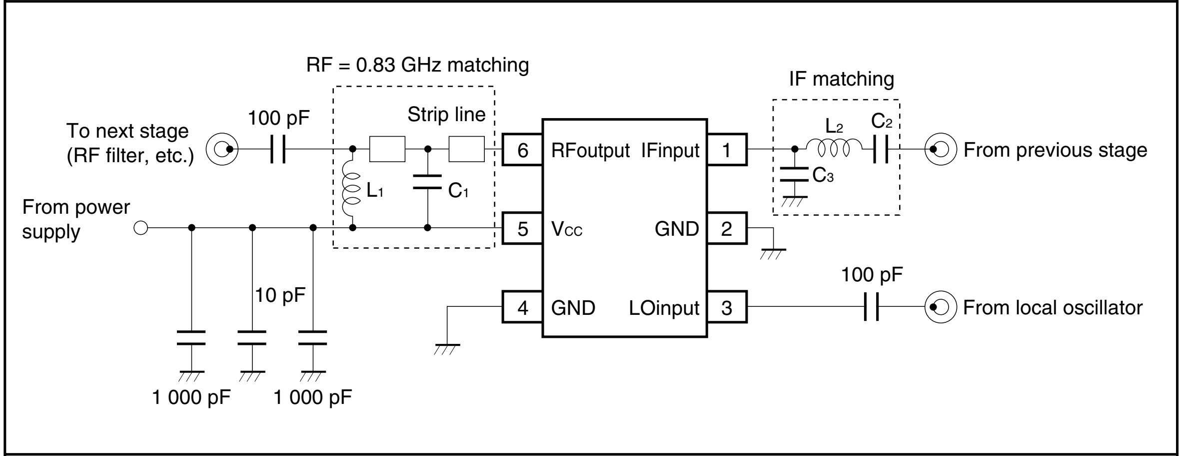
Remarks 1. Determine L_1 and C_1 according to the frequency and the RF port's S-parameter, including the strip line length on the mounting surface.

2. High-pass type output matching is used for f_{RFout} = 0.9 GHz and low-pass type output matching is used for f_{RFout} = 1.9 GHz and f_{RFout} = 2.4 GHz.

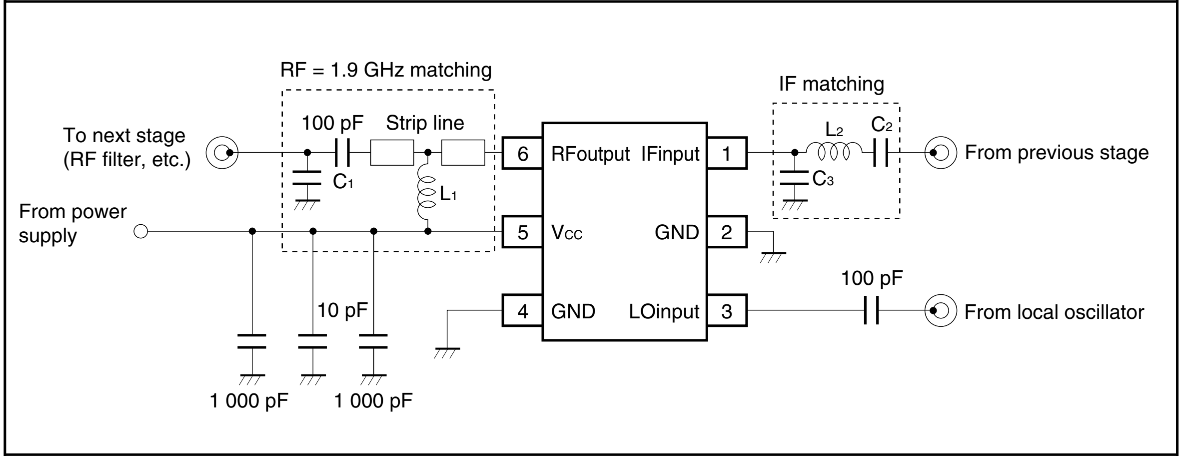
3. Determine whether or not matching is required for input according to how the input relates to the previous stage's impedance.

