MICRF102

QwikRadio™ UHF ASK Transmitter

General Description

The MICRF102 is a single chip Transmitter IC for remote wireless applications. The device employs Micrel's latest QwikRadio™ technology. This device is a true "data-in, antenna-out" monolithic device. All antenna tuning is accomplished automatically within the IC which eliminates manual tuning, and reduces production costs. The result is a highly reliable yet extremely low cost solution for high volume wireless applications. Because the MICRF102 is a true single-chip radio transmitter, it is easy to apply, minimizing design and production costs, and improving time to market.

The MICRF102 uses a novel architecture where the external loop antenna is tuned to the internal output stage. This transmitter is designed to comply with worldwide UHF unlicensed band intentional radiator regulations. The IC is compatible with virtually all ASK/OOK (Amplitude Shift Keying/On-Off Keyed) UHF receiver types from wide-band super-regenerative radios to narrow-band, high performance super-heterodyne receivers. The transmitter is designed to work with transmitter data rates from 100 to 20k bits per second.

The automatic tuning, in conjunction with the external resistor, ensures that the transmitter output power stays constant for the life of the battery.

When used with Micrel's family of QwikRadio™ receivers, the MICRF102 provides the lowest cost and most reliable remote actuator and RF link system available.

Data sheets and support documentation can be found on Micrel's web site at: www.micrel.com.



QwikRadio™

Features

- Complete UHF transmitter on a monolithic chip
- Frequency range 300MHz to 470MHz
- Data rates to 20kbps
- Automatic antenna alignment, no manual adjustment
- Low external part count
- Low standby current <0.04µA

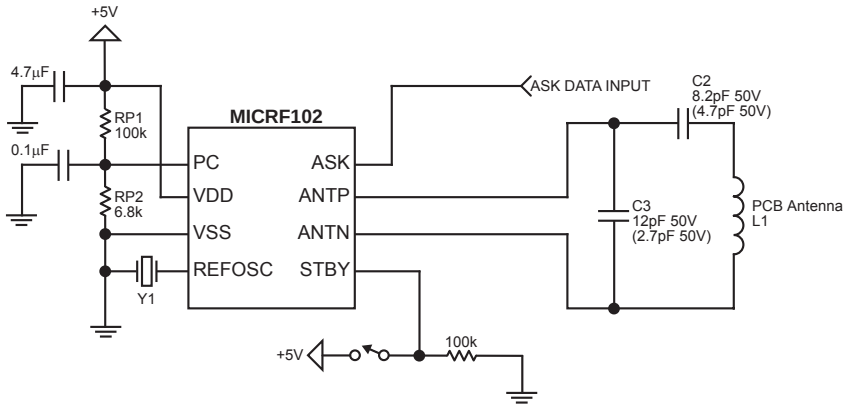
Applications

- Remote Keyless Entry systems (RKE)
- Remote fan/light control
- Garage door opener transmitters
- Remote sensor data links
- Tire Pressure Monitoring System (TPMS)
- Telemetry

Ordering Information

Part Number		Temperature Range	Package
Standard	Pb-Free		
MICRF102BM	MICRF102YM	-40°C to +85°C	8-Pin SOIC

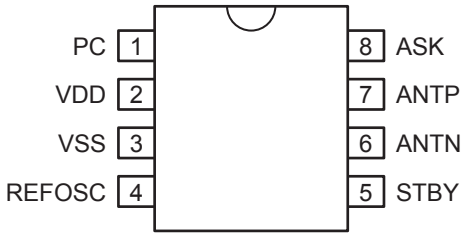
Typical Application



QwikRadio is a trademark of Micrel, Inc. The QwikRadio ICs were developed under a partnership agreement with AIT of Orlando, Florida

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Pin Configuration



8-Pin SOIC (M)

