TEXAS INSTRUMENTS

TRF6900A Frequently Asked Questions

Note: For additional information, refer to the TRF6901 FAQs, which contain topics applicable to both TRF6900A and TRF6901.

- **What are the wireless devices that TI offers for ISM (Industrial, Scientific, Medical) applications?**

DEVICES FOR SHORT RANGE WIRELESS APPLICATIONS

Product	TRF6901	TRF6900A	TRF4900	TRF4400
Description	Transceiver	Transceiver	Transmitter	Transmitter
Operation	Half-duplex	Half-duplex		
Max data rate*, kbps	64	115	115	115
Modulation type	FSK, OOK	FSK, OOK*	FSK, OOK	FSK, OOK
Freq range, intended use, MHz	868-870, 902-928	868-870, 902-928	868-870, 902-928	420-450
Freq range, max*, MHz	750-950	300-950	300-950	300-950
Freq synthesis	Integer N PLL	DDS	DDS	DDS
VCO tank	Internal	External	External	External
Freq resolution, example	100 kHz	400 Hz	400 Hz	400 Hz
Temperature range, C	-40 to +85	-20 to +65*	-20 to +65*	-20 to +65*
Tx max power, dBm	9	4.5	7	7
Tx attenuation steps, dB	0, 10, 20	0, 10, 20	0, 10, 20	0, 10, 20
Rx input sensitivity, dBm*	-99	-96		
Supply, V	1.8 to 3.6	2.2 to 3.6	2.2 to 3.6	2.2 to 3.6
Current, Tx, mA*	32	37	58	57
Current, Rx, mA	18	26		
Current, standby, uA	0.6	0.5	0.5	0.5

*Notes:
TRF6900 operates up to 115 kbps in 2-FSK, performance not guaranteed
TRF6901 operates up to around 94 kbps in 2-FSK, performance not guaranteed
Operation at frequencies outside intended use require external component changes; performance not guaranteed
Operation -40 C to +85 C with Vcc 3.0 to 3.6 V; performance not guaranteed
TRF6900A OOK requires toggling standby, mode, or attenuation setting
Transmit current is lower for 10, 20 dB attenuation
Higher data rates achievable with direct VCO modulation and narrow loop filter
Receive sensitivity is highly dependent on hardware implementation

- **Where can I find relevant documentation?**

Go to www.ti.com and type the document number in the "Search" box:

TEXAS INSTRUMENTS

TRF6900A Frequently Asked Questions

Document Number	Document
SLAS258	TRF6900A data sheet
SWRA033	Designing with the TRF6900 Single-Chip RF Transceiver
SLAA121	Implementing a Bidirectional Half-Duplex FSK RF Link with TRF6900/MSP430
SWRA030	Understanding and Enhancing Sensitivity in Receivers for Wireless Applications
SWRA032	User manual abstract, TRF6900/MSP430
SWRA034	User guide for MSP-US-TRF6900 RF link evaluation kit
SWRA035	TRF6901 Design Guide

On the TI Web site you can find additional documents relating to frequency sources, phase-locked loops, and other wireless communications topics or products.

- **What's the difference between the TRF6900A and the TRF6901?**

In brief, the TRF6900A has a DDS frequency source and external VCO tank, so it has fine frequency resolution and can be made to work between 300 and 950 MHz (the frequency range specified in the data sheet is 850-950 MHz). The TRF6901 has a simpler integer-N PLL (more coarse frequency resolution), an integrated VCO tank, and consumes less current. The TRF6900A operates in binary frequency shift keying (FSK) mode. The TRF6901 operates in FSK or on-off keying (OOK) modes.

- **What are the practical minimum and maximum data rates for the TRF6900A?**

2.4 to 115 kbps for normal operation in 2-FSK, not including training sequences, error correction, or other overhead. These are not hard limits. The higher data rates assume NRZ or similar data coding. The maximum OOK data rate that can be detected at the RSSI is listed in the data sheet as 100 kbps.

- **Does the TRF6900A operate at extended temperatures, -40 to +85 C?**

The TRF6900A specifies operation from –20 to +60 C. The semiconductor process will work from –40 to +85 C, but there are some caveats to using the TRF6900A over this temperature range. The VCO tuning range tends to narrow at extreme temperature. The power supply should be 3.0 to 3.6 volts. Operation of the TRF6900A over conditions outside those stated in the datasheet is undertaken at the user's responsibility.

- **Does the TRF6900A operate at frequencies other than 870 and 915 MHz?**

Operation of the TRF6900A over frequencies outside those stated in the datasheet is undertaken at the user's responsibility.

The versatility of the DDS and external VCO tank make it possible for the TRF6900A to operate over a wide frequency range, roughly 300 MHz to 950 MHz. The product was designed for the European 868-870 MHz and North American 902-928 MHz ISM bands. There are companies using the TRF6900A at 315, 360, and 433 MHz. Usually the circuits needing adjustment for operation at these frequencies are the LNA input and output matching circuits, PA output matching circuit, and VCO tank. One configuration alone will not cover all frequencies from 300 to 950 MHz.

TRF6900A Frequently Asked Questions

- **Will the TRF6900A (TRF6901) do frequency-hopping spread spectrum or direct-sequence spread spectrum?**

FHSS and DSSS require more elaborate radio transceivers like those found in cellular phones--their features and throughput are discussed in communications textbooks and trade journals.

The TRF6900A (TRF6901) is more of a fast channel-changing transceiver, where the channel dwell time is fairly long, up to 400 msec for North American applications, and the data rate is usually under 115 kbps.

- **What data (line) coding schemes are most popular? (TRF6900A, TRF6901)**

Manchester coding and non-return to zero (NRZ) coding. With Manchester coding, the data rate and binary-FSK frequency modulation rate are the same. With NRZ or equivalent coding, the modulation rate is approximately half the data rate, allowing a narrower loop filter and a relaxed PLL lock time requirement.

- **How are the LEARN and HOLD modes used with non-return to zero (NRZ) and Manchester data? (TRF6900A, TRF6901)**

A learning sequence must precede data regardless of the data coding scheme; this sets a voltage reference for the receive data slicer. The TRF6900A must remain in the LEARN mode while the learning sequence is received. If Manchester coding is used the TRF6900A can receive data in LEARN or HOLD mode. If NRZ coding is used, the TRF6900A must be switched from LEARN to HOLD mode to receive data.

- **Why is a training sequence needed? (TRF6900A, TRF6901)**

Terminal 29 is connected to the sample-and-hold (S&H) capacitor, which holds the reference voltage for the data slicer. This voltage is derived from the training sequence, and depends on the RC time constant of the data slicer circuits and how long the training sequence is sent.

The average voltage at the S&H cap also depends on the transmit deviation and the spectral content of the IF signal. Since the FM demodulator puts out a frequency-dependent voltage, it is hard to predict with accuracy just what the exact reference voltage should be. There is variance (frequency jitter) in the transmitter FSK frequencies, influence from spurs or other RF interference, effects from the IF filter response, and some nonlinearity in the demodulator output--all of these may add up to affect the voltages for data=0 and data=1 that are presented to the data slicer. This is why the training sequence is needed to establish a good decision threshold.

In theory, a designer could connect terminal 29 to his own separate voltage reference and forget about the training sequence, thus saving time and effort. However, this has not proved to be very practical in actual use. Virtually all designers use a training sequence.

You can use an oscilloscope to monitor the S&H voltage during the training sequence to determine if you are sufficiently charging the S&H capacitor during training, and to see how fast it discharges when receiving data.

The sample-and-hold cap is normally 0.1 uF to 0.01 uF. Its value has to be low enough to charge quickly during the training sequence, but large enough to provide a stable reference during data transmission. During long data transmissions, the data stream might have to be interrupted to refresh the reference voltage with another training sequence. A typical training sequence might be 64 to 256 pulses.

TRF6900A Frequently Asked Questions

- **What are the major steps in designing and testing a transceiver system? (TRF6900A, TRF6901)**

Choose a data rate and coding scheme. For data rates less than about 20 kbps, Manchester or NRZ coding will do. For data rates above 20 to 30 kbps, use NRZ coding to reduce the required loop filter bandwidth. Decide on the major circuit features of the transceiver: common RF port vs. SPDT switch, need for external power amplifier or low-noise amplifier, type of antenna (wire, dipole, integrated PCB, etc.). Configure the transceiver circuits (loop filter, low-pass post-detect filter, etc.). Test the transceiver in transmit, then receive. Test two transceivers cabled together. Test a wireless link with a simple square-wave data input. Test the link with real or pseudorandom data.

- **What is the effect of changing the charge pump bias resistor? (TRF6900A)**

The higher the bias resistor (connected to terminal 8), the lower the charge pump current; this lowers DDS spur levels at the expense of higher phase noise. Designs have been implemented with bias resistors of 68 k, 100 k, 150 k, 200 k, and 300 kOhm. In general, the lower the bias resistor (down to 68 kOhm) the better, as long as the spur levels meet the appropriate regulatory levels in the final system design. During speed-up mode (APLL), the charge pump output is saturated when the bias resistor is less than 150 kOhm.