★ **Figure 4-1. Examples of External Circuit Configurations (μPC8187TB) (2/2)**

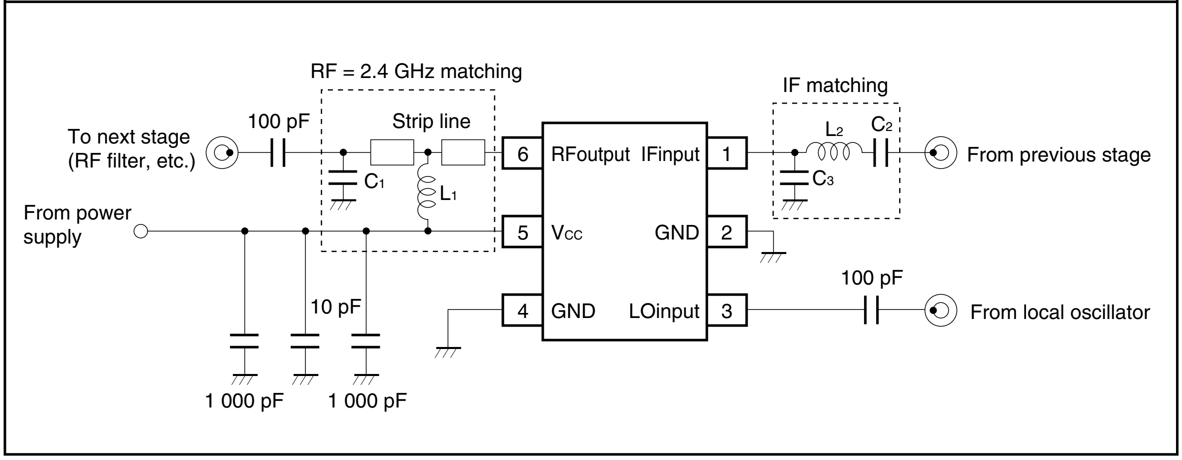
When f_{RFout} = 0.83 GHz matching



When f_{RFout} = 1.9 GHz matching



When f_{RFout} = 2.4 GHz matching



Remarks 1. Determine L_1 and C_1 according to the frequency and the RF port's S-parameter, including the strip line length on the mounting surface.

2. High-pass type output matching is used for f_{RFout} = 0.83 GHz and low-pass type output matching is used for f_{RFout} = 1.9 GHz and f_{RFout} = 2.4 GHz.

4. Determine whether or not matching is required for input according to how the input relates to the previous stage's impedance.

Figure 4-2. Smith Charts and S-Parameters (Without External Component) of Each Port (1/4)

(a) μPC8172TB (1/2)

($V_{CC} = V_{PS} = V_{RFout} = 3.0$ V, $T_A = +25$°C)

