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Manufacturing Friendly Circulator with Low Insertion Loss

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Skyworks has successfully developed a manufacturing-friendly circulator with industry leading insertion loss performance. The SKYFR-000827 operates in the frequency band 2300MHz to 2400MHz and has a typical insertion loss of just 0.10dB. The device is housed in a surface mount, 'robust lead' package and shipped in tape-and- reel.

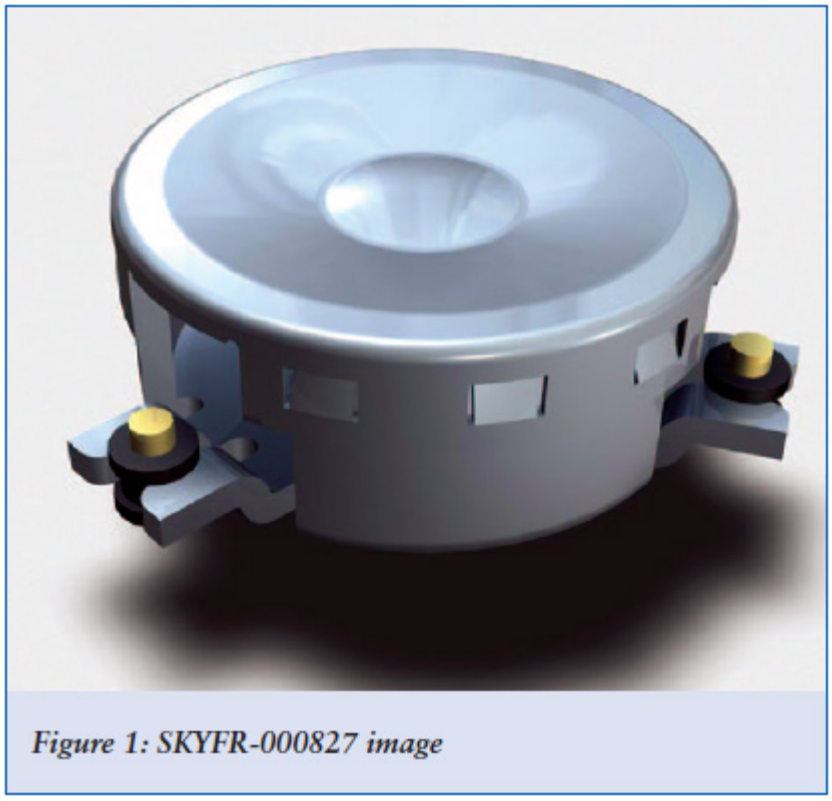
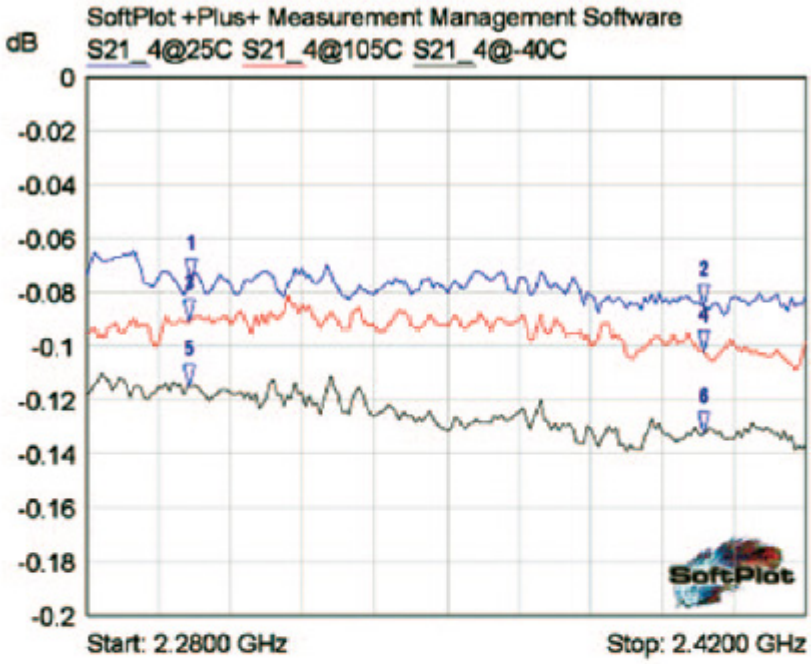