The current from PD_OUT2 at terminal 9 is the speed-up mode current, which operates for a brief time when a new frequency is selected. It charges up the large capacitor in the loop filter at a faster rate than would be achieved by the current from PD_OUT1, terminal 10. Once the PLL is locked at the new frequency (or the capacitor charges to a certain value) it is turned off by the TRF6900. The user should set APLL to 111 for fast lock time.

The data sheet and design guide have detailed information regarding PLL operation. The data sheet has specific instructions for initializing the four control word registers and the E test register at startup.

- **Mapping DDS spurs (TRF6900A)**

DDS spurs occur irregularly in the frequency spectrum, according to the VCO output frequency and the external crystal frequency. For this reason, designers are encouraged to examine the transmit and receive frequency range every 10 kHz to 100 kHz to find channel frequencies that will be sufficiently free of frequency spurs. A rule of thumb is to find transmit and receive frequency pairs that have spurs less than –30 dBc within the IF bandwidth, and less than –40 dBc within 500 kHz of the RF or LO signal. Since the same oscillator is used to generate the transmit and LO signals, these tests are done on the transmitted RF signal for both transmit and receive frequencies.

- **Should amplifier harmonics be taken into consideration? (TRF6900A, TRF6901)**

Amplifier harmonics are generated by the transmit power amplifier at integer multiples of the output RF signal. The second and third harmonics are generally the ones that designers have to worry about. For higher-end systems, it is common practice to use a SAW band-pass filter or discrete low-pass filter to attenuate harmonics to acceptable levels. Amplifier harmonics are not the same as DDS spurs although both may be classified as spurious output signals for regulatory compliance.

- **Which loop filter should be used? (TRF6900A)**

TRF6900A Frequently Asked Questions

The loop filter is a second order discrete filter that consists of a capacitor to ground (C1) in parallel with a series RC to ground (R2, C2). C2 is always greater than C1. The loop filter bandwidth is chosen to be approximately 20% greater than the expected frequency modulation rate. The filter component values depend on the bandwidth, the charge pump current, phase margin, and the desired damping of the loop filter response. In general the phase margin should be 45 to 57 degrees, and the damping factor between 0.707 and 1.00.

The following example loop filters are designed assuming 50 degrees of excess phase margin, damping factor of 0.8 to 0.9, Kv = 30 MHz/V, divider ratio 256, and dual Alpha 1247 varactor diodes. The loop filters are listed by charge pump bias resistor values and loop filter bandwidth (LF BW). The actual loop filter bandwidth, damping, and other performance parameters may vary due to component values (rounded to the nearest standard value), and circuit board parasitic capacitance and part variation. Once a circuit board is built and tested, Kv should be measured and the loop filter adjusted if necessary.

Rbias = 68 kOhm

Data rate, kbps	LF BW, kHz	C1, pF	R2, kOhm	C2, pF
2.4	5	6800	2	47000
9.6	12	1000	6.8	6800
19.2	22	330	9.1	2200
64	38	100	18	680
115	69	33	30	220

Rbias = 100 kOhm

Data rate, kbps	LF BW, kHz	C1, pF	R2, kOhm	C2, pF
2.4	5	4700	2.7	33000
9.6	12	750	7.5	4700
19.2	22	220	13	1500
64	38	68	27	470
115	69	22	43	150

Rbias = 150 kOhm

Data rate, kbps	LF BW, kHz	C1, pF	R2, kOhm	C2, pF
2.4	5	2700	4.7	18000
9.6	12	470	12	3300
19.2	22	150	20	1000
64	38	47	36	330
115	69	15	68	100

Rbias = 200 kOhm

Data rate, kbps	LF BW, kHz	C1, pF	R2, kOhm	C2, pF
2.4	5	2200	6.2	15000
9.6	12	390	15	2700
19.2	22	120	27	820
64	38	39	47	270

115	69	10	91	68

Rbias = 300 kOhm				
Data rate, kbps	LF BW, kHz	C1, pF	R2, kOhm	C2, pF
2.4	5	1500	9.1	10000
9.6	12	270	22	1800
19.2	22	82	39	560
64	38	27	68	180
115	69	7	130	47

- **What are the recommended startup and troubleshooting procedures? (TRF6900A)**

A good routine to follow when testing a TRF6900A RF board is to check DC performance first, then transmit, and finally receive sensitivity. The following steps refer to testing a TRF6900A RF EVM board, but they may apply generally to other circuit implementations as well.

Check the regulator output voltage and board current consumption. The regulator Vcc to the TRF6900A is often set at 3.0-3.3 V. The circuit board consumption in transmit is around 65 mA.

Put the TRF6900A into the transmit mode and check the frequency accuracy and power output. The output RF frequency may be 10 to 30 kHz off depending on the circuit board. Frequency correction involves changing the digital word to compensate for the error. After correction, frequency error should be 1 to 5 kHz. Check RF output power with a power meter or spectrum analyzer; it should be 5 to 8 dBm, depending on losses in the circuit board and RF cables. The transmit signal should be examined in the expected ISM bandwidth (868-870 or 902-928 MHz) plus 10.7 MHz at the high or low end of the band to account for operation in the receive mode, where the VCO serves as the local oscillator (LO). DDS spur characteristics can change rapidly with output frequency.

The above steps also generally apply to the TRF6901, except that reference spurs will be of interest rather than DDS spurs.

- **Adjusting the VCO tank (TRF6900A)**

The following comments apply to VCO tank adjustments with two Alpha 1247 varactor diodes oriented so they are in shunt with the anode grounded, as in the TRF6900A data sheet example schematic for the North American ISM band. The series capacitor C24 to terminal 13 tends to set the lower end of the tuning range and influences the tuning range width. The series capacitor C23 to terminal 14 tends to set the upper end of the tuning range and also influences the tuning range width.

Initial tuning of the VCO tank with a 10 nH inductor should be done by setting C23 and C24 to the same value--around 3 pF for the 902-928 MHz band with TI's RF-only evaluation board. The capacitors' value can be adjusted up or down to center the tuning range.

The parasitic circuit board capacitance will have an effect on the required capacitor values. Thick, two-layer FR4 circuit boards tend to shift the tuning range up since the parasitic capacitance is lower than for four-layer boards.

The goal is to adjust the capacitor values so that the middle of the tuning range corresponds roughly to half the Vcc rail voltage. The width of the tuning range should cover the desired frequency bands, with allowance for the receive LO frequency and extra bandwidth for production tolerance. An example tuning range for the North American 902-928 MHz ISM band with low side LO injection in the receive mixer would be approximately 880 to 940 MHz.

VCO tank stability can be tested by using mode 0 and mode 1 to toggle rapidly between two widely spaced frequencies; the output RF signal should move quickly, not drag or break up as the PLL relocks to the new frequency. The external clock crystal can be temporarily interrupted by grounding terminal 23 (XOSC1) or at the series resistor (R7) connected to terminal 23 to see if the PLL relocks quickly. VCO startup should be quick at IC power-on.

If the entire tuning range is centered too low or high in frequency, the inductor value may have to be changed and the capacitor tuning process started over again. In general, reducing the inductor value will shift the tuning range higher.

There is no recommended minimum L value for the VCO tank inductor. It is a good idea to start with the VCO tank configuration listed in the data sheet. It specifies a 10 nH wirewound, high-Q inductor, such as Murata's LQW1608 product line.

- **How can the post-detect low-pass filter be adjusted? (TRF6900A, TRF6901)**

The post-detect filter bandwidth is supposed to be about twice the frequency modulation rate. The filter is wide so the FSK modulation rate is not a problem, even if it varies, which it may, depending on data content (NRZ coding).

You can use an oscilloscope to observe the charge-discharge cycle at LPF_OUT. Adjust the filter narrower (bigger cap) if you have a lot of receive noise or if the charge time is way too short. Adjust the LPF wider if the charge time is too long (approaches the symbol period).

- **How do I set up FSK modulation and center the IF band response? (TRF6900A, TRF6901)**

The amount of frequency deviation is set by the control words.

You should center the two FSK frequencies so (Fout_low + Fout_high)/2 gives an IF of 10.7MHz +/- (Fdev/2).

The receive mixer will give primarily sum and difference frequencies of the transmitted RF and the LO. The sum frequencies are well above the IF band. The difference frequencies are within the IF band. The user can choose to place the LO below or above the expected RF transmit frequency.

If you are transmitting on 915 MHz (tx_data=0) and 915.1 (tx_data=1) and set LO=904.3, then your IF frequencies are 10.7 and 10.8 MHz which are not centered in the passband of the IF filter. If the filter is very wide it should not matter, but then the wide IF filter allows more noise into the IF signal. If you transmit on 914.95 and 915.05 MHz, the IF frequencies (10.65, 10.75 MHz) will be centered. This is an advantage of the DDS frequency source: there is very fine adjustment in the transmit and receive LO frequencies.