FREQUENCY	LO port		RF port	
	S_{11}		S_{22}	
MHz	MAG.	ANG.	MAG.	ANG.
400.0000	0.918	–21.2	0.952	–11.0
450.0000	0.919	–22.9	0.947	–12.2
500.0000	0.913	–25.2	0.941	–13.3
550.0000	0.907	–27.6	0.935	–14.4
600.0000	0.900	–30.0	0.929	–15.5
650.0000	0.892	–32.5	0.923	–16.6
700.0000	0.888	–34.6	0.918	–17.6
750.0000	0.881	–36.8	0.912	–18.7
800.0000	0.875	–39.3	0.907	–19.7
850.0000	0.867	–41.6	0.901	–20.7
900.0000	0.858	–44.0	0.896	–21.7
950.0000	0.853	–46.2	0.890	–22.7
1000.0000	0.849	–48.3	0.885	–23.7
1050.0000	0.841	–50.7	0.880	–24.7
1100.0000	0.841	–53.1	0.875	–25.7
1150.0000	0.823	–55.5	0.869	–26.7
1200.0000	0.819	–57.7	0.864	–27.7
1250.0000	0.812	–59.8	0.859	–28.7
1300.0000	0.805	–62.3	0.853	–29.7
1350.0000	0.796	–64.5	0.847	–30.8
1400.0000	0.786	–67.0	0.839	–31.9
1450.0000	0.779	–69.1	0.832	–32.7
1500.0000	0.773	–71.1	0.826	–33.6
1550.0000	0.767	–73.5	0.822	–34.6
1600.0000	0.757	–76.0	0.814	–35.6
1650.0000	0.743	–78.3	0.807	–36.6
1700.0000	0.743	–80.2	0.798	–37.6
1750.0000	0.737	–82.0	0.787	–38.4
1800.0000	0.730	–84.6	0.780	–39.1
1850.0000	0.729	–86.6	0.771	–39.9
1900.0000	0.718	–89.3	0.761	–40.6
1950.0000	0.711	–91.9	0.752	–41.0
2000.0000	0.701	–94.1	0.747	–41.2
2050.0000	0.687	–96.8	0.745	–41.6
2100.0000	0.678	–98.8	0.746	–42.1
2150.0000	0.663	–101.0	0.746	–42.8
2200.0000	0.657	–103.2	0.748	–43.8
2250.0000	0.649	–104.7	0.744	–44.8
2300.0000	0.640	–107.0	0.741	–45.6
2350.0000	0.630	–108.8	0.738	–46.5
2400.0000	0.622	–111.0	0.733	–47.5
2450.0000	0.618	–112.9	0.729	–48.4
2500.0000	0.609	–115.3	0.725	–49.2

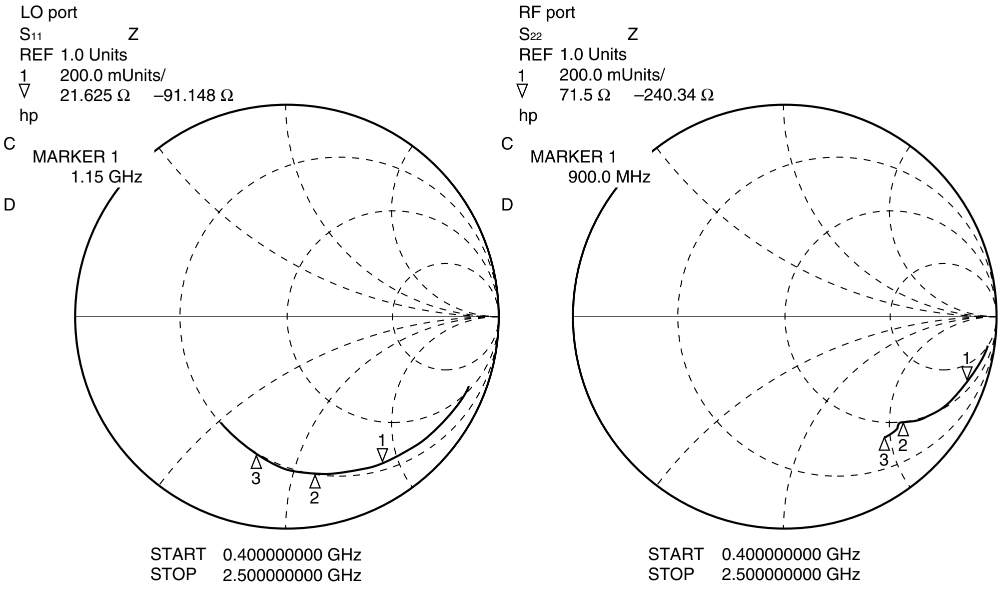


Figure 4-2. Smith Charts and S-Parameters (Without External Component) of Each Port (2/4)

(a) *μ*PC8172TB (2/2)

($V_{CC} = V_{PS} = V_{RFout} = 3.0$ V, $T_A = +25$°C)