Figure 1: SKYFR-000827 image

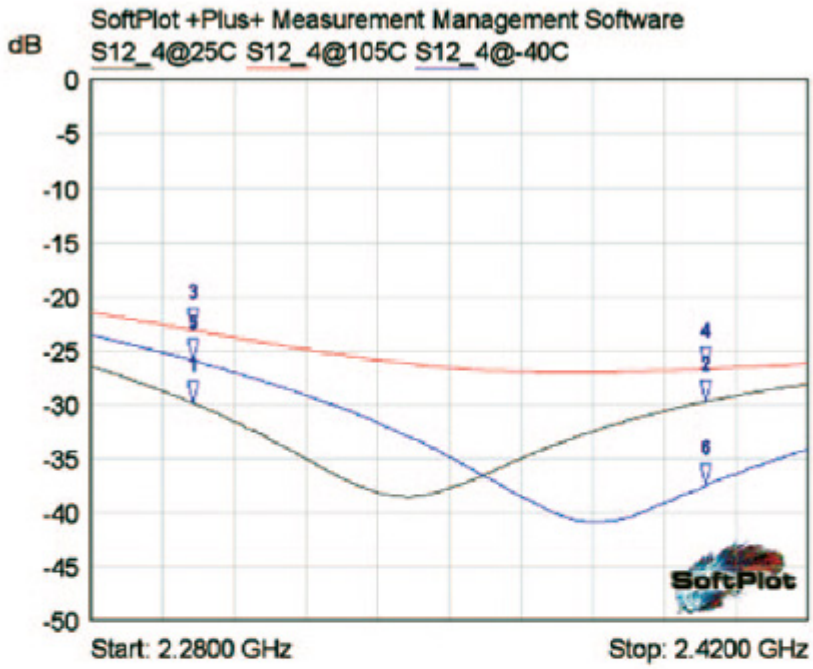
The traditional drop-in circulator is inadequate for the modern pick-and-place assembly line. The drop-in circulator requires a production operator to physically remove each device from the packing tray and place it onto the customer's PCB. The operator must then install the circulator using screws and manually solder the leads to the PCB. Deformed leads and poor manual solder joint quality are reoccurring problems.



Mkr	Trace	X-Axis	Value	Notes
1	S21_4@25C	2.3003 GHz	-0.08 dB	
2	S21_4@25C	2.4000 GHz	-0.09 dB	
3	S21_4@105C	2.3000 GHz	-0.09 dB	
4	S21_4@105C	2.4000 GHz	-0.10 dB	
5	S21_4@-40C	2.3000 GHz	-0.11 dB	
6	S21_4@-40C	2.4000 GHz	-0.13 dB	

Figure 2: SKYFR-000827 insertion loss over operating temperature range

Skyworks' patented 'robust lead' package allows the circulator to be populated onto the customer's PCB using modern surface-mount technology. The robust lead circulator is shipped in tape-and- reel for automated placement. The package uses a unique vertical lead to connect the center conductor of the circulator to the customer's PCB. The gold plated lead is firmly encased inside a high temperature plastic, insuring a robust design and excellent co-planarity. The main body of the device is plated with silver for excellent solderability and can be attached to the PCB using a standard reflow profile.



Mkr	Trace	X-Axis	Value	Notes
1	S12_4@25C	2.3000 GHz	-29.87 dB	
2	S12_4@25C	2.4000 GHz	-29.71 dB	
3	S12_4@105C	2.3000 GHz	-23.08 dB	
4	S12_4@105C	2.4000 GHz	-26.66 dB	
5	S12_4@-40C	2.3000 GHz	-25.92 dB	
6	S12_4@-40C	2.4000 GHz	-37.54 dB	

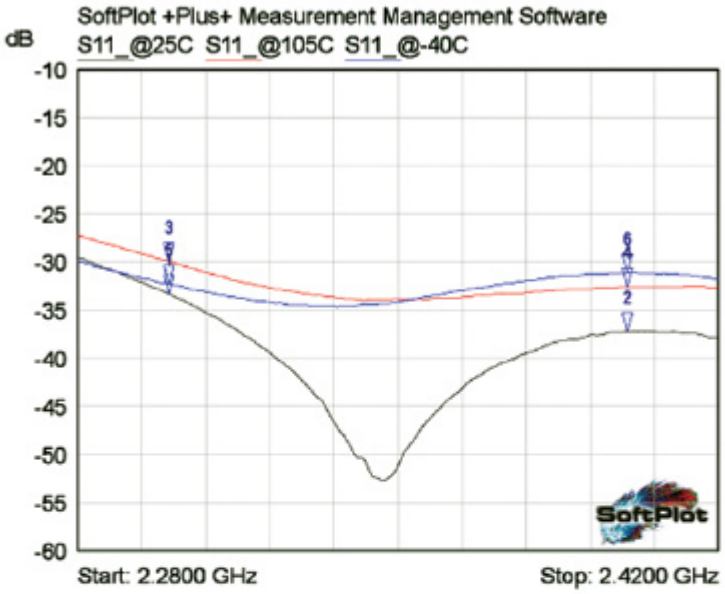
Figure 3: SKYFR-000827 isolation over operating temperature range

The surface-mount robust lead circulator is extremely reliable, which has been confirmed by numerous reliability tests, including thermal shock, humidity, vibration and high temperature soak. In one case, robust lead devices were subjected to 12,000 temperature cycles (0°C to 100°C, 10 minute dwell) without a single solder joint failure. The part will also withstand up to 200W of CW RF power when mounted on a PCB with good thermal grounding. See Skyworks application note 201790, Robust Lead Circulators and Isolators, for more information.