- **How do I test a data link? (TRF6900A, TRF6901)**

When setting up a link, start by checking the operation of each RF circuit board, then cabling them together, then testing a wireless link.

TRF6900A Frequently Asked Questions

Although the products are designed for easy use, they are not quite plug-and-play. A typical test and setup routine starts with the transmit side (this is the majority of the setup work):

- Check regulator output voltage, board current consumption.
- Check transmit frequency CW waveform and output power on spectrum analyzer.
- Enter frequency (digital word) correction if necessary (usually 20-30 kHz on our boards).
- Check tuning range for 902-928 MHz ISM band, plus 10.7 MHz for low or high side injection.
- Enter frequency deviation and check the FSK-modulated waveform on spectrum analyzer by exercising tx_data.

We test the receive side of the TRF6900A with a Rohde and Schwarz SMT03 signal generator that produces a very clean FSK signal at a set center frequency, deviation (usually 100 kHz total), and modulation rate (5-10 kHz or whatever the data rate is). If you don't have an instrument like this you can use another TRF6900A RF circuit board for the transmit signal.

Set the receive LO so that the two FSK frequencies will be centered in the IF bandwidth after downconversion. Look for a square wave out of the receive unit at rx_data with the test RF input signal at -80 to -95 dBm.

Some things that commonly interfere with good results:

- Improper centering of FSK frequencies in IF bandwidth (transmit and receive frequency settings).
- Excessive frequency error at transmit or receive DDS.
- Excessive DDS spurs in the downconverted IF bandwidth (degrades sensitivity).
- Deviation set too high, wider than IF bandwidth, or IF bandwidth too low.
- Data rate wider than loop filter bandwidth.
- RF signal level too high at receive input, should be less than -30 dBm and more like -60 to -90 dBm.

If the receiver is not working, use the spectrum analyzer to look at the downconverted 10.7 MHz IF waveform at the output of the mixer and IF filter. Use an oscilloscope to examine the baseband signal at amp_out (terminal 30).

- **What should be done about DDS spurs in the IF filter bandwidth? (TRF6900A)**

For wide channel spacing, you will get better receive sensitivity from a frequency deviation of around 100 kHz. Selection of data rate, coding scheme, deviation, modulation frequency, and loop filter bandwidth are covered in detail in the design guides for the TRF6900A and the TRF6901.

Lowering the charge pump current and using a narrower loop filter will, in general, reduce DDS spur levels. Reducing the charge pump current will increase lock time and phase noise. The narrower loop filter will improve phase noise outside the loop filter bandwidth; it will also lower the maximum data rate.

The receive data slicer has an easier time detecting a wide frequency deviation like 100 kHz. If the deviation is too wide, the IF filter bandwidth will also necessarily be wide, and will allow more noise into the IF signal. The IF filter bandwidth should be wide enough to accommodate the 100 kHz deviation, perhaps 150 to 220 kHz.

The DDS will produce spurs regardless of crystal frequency. The 25.6 MHz crystals usually look better at the upper end of the US ISM band. The 26 MHz crystal looks very good around 915 MHz. DDS spurs change with frequency, so the DDS word has an effect on spur distribution and signal strength.

Look at the entire ISM band to find transmit/receive frequency pairs that are sufficiently free of spurs to give good performance. If you are doing low-side LO injection you need to look from 891-928 MHz for the N. American band. Transmit spurs that are very close to the fundamental, perhaps within 5-10 kHz, may not be a severe problem with a high FSK frequency deviation around 100 kHz--it looks just like part of the data to the receiver.

DDS spurs stronger than -20 to -30 dBc within the IF bandwidth that are substantially offset from the fundamental RF signal may cause problems.

Spur problems can be made worse by signal leakage paths from the transmit power supply or RF output path to the VCO power supply or tuning voltage path. This phenomenon is often a circuit board layout or power supply distribution problem.

- **What if the PLL locks in transmit but not in receive? (TRF6900A)**

Usually if there is a serious external hardware problem with the VCO tank or loop filter, neither transmit nor receive works after startup. Occasionally the PLL will lock in one mode but not the other.

Software items to check:

- If you are using the parallel port EVM software that TI provides, you need to configure both modes and send the words to get the part to function correctly when toggling mode. Configure mode 1, send, mode 0, send, and vice-versa. You can lose the information for one mode if you don't send the control words before switching screens and configuring the second mode.
- If you are using your own software, initialize after power-up by sending all of the control words, configuring mode 0 for transmit and mode 1 for receive.
- Try configuring mode 0 for transmit and mode 1 for receive but both set to the transmit frequency, or to frequencies that differ by perhaps 1 MHz.
- Try initializing with mode 0 set up to receive and mode 1 for transmit, with the frequencies you normally use.
- Review the initialization notes in the data sheet--there is a so-called "E latch" that is for test purposes. It is possible to put the TRF6900A into test mode if the E latch is inadvertently activated in which case you may get a noisy signal at rx_out.

Hardware items to check:

- It's possible you have a tuning range problem, where the receive LO frequency is at the edge of the tuning range, and is hard to lock, whereas the transmit frequency is better centered and easier for the PLL to lock to.
- Ideally, you should have 5-10 MHz of tuning range margin for the transmit channels and associated receive LO frequencies. As an example, a tuning range from 895-935 MHz (low-side mix) should have a corresponding tuning voltage of perhaps 0.5 to 2.8 V for a 3.3 V supply.
- Check to see that the tuning voltage (pin 10) remains stable (to a few tenths of a volt) over a period of 30 minutes to an hour in either transmit or receive. The 100 K resistor to ground at terminal 14 helps to stabilize the tuning voltage by providing a dc return.
- Change the tx-rx frequency pair. Put them near the top, center, bottom of the tuning range; see if that changes the behavior.
- Residual solder flux or poor solder joints at the VCO or loop filter can cause PLL locking problems. Reflowing the solder connection and cleaning can clear things up. The current going into the VCO at pins 13 & 14 is tiny and can be affected by poor connections or stray capacitance.
- Change the PLL setup to the data sheet configuration and see if that changes the locking behavior.

- o Observe locking behavior while cycling the standby line in transmit and receive.

- **What parts should I use for the TRF6900A demodulator tank?**

Murata 2.2 uH, 2%, Q=60, shielded, part number LQS33N2R2G04, global part number LQH3ERN2R2G01L

Coilcraft 2.2 uH, 2%, Q=34, not shielded, part number 1008LS-222XG
Toko 2.2 uH, 2%, Q=30, not shielded, part series LLM2520 or LLM3225

Murata, Coilcraft, and Toko make parts that are appropriate for the demod tank. The Murata part has a higher Q, and a 10K resistor is sometimes added to the demod tank to de-Q it a little and increase the response bandwidth. The Coilcraft and Toko parts have lower Qs and the resistor is not needed. If cost is secondary to performance and you need all the receive sensitivity you can get, use the Murata part. Some customers use the Murata part without the 10K resistor and tune the demodulator tank for maximum sensitivity. The shielding on the Murata inductor is sometimes necessary depending on the application.

Venkel sells a 1%, NPO, 100 pF capacitor that is useful for the demodulator tank circuit. A 5% cap may be acceptable for general use. The tighter-tolerance components will allow tuning the maximum tank response closer to the IF frequency (usually 10.7 MHz).

- **What if I can't find Murata part numbers at their Web site?**

Conversion from old part numbers to new global PN for Murata high-Q inductors are as follow:

Old	Global	Package
LQW1608	LQW18A	0603
LQG21C	LQM21D	0805
LQS33	LQH3E	1214

- **What are some example parts for SAW filters and SPDT RF switches?**

SAW filter for 915 MHz ISM band: Murata SAFCH915MAL0N00, 4.5 dB insertion loss, 50 ohm impedance
SAW filter for 868 MHz ISM band: Murata SAFCH869MAM0T00, 4.5 dB insertion loss, 50 ohm impedance
SAW filter for 433 MHz ISM band: Murata SAFCH434MAM0T00, 4.5 dB insertion loss, 50 ohm impedance

SPDT transmit/receive RF switch: Hittite HMC190MS8, 0.4 dB insertion loss, 0/+3V switching input
SPDT transmit/receive RF switch: Hittite HMC226, 0.6 dB insertion loss, 0/+3V switching input

- **Will the TRF6900A or TRF4900 do on-off keying/amplitude-shift keying (OOK/ASK)?**

The TRF6900A and TRF4900 will do OOK by using the control word to switch the transmit amplifier on/off instead of using tx_data. The drawback is that the user is limited to a data rate that is set by the serial word throughput of the system. The TRF4900 will also do on-off keying by toggling tx_data.

An alternate approach for tx-only would be to load mode 0 and 1 with the same configuration info but turn the transmit amp off in mode 0 (on in mode 1), then modulate through the mode line after transceiver configuration is complete.

During OOK, the tx_data line modulates the power amplifier bias in the TRF4900. The amplifier stability in OOK operation should be checked.