FREQUENCY MHz	IF port S_{11} MAG.	 ANG.
100.0000	0.940	–3.3
120.0000	0.941	–3.7
140.0000	0.939	–4.2
160.0000	0.937	–4.9
180.0000	0.937	–5.6
200.0000	0.935	–6.0
220.0000	0.932	–6.7
240.0000	0.932	–7.3
260.0000	0.930	–7.9
280.0000	0.926	–7.9
300.0000	0.927	–8.8
320.0000	0.925	–9.4
340.0000	0.924	–10.3
360.0000	0.921	–10.6
380.0000	0.920	–11.0
400.0000	0.915	–11.3
420.0000	0.916	–12.1
440.0000	0.915	–12.6
460.0000	0.913	–12.7
480.0000	0.909	–13.7
500.0000	0.908	–14.2
520.0000	0.905	–15.0
540.0000	0.904	–15.2
560.0000	0.903	–15.7
580.0000	0.899	–16.3
600.0000	0.898	–16.7
620.0000	0.898	–17.2
640.0000	0.894	–17.9
660.0000	0.892	–18.2
680.0000	0.891	–18.7
700.0000	0.891	–19.2
720.0000	0.885	–19.8
740.0000	0.885	–20.2
760.0000	0.881	–20.7
780.0000	0.879	–21.2
800.0000	0.878	–21.7
820.0000	0.877	–22.2
840.0000	0.873	–22.7
860.0000	0.871	–23.2
880.0000	0.888	–22.3
900.0000	0.866	–24.2
920.0000	0.864	–24.6
940.0000	0.863	–25.1
960.0000	0.859	–25.6
980.0000	0.857	–26.0
1000.0000	0.856	–26.5

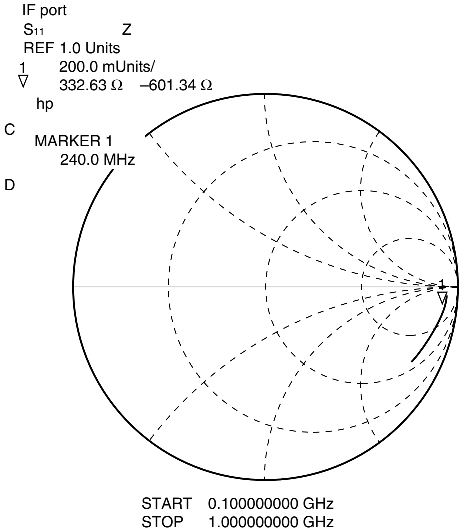


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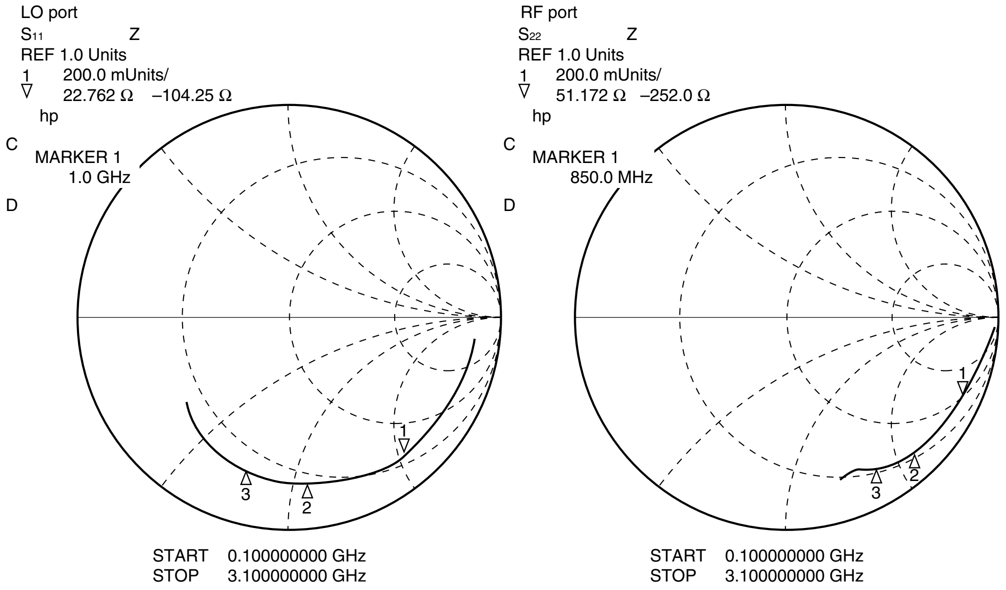
Figure 4-2. Smith Charts and S-Parameters (Without External Component) of Each Port (3/4)