Table 1: SKYFR-000827 Intermodulation Distortion

F1(MHz), 40W	F2(MHz), 40W	Measured (MHz)	IMD@25°C (dBc)	IMD@-40°C (dBc)	IMD@+105°C (dBc)
2300	2305	2310	79.6	82.1	75.2
2300	2305	2295	76.1	81.8	71.3
2348	2353	2358	78.1	84.2	73.6
2348	2353	2343	76.1	80.8	71.7
2395	2400	2405	77.4	81.7	68.5
2395	2400	2390	75.2	80.3	67.0

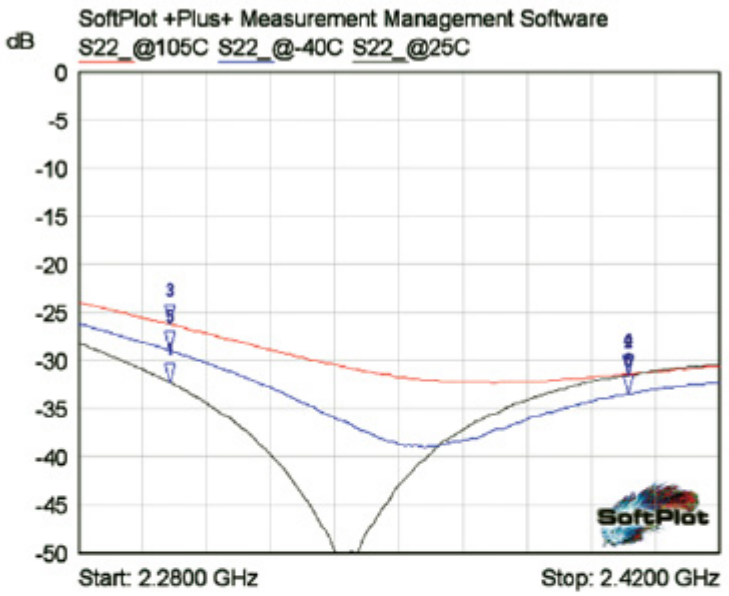
The insertion loss of the output circulator of a power amplifier is critical. It is estimated that every 0.1dB of insertion loss at the power amplifier output cost >3W of RF power further up the chain. Our engineering teams have successfully developed new manufacturing processes for the ferrite disk, resulting in circulator designs with industry leading insertion loss performance. The SKYFR-000827 is a single junction circulator in a 25mm diameter housing (see **Figure 1**), designed to operate in the standard band of 2300 MHz to 2400 MHz. This circulator can achieve insertion loss performance of better than 0.15dB over the operating temperature range of -40°C to +105°C. The isolation and the return loss are typically at least 25dB and the intermodulation distortion (IMD) performance is better than 70dBc with two 40W CW tones. See Table 1 for IMD data.



Mkr	Trace	X-Axis	Value	Notes
1	S11_@25C	2.3000 GHz	-33.33 dB	
2	S11_@25C	2.4000 GHz	-37.26 dB	
3	S11_@105C	2.3000 GHz	-29.98 dB	
4	S11_@105C	2.4000 GHz	-32.58 dB	
5	S11_@-40C	2.3000 GHz	-32.32 dB	
6	S11_@-40C	2.4000 GHz	-31.12 dB	

Figure 4: SKYFR-000827 input return loss over operating temperature range

The key to achieving this very low insertion loss is the ferrite/dielectric disk. The ferrite and dielectric materials are selected to guarantee the best possible performance from Trans-Tech's range of low linewidth magnetic materials and low loss D2000 series dielectric materials. The materials are then paired into a co-fired garnet/dielectric ring assembly, a patented process in which both materials are processed simultaneously and the net result is a joint with no air gap and no lossy glue. These two factors, plus the excellent transmission and reflection s-parameters of the device, combine to give the very low insertion loss performance.



Mkr	Trace	X-Axis	Value	Notes
1	S22_@25C	2.3000 GHz	-32.30 dB	
2	S22_@25C	2.4000 GHz	-31.59 dB	
3	S22_@105C	2.3000 GHz	-26.25 dB	
4	S22_@105C	2.4000 GHz	-31.44 dB	
5	S22_@-40C	2.3000 GHz	-28.97 dB	
6	S22_@-40C	2.4000 GHz	-33.51 dB	

Figure 5: SKYFR-000827 output return loss over operating temperature range

Figures 2, 3, 4 and 5 show the s parameter performance of the SKYFR-000827 over temperature. This part is a manufacturing friendly design with industry leading insertion loss performance. The outstanding insertion loss is the result of improved manufacturing processes of the ferrite disk and careful magnetic and electrical design in the circulator junction. The device is housed in a surface mount 'robust lead' package and shipped on tape-and- reel, making it ideal for today's surface-mount assembly processes. Skyworks is currently developing low insertion loss circulators for all wireless infrastructure frequency bands.

For more information, visit our website.

Skyworks Solutions, Inc.

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