So, there are 2 ways to do OOK for the TRF6900A, and 3 ways for the TRF4900.

The RSSI can be used to receive OOK signals.

- **Will the TRF6900A work at frequencies below 800 MHz?**

The TRF6900A transceiver covers 750-950 MHz and is intended for the European 868 MHz and North American 915 MHz ISM bands, as stated in the data sheet.

With modifications it will operate from around 300 MHz up to around 950 MHz. One single hardware configuration will not cover 300-950 MHz; users modify the setup for the particular region they are interested in. Some of these applications are "off the data sheet," so performance can not be guaranteed by TI, even though customers successfully use the TRF6900A at 315, 360, 433, and 460 MHz.

The current opinion is that 300 MHz is about the bottom of the frequency range for practical applications with the TRF6900A. The VCO can be configured for operation below 300 MHz.

Both the TRF4900 and TRF6900A are intended for use from 800-950 MHz, but can go as low as 300 MHz with modifications to the VCO tank. With other modifications to the reference frequency, loop filter, output matching, etc, they might go lower.

- **Will the TRF6900A transmitter work above 950 MHz?**

No, it is not designed to work that high. However, there are some options.

- One approach is to pick off the power amplifier's second harmonic and amplify it for transmit. You may have to use a separate receive mixer for downconversion if the second harmonic isn't present in the VCO output or if it isn't strong enough to give you a good IF signal.
- A second approach is to use a frequency doubler.
- Another option is to increase the reference frequency and see if the DDS/VCO will generate a signal at the desired frequency. The DDS doesn't have enough bits to generate a signal above about 1 GHz with the crystal frequencies normally used. The successful operation of the rest of the chip (demodulator, etc.) should be checked. There may be regulatory issues regarding transmission above the 902-928 MHz band.

- **Will the TRF6900A do analog voice communication?**

Inexpensive analog voice communications is an advanced application. The TRF6900A can do rudimentary analog voice at the usual 800+ MHz, but you have to modulate the VCO directly and the resulting hardware setup costs you PLL lock time (and therefore fast channel scanning). Received signal fidelity may be an issue. A voltage divider is used to superimpose an analog signal of perhaps 10 mV PP on the tuning voltage presented to the VCO. The loop filter must be very narrow. A rule of thumb is that the ac modulating signal must be 5-10 times the loop filter bandwidth.

TRF6900A Frequently Asked Questions

- **Can the TRF6900A (TRF6901) be used for digital voice communication?**

Yes. A microprocessor can be used to digitize and compress voice data for transmission. Two transceivers can be set up to alternately transmit and receive at a high rate, achieving near-full-duplex operation. Sound quality is modest.

- **Can I use an external oscillator instead of a crystal to run the TRF6900 (TRF6901)?**

Yes, the TRF6900A can be run with an external oscillator signal through a 100 ohm resistor to terminal 23 or 24. The signal at the input to the TRF6900A should swing 0 to Vcc. Don't exceed the 4.5 V maximum voltage rating for an external input to the TRF6900. The crystal and shunt capacitors should be removed if they are not used.

- **Amp_out looks OK but rx_data has a lot of hash on it—what's wrong? (TRF6900A)**

This is an initialization problem where the TRF6900A is inadvertently configured in test mode. Refer to the data sheet for proper initialization of the test register.

- **Can I use an external VCO to operate the TRF6900A?**

Yes, about 10 mW of drive at terminal 14 is required.

- **I disconnected the receive circuits for a transmit-only application and now the IC does not work at all—what's wrong?**

The band-gap reference is powered through the demodulator Vcc connection. Reconnect terminal 36 to the power supply. You may need to provide a capacitor to ground at terminal 37.

- **What are the suggested starting component values for 433 MHz? (TRF6900A)**

Reference designators are from TRF6900A data sheet schematic for 902-928 MHz

CQ1 26 MHz crystal, ICM HC45U fundamental

PA output match
L1 18 nH
C4 10 pF

LNA input match
L2 8.2 nH
C7 12 pF
C32 12 pF

LNA output match

L3	18 nH
C9	12 pF
L4	15 nH

Charge pump bias (PD_SET)

R3	200 K

VCO tank

V1, V2	1247-079
L8	33 nH
C24	27 pF
C23	20 pF

VCO tank

V1, V2	1249-011
L8	22 nH
C24	12 pF
C23	10 pF

- **What's an EVM? (TRF6900A, TRF6901)**

It stands for evaluation module, usually just the TRF69xx on a RF-only circuit board with an input buffer and a parallel cable connector and no controller. The term "EVK" has been used at times to denote an evaluation kit that contains both the TRF69xx and MSP430xx in one unit for demonstrating a wireless data link; this setup has an input buffer and a serial cable connector. The EVM is intended as a demonstration tool for the RF transceiver, so it has extra connectors and separate voltage regulators for the digital and RF sections. There are a lot of extra parts; a design intended for production would have a simpler bill of materials.

- **How do two EVMs establish a data link? (TRF6900A, TRF6901)**

Each EVM turns on in the receive state. When the transmit unit sends an alphanumeric string, it is preceded by a training sequence. The receiving microprocessor monitors the TRF6900A rx_data line for activity. When it goes high, the microprocessor starts counting pulses. When it receives eight consecutive pulses of approximately correct width, it recognizes this as a valid training sequence and starts looking for the start bit. The start bit is three times longer than a standard data pulse, and is followed by a delay. During the delay the receiving unit switches to hold mode and prepares to receive the data string. The receiver will calculate a checksum and if correct, will transmit an acknowledgement to the transmitting unit. The procedure is explained in more detail in the application note available on the TI website.

- **How can I fabricate an expedient wire antenna? (TRF6900A, TRF6901)**

Use a quarter-wave wire soldered to the center connector of an SMA edge connector. At 915 MHz a quarter-wavelength is about 3.2 inches, or 8.2 cm. Transmit and receive antennas should be co-oriented, i.e. both vertical or both horizontal.

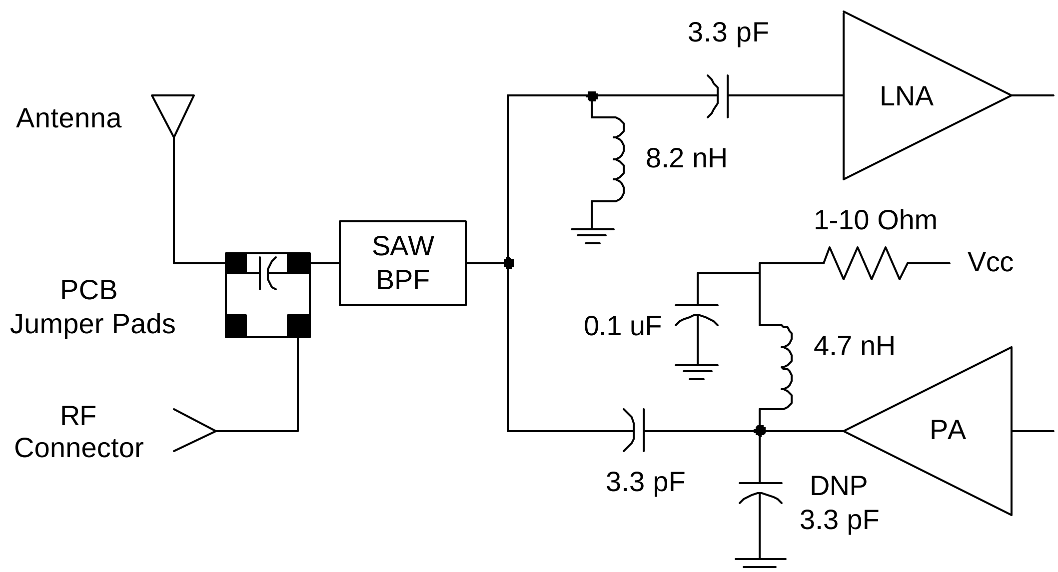
- **Can I use a common antenna for transmit and receive without using a SPDT TR switch? (TRF6900A, TRF6901)**

Best performance with a common antenna is achieved with a SPDT transmit-receive switch. This allows more RF power transfer between the antenna and the receive LNA or transmit power amplifier without losing power in the off circuit.

Without using a transmit-receive switch to a common antenna, it's difficult to get a simultaneous match to the on and off state impedances of both transmit and receive paths, so the transmit power and receive sensitivity will each be degraded perhaps by 3 dB. However, for many applications lower cost outweighs a slight loss of performance.