(b) μPC8187TB (1/2)

($V_{CC} = V_{RFout} = 2.8$ V, $T_A = +25$°C)

FREQUENCY MHz	LO port S_{11} MAG.	LO port S_{11} ANG.	RF port S_{22} MAG.	RF port S_{22} ANG.
100.0000	0.864	–6.8	0.982	–2.7
200.0000	0.862	–11.6	0.979	–5.8
300.0000	0.852	–16.7	0.962	–8.2
400.0000	0.845	–22.3	0.948	–11.4
500.0000	0.840	–26.6	0.944	–13.9
600.0000	0.837	–32.0	0.940	–16.2
700.0000	0.827	–37.1	0.937	–18.4
800.0000	0.815	–42.0	0.937	–20.4
900.0000	0.812	–46.5	0.922	–22.7
1000.0000	0.804	–51.5	0.912	–25.4
1100.0000	0.807	–56.5	0.909	–28.2
1200.0000	0.807	–62.1	0.900	–30.6
1300.0000	0.793	–67.1	0.907	–32.9
1400.0000	0.784	–71.7	0.901	–35.2
1500.0000	0.771	–75.9	0.885	–36.9
1600.0000	0.770	–79.2	0.886	–39.8
1700.0000	0.763	–83.7	0.881	–42.1
1800.0000	0.757	–88.2	0.875	–45.2
1900.0000	0.752	–92.6	0.869	–47.4
2000.0000	0.746	–96.7	0.863	–49.9
2100.0000	0.741	–101.3	0.852	–53.0
2200.0000	0.723	–105.5	0.846	–55.8
2300.0000	0.715	–110.5	0.835	–58.4
2400.0000	0.708	–115.4	0.823	–60.6
2500.0000	0.694	–120.5	0.800	–62.9
2600.0000	0.677	–125.6	0.778	–64.9
2700.0000	0.659	–130.7	0.761	–66.5
2800.0000	0.645	–134.1	0.766	–68.4
2900.0000	0.627	–137.5	0.773	–70.2
3000.0000	0.620	–140.1	0.780	–71.4
3100.0000	0.606	–143.4	0.784	–73.2



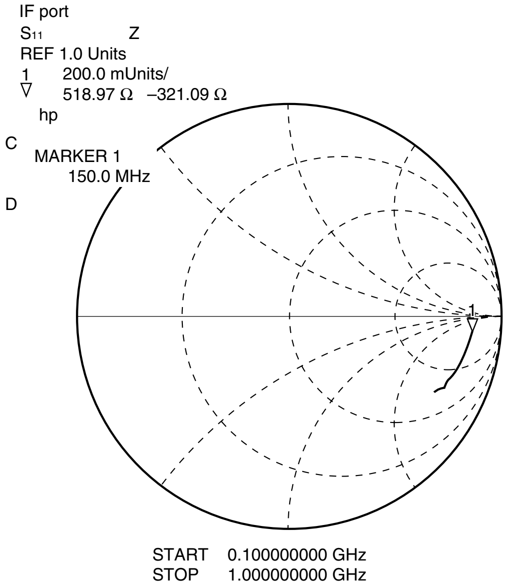
★ **Figure 4-2. Smith Charts and S-Parameters (Without External Component) of Each Port (4/4)**

(b) *μ*PC8187TB (2/2)

($V_{CC} = V_{RFout} = 2.8$ V, $T_A = +25$°C)