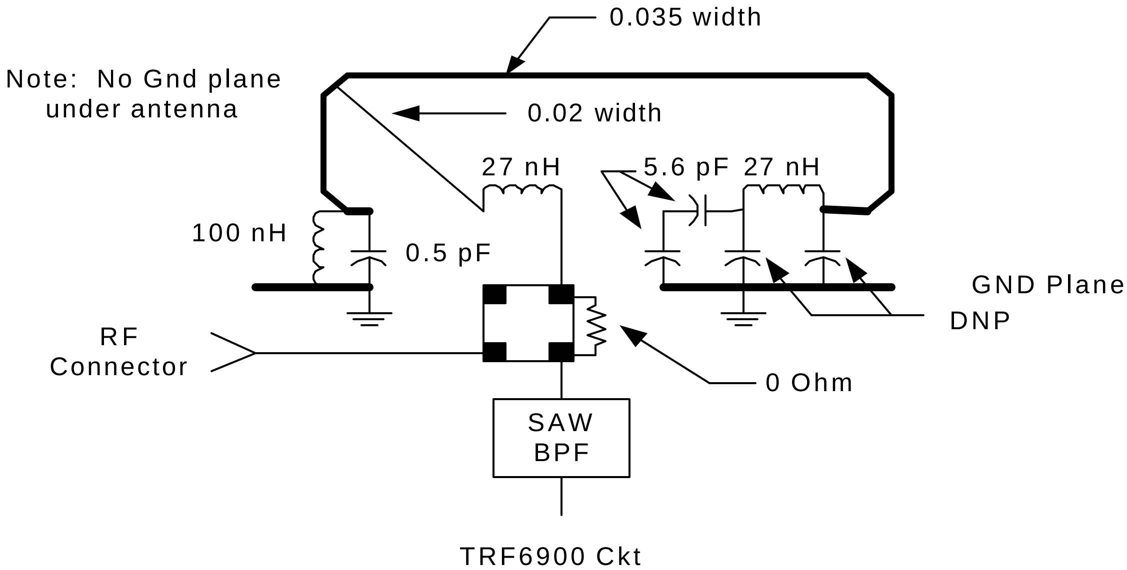
- **How can I implement a common RF port for the TRF6900A at 915 MHz?**

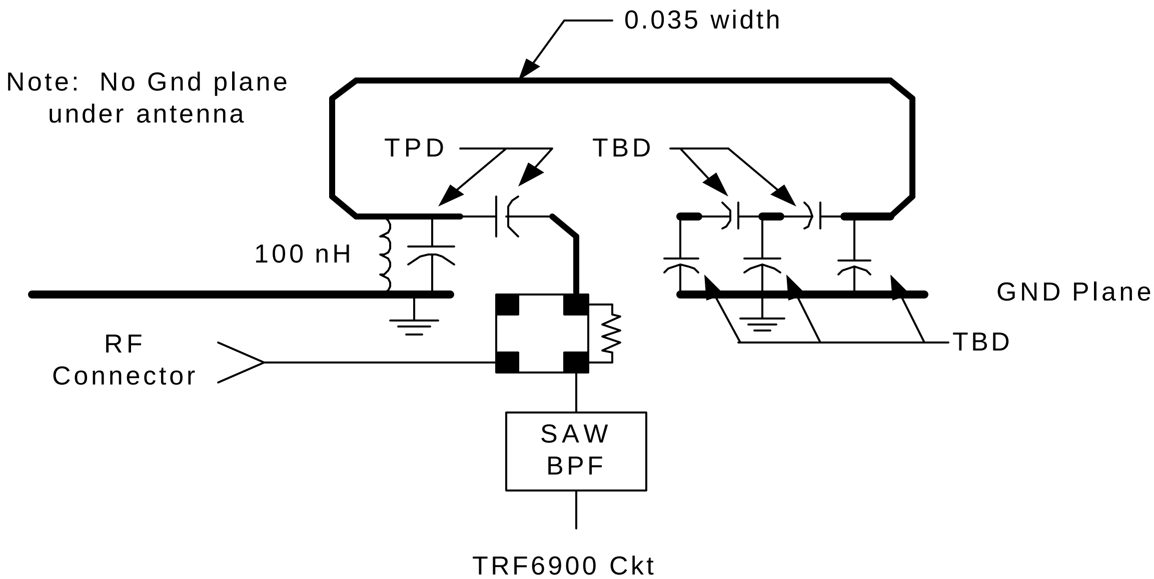
The 3.3 pF shunt capacitor to ground (marked DNP) at the PA output is for additional third harmonic suppression.



- **Circuit board antennas for the TRF6900A, TRF6901**

The following figures show examples of antennas that can be implemented on circuit boards. For small circuit boards, the longer the antenna is the more gain it will have. The zero-ohm jumper provides a connection to either the printed antenna or to a RF connector.


0.035 width
Note: No Gnd plane
under antenna
0.02 width
27 nH
5.6 pF
27 nH
100 nH
0.5 pF
GND Plane
DNP
RF
Connector
0 Ohm
SAW
BPF
TRF6900 Ckt


0.035 width
Note: No Gnd plane
under antenna
TPD
TBD
100 nH
GND Plane
TBD
RF
Connector
SAW
BPF
TRF6900 Ckt

- **What are some of the alternative configurations for the TRF6900A VCO tank circuit?**

1.0) Introduction

The default VCO tank configuration is shown in the data sheet and in Fig. 2.2 in this section. Shown in following figures are various VCO tank circuits. Which circuit should be used depends on the user's requirements and frequency range of operation. Once a VCO circuit is selected it is important to check for VCO stability. The stability of the VCO depends on the PA circuit configuration as well as the values of circuit components used in the VCO circuit itself (PA circuit topology is discussed in section 3).

2.0) VCO Circuits

Shown in Figure 2.1 is a typical VCO circuit for a 915 MHz application. The 100K resistor helps to stabilize the VCO tuning voltage during long periods of operation. The 100K resistor can be added to either terminal 13 or 14. Depending on circuit board parasitic capacitance, adding the 100K resistor may or may not effect the VCO tuning range. The ferrite bead (FB) is used for noise reduction in applications where DC-DC converters or charge-pump regulators are used to supply power to the TRF6900A. Example part numbers for the ferrite bead are Steward (www.steward.com), part number HZ0603C601R-00 (600 ohms @ 100 MHz), or Murata (www.murata.com) BLM11B252SDPT (2500 ohms @ 100 MHz). Capacitor C5 is used to both lower and center the VCO tuning range. The placement of C5 allows adjustment of the VCO gain (Kv) or tuning range. This is useful for ultra-low phase noise applications where the VCO gain (or tuning range) needs to be reduced (a typical value for C5 would be in the range of 0.5 pF to 1.5 pF) for 900 MHz applications. For most applications, the selection of inductor L1 (provides coarse adjustment of the VCO operating point) is sufficient for centering the VCO operating frequency. Depending on the selected VCO topology, the fixed capacitors allow fine adjustment of the VCO center frequency. Ideally, for a VCO tuning from 0 to 3.3 volts, the VCO's tuning range would be adjusted to have the center frequency correspond to a tuning voltage of 1.5 volts.

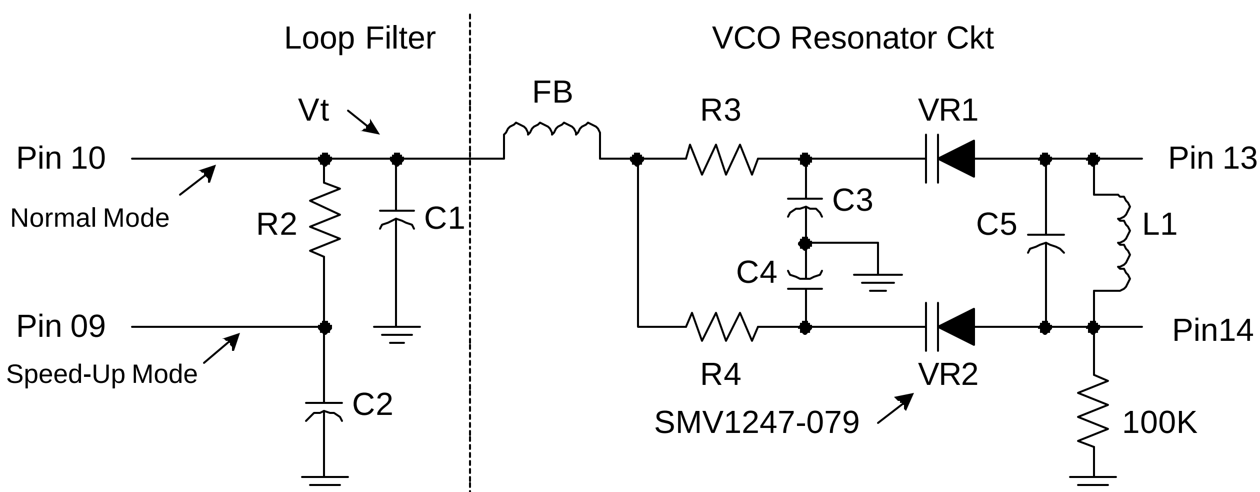


Figure 2.1
$X_C > X_L$

2.1) VCO Stability Check

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It is important to ensure that the VCO is stable over the full tuning range. This can be checked by applying a short to terminal 24 (the input to the clock inverter). Applying the short will turn the reference clock off, allowing the VCO to drift to the 0-volt rail. While observing the RF transmit signal on a spectrum analyzer ensure that the VCO signal is present and stable with a normal noise pedestal (at the 0-volt rail). Likewise, also check that the VCO spectrum is normal when the power amplifier attenuation is cycled through 0, 10, and 20 dB attenuation settings. At each PA attenuation setting, toggle the Standby/Enable line to ensure that the VCO starts. An unstable VCO will show additional side band signals or noise spurs on either side of the main RF signal. When the VCO is enabled it may or may not start at the 0-volt control rail. When enabled, it may start at some other point in the tuning spectrum, which is normal. What is important is that the VCO starts. Failure of the VCO to start is probably due to incorrect selection of component values in the PLL loop filter or VCO tank circuit.

When the short is removed the PLL should instantly lock again (chip is enabled). Applying the momentary short with tweezers will not damage the TRF6900A or circuit components. If doing this test shows an unstable condition then either the VCO circuit values need to be corrected or the PA circuit topology is incorrect.

Note: In order for the VCO circuit shown in Figure 2.1 to be stable and to ensure that the VCO does not have a start-up problem, X_C should be greater than X_L. X_C and X_L are the values of C3, C4, and L1 respectively at the minimum and maximum VCO tuning limits. Also note this condition changes depending on the topology of the VCO circuit being implemented. Table 2.1 shows an example of X_C and X_L values for a typical VCO circuit as drawn in Figure 2.1.

Typical Component Value	R3 & R4	C3 & C4	C5	L1
	10K	2.0 pF	Not Placed	10 nH
X_L =	53.0 ohms	57.4 ohms	61.8 ohms	
Freq =	845 MHz	915 MHz	985 MHz	
X_C =	94.1 ohms	86.9 ohms	80.7 ohms	

Table 2.1

Typical VCO Example

Which VCO circuit to use depends on the application, circuit board parasitic capacitance, and required tuning range. Typically, the VCO circuits shown in Figures 2.1 or 2.2 are recommended. A typical tuning range for the circuit in Figure 2.1 is 120 to 140 MHz. Note that for all VCO circuits shown, the tuning range is based on Vcc set at 3.3 volts.

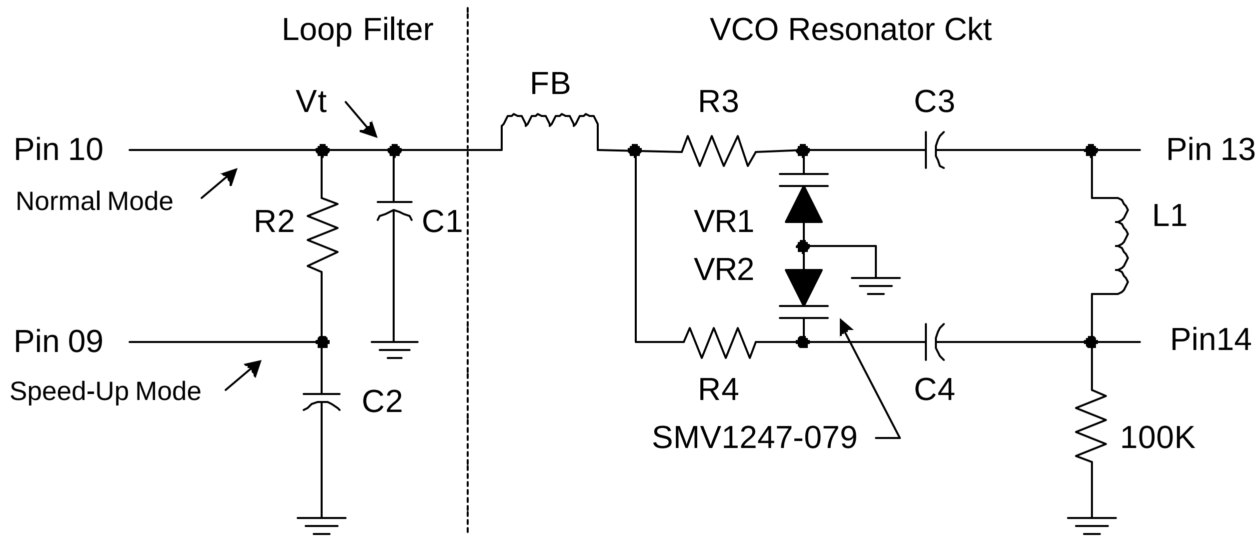

Figure 2.2

$X_L > X_C$

A typical tuning range for the VCO circuit in Figure 2.2 is 90 MHz.

Shown in Figure 2.3 is a VCO circuit used for a 418 / 433 MHz application.

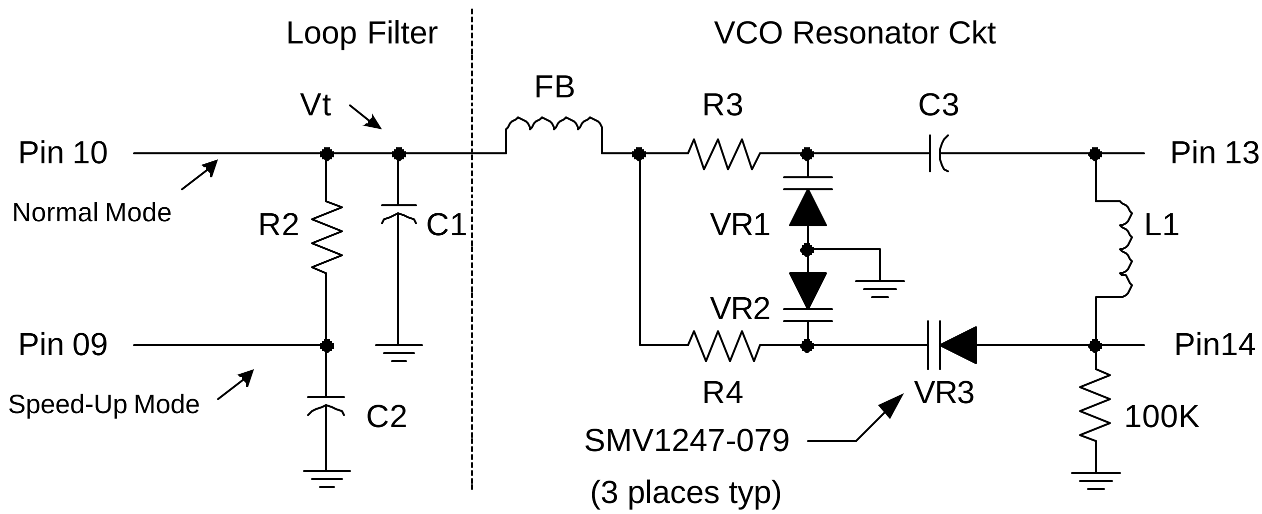

Figure 2.3
$X_L > X_C$

Capacitor C3 determines the lower frequency limit of operation as well as the overall tuning range. Increasing the value of C3 will decrease the low-end frequency limit while increasing the tuning range. Note the limitation on C3 where the value of X_C for C3 must be less than the value of X_L for L1. A typical value for C3 and L1 might be 10 pF and 39 nH. Typical VCO tuning adjustment with these values might be 380 MHz to 475 MHz (Vcc = 3.3 volts), for a VCO tuning range of 95 MHz.

Shown in Figure 2.4 is another version of the VCO circuit of Figure 2.3. Note that if the circuit values of Figure 2.3 were used in Figure 2.4 the VCO circuit would be unstable due to the restrictions of X_C & X_L for the VCO topology.

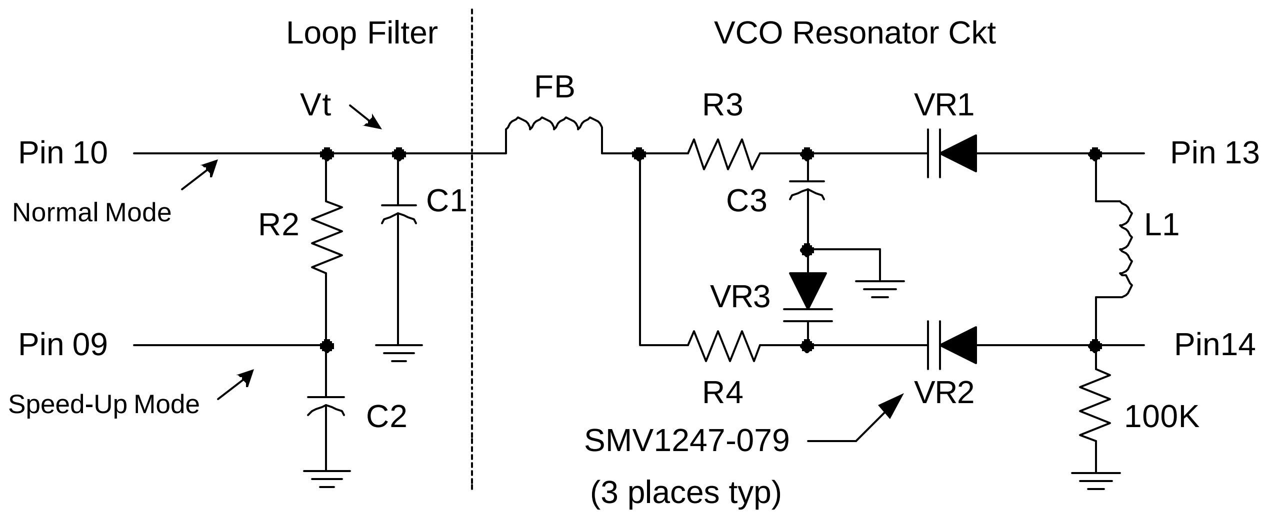

Figure 2.4
$X_C > X_L$

Almost any combination of capacitors or varactor diodes can be used to make up the VCO tank circuit--however, the VCO conditions for stability must be maintained. Figures 2.5 through 2.11 show other VCO circuit topologies.