IF port

FREQUENCY MHz	S_{11} MAG.	 ANG.
100.0000	0.897	–3.3
150.0000	0.898	–4.6
200.0000	0.896	–6.2
250.0000	0.892	–7.8
300.0000	0.888	–9.0
350.0000	0.882	–10.6
400.0000	0.881	–12.4
450.0000	0.873	–13.7
500.0000	0.872	–15.2
550.0000	0.873	–16.8
600.0000	0.870	–18.8
650.0000	0.866	–20.6
700.0000	0.867	–22.3
750.0000	0.867	–23.7
800.0000	0.865	–25.3
850.0000	0.861	–26.9
900.0000	0.862	–28.4
950.0000	0.865	–29.9
1000.0000	0.869	–31.4



★ 5. APPLICATION CHARACTERISTICS

5.1 Operation Rise/Fall Times

The measurement of the rise and fall times at the V_{CC} and PS pins is controlled at high speed by turning on and off the pins using a pulse pattern generator. Moreover, the time from when the output of the desired RF frequency is at the maximum level to when it is at the minimum level is set using the zero-span mode of a spectrum analyzer. Because the rise time is dependent on the DC cut capacitor, a DC cut capacitor of about 100 pF is required to obtain the same value as that in the data sheet. The measurement results are shown in Table 5-1, and the rise/fall waveforms of the μPC8172TB are shown in Figure 5-1 as a typical example.

Table 5-1. Rise/Fall Times per Capacitance of DC Cut Capacitor at IF Pin

- **Rise time**

Part Number	Control Pin[Note]	Capacitance of DC Cut Capacitor at IF Input Pin		
		1 000 pF	400 pF	100 pF
μPC8172TB	PS	10 μs	4.5 μs	2 μs
	V_{CC}	6 μs	2.5 μs	1.5 μs
	PS, V_{CC} simultaneously	10 μs	4.5 μs	2 μs
μPC8187TB	V_{CC}	4 μs	2 μs	1.5 μs

- **Fall time**

Part Number	Control Pin[Note]	Capacitance of DC Cut Capacitor at IF Input Pin		
		1 000 pF	400 pF	100 pF
μPC8172TB	PS	6.5 μs	2.5 μs	1.5 μs
	V_{CC}	0.5 μs	0.5 μs	0.5 μs
	PS, V_{CC} simultaneously	1 μs	0.5 μs	0.5 μs
μPC8187TB	V_{CC}	0.5 μs	0.5 μs	0.5 μs

Note
- PS pin control: 3 V always applied to V_{CC} pin (2.8 V for μPC8187TB), ON/OFF pulse waveform inserted at PS pin.
- V_{CC} pin control: 3 V always applied to PS pin (2.8 V for μPC8187TB), ON/OFF pulse waveform inserted at V_{CC} pin.
- PS, V_{CC} pin simultaneous control: ON/OFF pulse waveform inserted at PS and V_{CC} pins simultaneously.

Figure 5-1. Rise/Fall Waveforms of μPC8172TB (1/3)

Measurement conditions: f_{IFin} = 240 MHz, P_{IFin} = –30 dBm, f_{LOin} = 1 140 MHz, P_{LOin} = –5 dBm