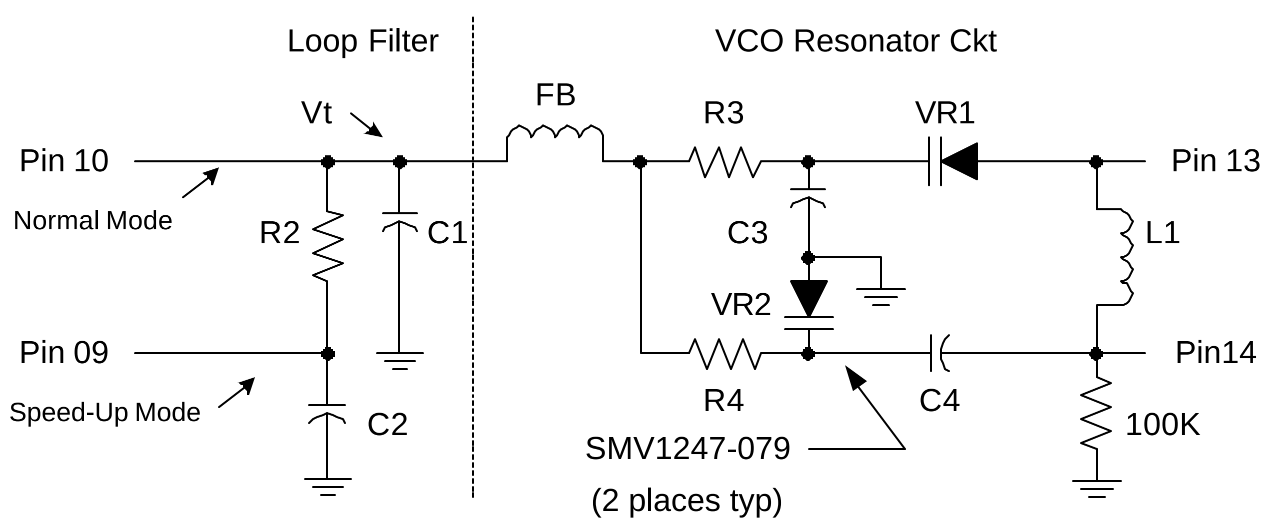

Figure 2.5
$X_{C3} > X_{L1} > X_{C4}$

Figure 2.6 shows another version of the VCO circuit of Figure 2.5. Note the condition for VCO stability. This circuit works well for 915 MHz applications, allowing a typical VCO tuning range of 135 MHz (or 45 MHz / volt), with Vcc set at 3.3 volts.

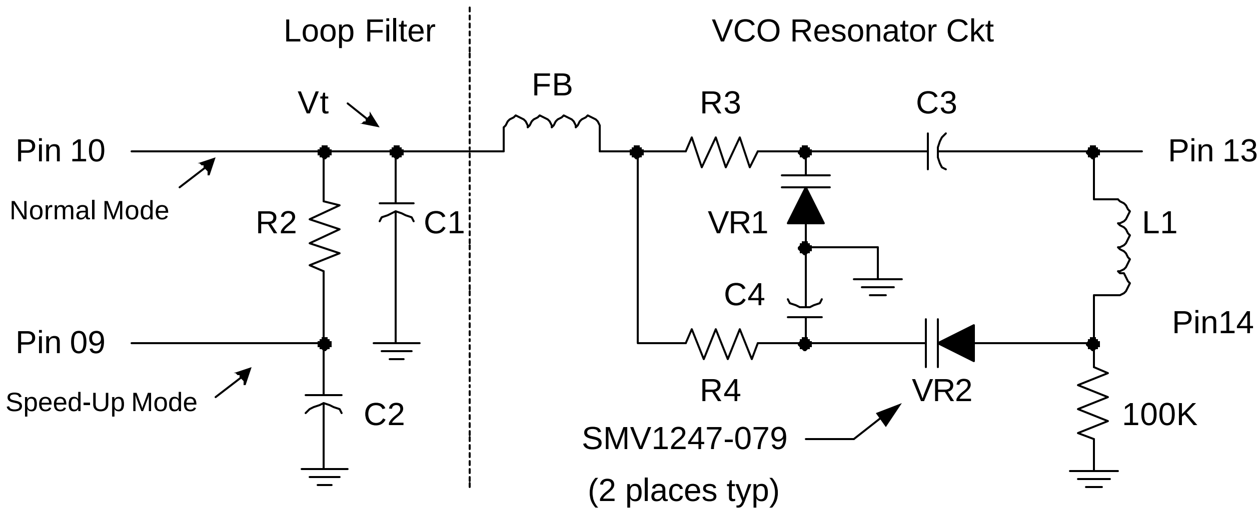

Figure 2.6
$X_{C4} > X_{L1} > X_{C3}$

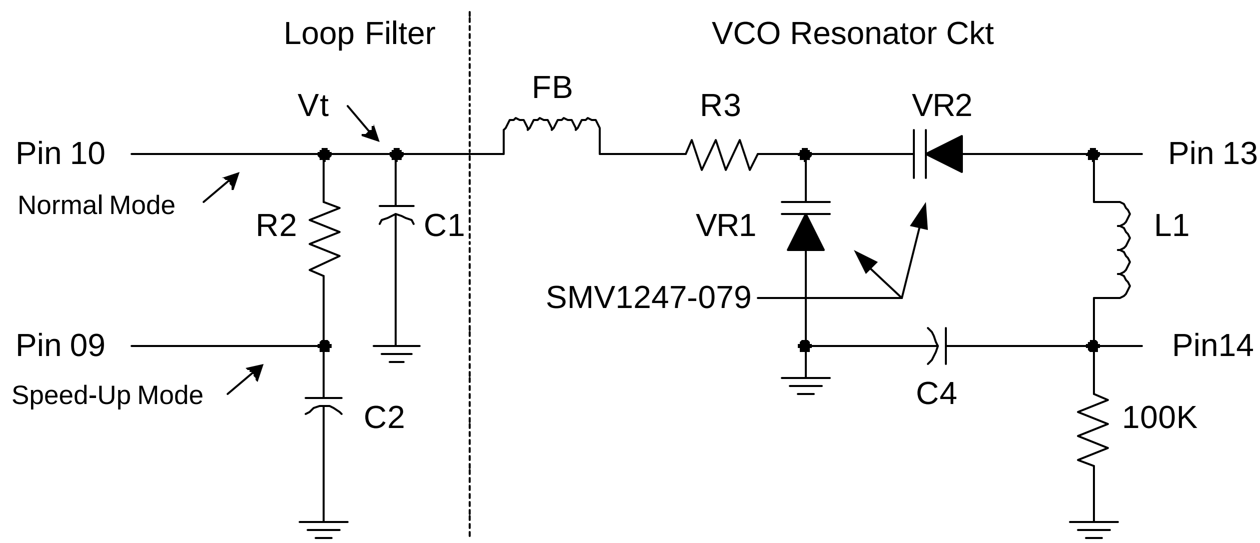

Figure 2.7
$X_C > X_L$

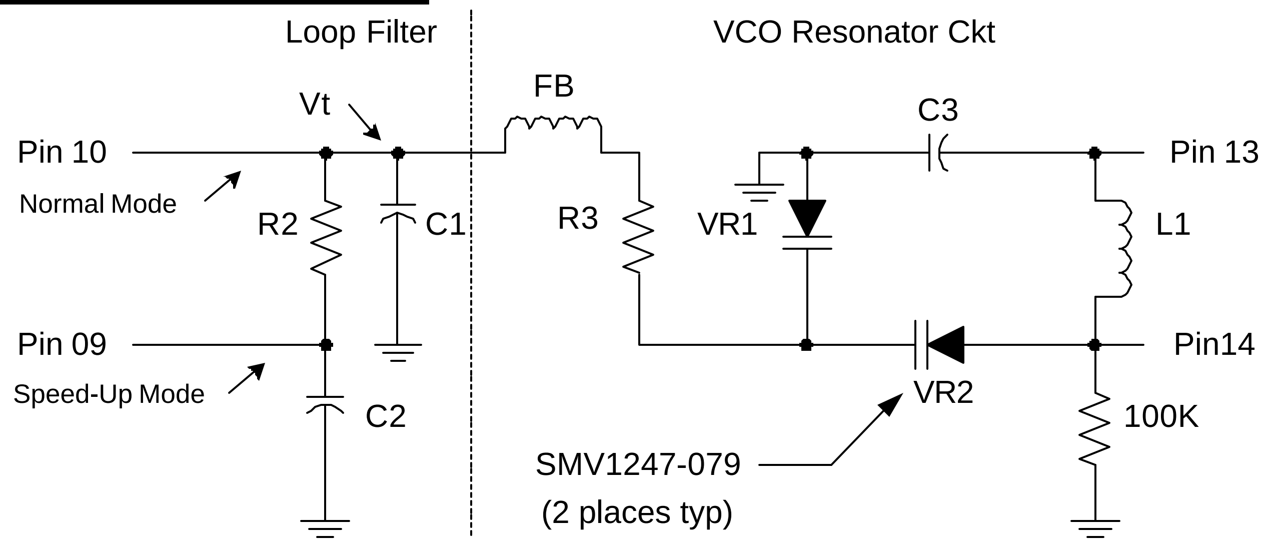

Figure 2.8

$X_C > X_L$

Placing the varactor diodes back-to-back gives a more linear tuning range.