(a) PS pin control

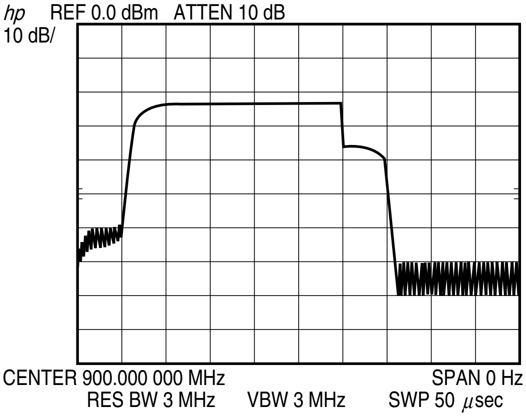
- With DC cut capacitor of 1000 pF

Rise time

T_{rise} = 10 μs

Fall time

T_{fall} = 6.5 μs



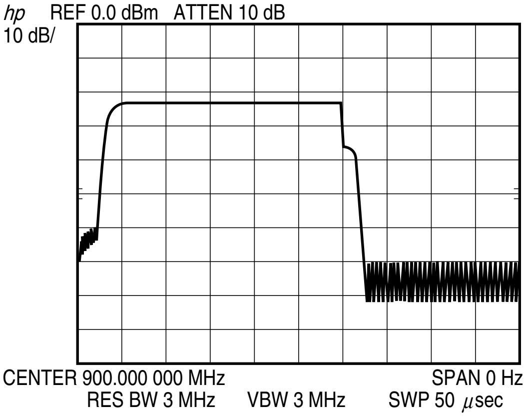
- With DC cut capacitor of 400 pF

Rise time

T_{rise} = 4.5 μs

Fall time

T_{fall} = 2.5 μs



- With DC cut capacitor of 100 pF

Rise time

T_{rise} = 2 μs

Fall time

T_{fall} = 1.5 μs

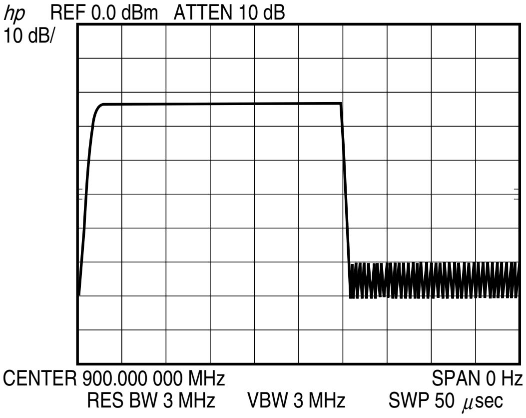


Figure 5-1. Rise/Fall Waveforms of μPC8172TB (2/3)

Measurement conditions: f_{IFin} = 240 MHz, P_{IFin} = –30 dBm, f_{LOin} = 1 140 MHz, P_{LOin} = –5 dBm

(b) V_{CC} pin control

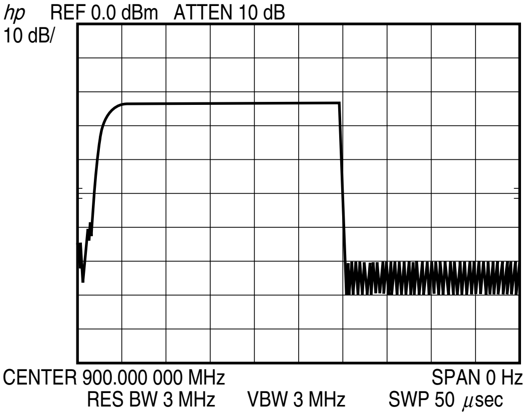
- With DC cut capacitor of 1000 pF

  Rise time

  T_{rise} = 6 μs

  Fall time

  T_{fall} = 0.5 μs



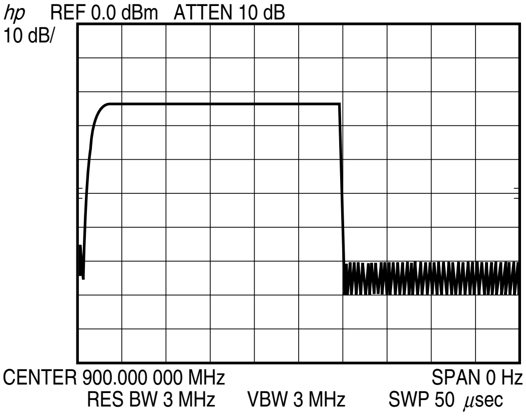
- With DC cut capacitor of 400 pF

  Rise time

  T_{rise} = 2.5 μs

  Fall time

  T_{fall} = 0.5 μs



- With DC cut capacitor of 100 pF

  Rise time

  T_{rise} = 1.5 μs

  Fall time

  T_{fall} = 0.5 μs

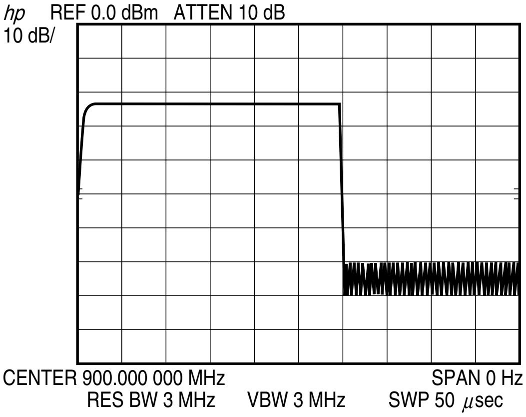


Figure 5-1. Rise/Fall Waveforms of μPC8172TB (3/3)

Measurement conditions: f_{IFin} = 240 MHz, P_{IFin} = –30 dBm, f_{LOin} = 1 140 MHz, P_{LOin} = –5 dBm

(c) PS/V$_{CC}$ pin control

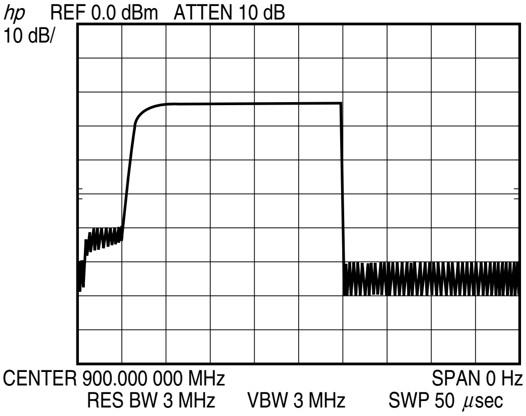
- With DC cut capacitor of 1000 pF

  Rise time

  T_{rise} = 10 μs

  Fall time

  T_{fall} = 1 μs



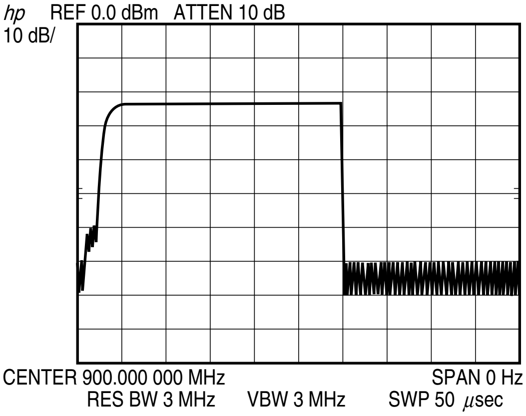
- With DC cut capacitor of 400 pF

  Rise time

  T_{rise} = 4.5 μs

  Fall time

  T_{fall} = 0.5 μs



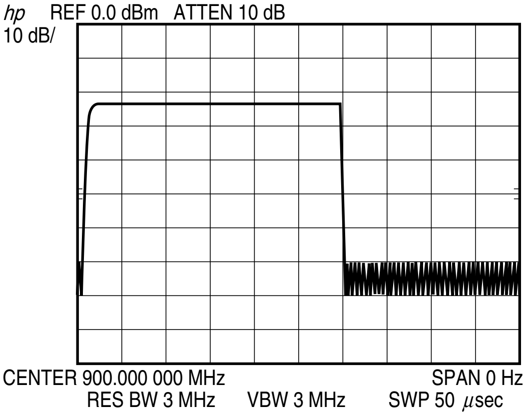
- With DC cut capacitor of 100 pF

  Rise time

  T_{rise} = 2 μs

  Fall time

  T_{fall} = 0.5 μs



6. CONCLUSION

This Application Note has briefly described the usage and application of the μPC8172TB and μPC8187TB up-converter ICs for mobile communication terminals. We will provide more substantial data concerning these ICs through future updates of this document.

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