Figures 2.9 and 2.10 show VCO circuits with one varactor diode.

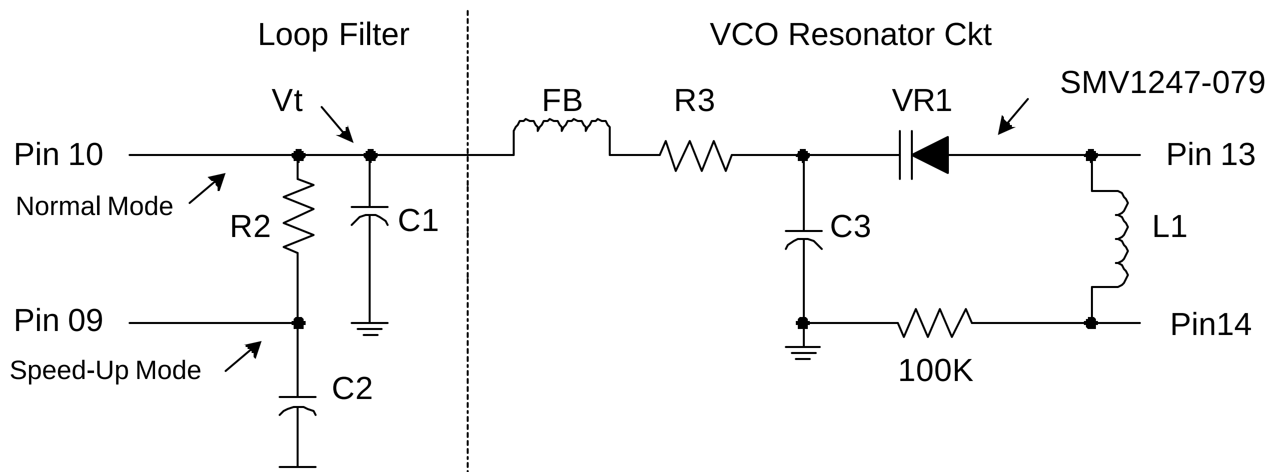

Figure 2.9

$\mathbf{X_C > X_L}$

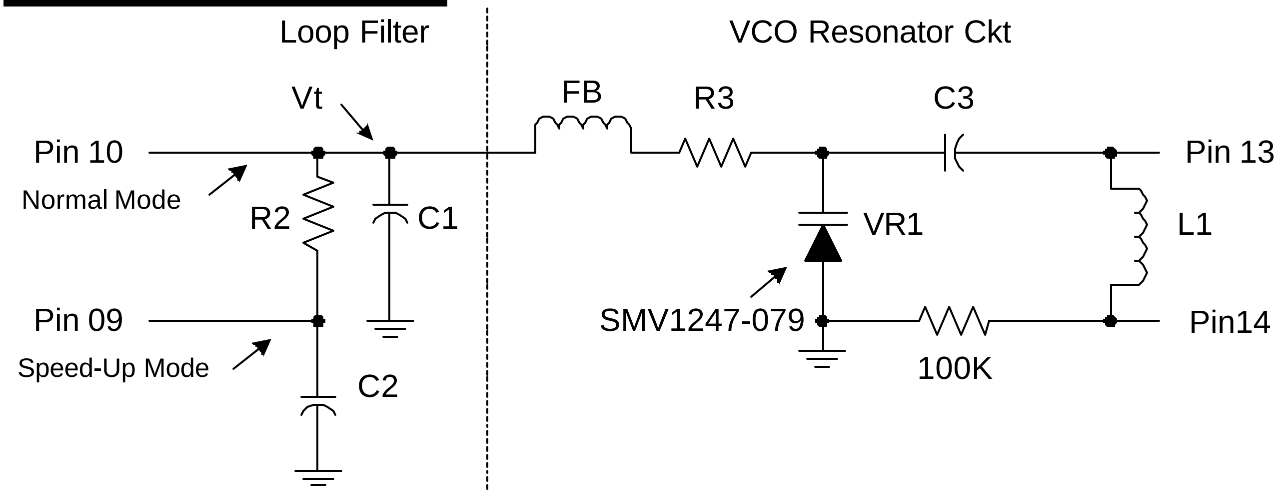

Figure 2.10
$X_L > X_C$

A typical tuning range for the VCO circuits shown in Figures 2.9 and 2.10 is 30 to 60 MHz. The VCO circuit in Figure 2.9 has a higher tuning range than the circuit in Figure 2.10.

Figure 2.11 shows a VCO circuit with four varactor diodes. In this case, the upper and lower tuning limits are determined by the varactor capacitance. The VCO center frequency is controlled through the selection of inductor L1.

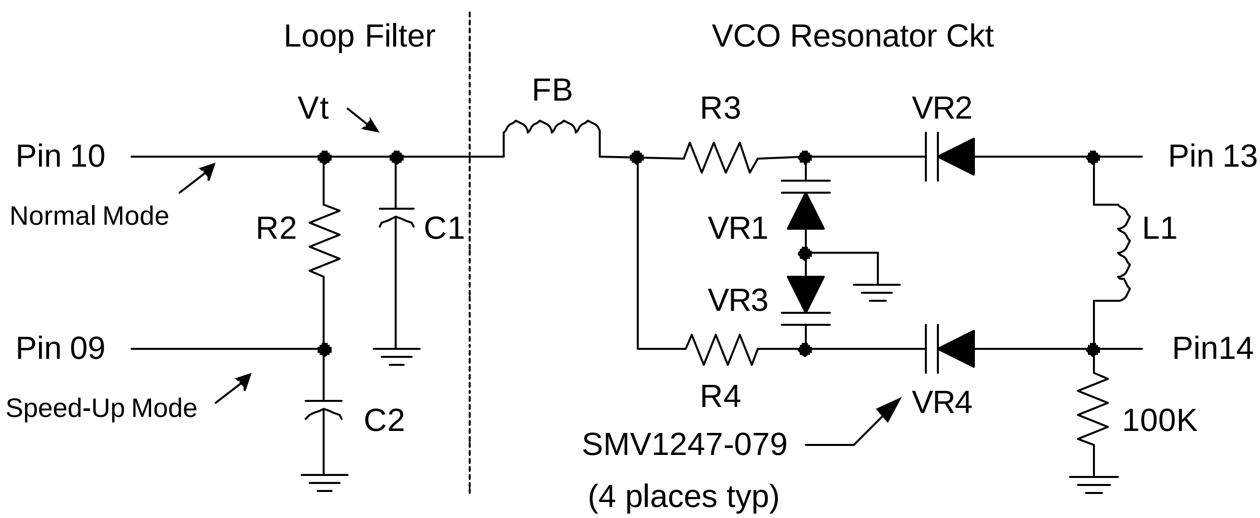

Figure 2.11

Stability is dependent on varactor capacitance and L1.

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- **For demodulation is it possible to use a ceramic discriminator instead of the external LC tank used along with the internal variable inductor?**

Yes the external LC tank can be replaced by a ceramic discriminator. The connection would be as followed:

1. Connect terminal 35 to terminal 34 with a series RF choke.
2. Connect the ceramic discriminator to terminal 34 and ground.

But this type of demodulation circuit is not recommended since the low modulation index capability of the TRF6900 has no function in receiver mode.

- **For certain applications that require more transmit power, would it be advantageous to alter the antenna-sharing circuit to increase the transmit range at the expense of the receive range?**

No, that not really practical with a shared antenna (single-port). A possible solution in that case would be to use a T/R switch which allows the matching of the antenna separately to the RX and TX.

- **Is it possible to turn the power off and still save the data entered?**

No, since this device doesn't have a none volatile memory, the proper register values need to be written every time it is turned on.

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