Pin Description

Pin Number	Pin Name	Pin Function
1	PC	Power Control Input. The voltage at this pin should be set between 0.15V to 0.35V for normal operation.
2	VDD	Positive power supply input for the IC. This pin requires a large capacitor for ripple decoupling. A 4.7µF is recommended.
3	VSS	This pin is the ground return for the IC. A power supply bypass capacitor connected from V_{DD} to V_{SS} should have the shortest possible path.
4	REFOSC	This is the timing reference frequency which is the transmit frequency divided by 32. Connect a crystal (mode dependent) between this pin and V_{SS}, or drive the input with an AC-coupled $0.5V_{PP}$ input clock. See *"Reference Oscillator"* section in this data sheet. The crystal needs to have a 10pF load capacitance.
5	STBY	Input for transmitter stand by control pin is pulled to V_{DD} for transmit operation and V_{SS} for stand-by mode. The device requires 0.0 volts to be placed in stand by.
6	ANTN	Negative RF power output to drive the low side of the transmit loop antenna. The RF output stage is tuned in the data transitions in the ASK pin.
7	ANTP	Positive RF power output to drive the high side of the transmit loop antenna. The RF output stage is tuned in the data transitions in the ASK pin.
8	ASK	Amplitude Shift Key modulation data input pin. For CW operation, connect this pin to V_{DD}. Several transitions of highs and lows are required to tune the output RF stages.

Absolute Maximum Ratings (Note 1)

Supply Voltage(V_{DD})..... +6V
Voltage on I/O Pins.....V_{SS}–0.3 to V_{DD}+0.3
Storage Temperature Range ..... –65°C to + 150°C
Lead Temperature (soldering, 10 seconds)..... + 300°C
ESD Rating..... **Note 3**

Operating Ratings (Note 2)

Supply Voltage (V_{DD}).....4.75V to 5.5V
Maximum Supply Ripple Voltage..... 10mV
PC Input Range..... 150mV < V_{PC} < 350mV
Ambient Operating Temperature (T_A) ..... -40°C to +85°C
Programmable Transmitter Frequency Range:
.....300MHz to 470MHz

Electrical Characteristics (Note 4)

Specifications apply for 4.75V < V_{DD} < 5.5V, V_{PC} = 0.35V, T_A = 25°C, $freq_{REFOSC}$ = 12.1875MHz, STBY = V_{DD}. **Bold** values indicate -40°C ≤ T_A ≤ 85°C unless otherwise noted.

Parameter	Condition	Min	Typ	Max	Units
Power Supply					
Standby Supply Current, I_Q	V_{STBY} < 0.5V, V_{ASK} < 0.5V or V_{ASK} > V_{DD} – 0.5V		0.04		µA
MARK Supply Current, I_{ON}	@315MHz, **Note 5**		6	**10.5**	mA
	@433MHz, **Note 5**		8	**12**	mA
SPACE Supply Current, I_{OFF}	@315MHz		4	**6**	mA
	@433MHz		6	**8.5**	mA
Mean Operating Current	33% mark/space ratio at 315MHz, **Note 5**		4.7		mA
	33% mark/space ratio at 433MHz, **Note 5**		6.7		mA
RF Output Section and Modulation Limits:					
Output Power Level, P_{OUT}	@315MHz; **Note 5, Note 6**		–4		dBm
	@433MHz; **Note 5, Note 6**		–4		dBm
Harmonics Output, **Note 7**	@315MHz 2nd harm. 3rd harm.		–46 –45		dBc
	@433 MHz 2nd harm. 3rd harm.		–50 –41		dBc
Extinction Ratio for ASK		**40**	52		dBc
Varactor Tuning Range	**Note 8**	**3**	5	**7**	pF
Reference Oscillator Section					
Reference Oscillator Input Impedance			300		kΩ
Reference Oscillator Source Current			6		µA
Reference Oscillator Input Voltage (peak-to-peak)		**0.2**		**0.5**	V_{PP}

Note 1. Exceeding the absolute maximum rating may damage the device.

Note 2. The device is not guaranteed to function outside its operating rating.

Note 3. Devices are ESD sensitive. Handling precautions recommended. Human body model, 1.5k in series with 100pF.

Note 4. Specification for packaged product only.

Note 5. Supply current and output power are a function of the voltage input on the PC (power control) pin. All specifications in the *"Electrical Characteristics"* table applies for condition V_{PC} = 350mV. Increasing the voltage on the PC pin will increase transmit power and also increase MARK supply current. Refer to the graphs *"Output Power Versus PC Pin Voltage"* and *"Mark Current Versus PC Pin Voltage."*

Note 6. Output power specified into a 50Ω equivalent load using the test circuit in Figure 2.

Note 7. The MICRF102 was tested to be compliant to part 15.231 for maximum allowable TX power. The transmitted power is measured 3 meters from the antenna using transmitter board TX102-2A in Figure 1. Measurement results are summarized in Table 1.

Note 8. The Varactor capacitance tuning range indicates the allowable external antenna component variation to maintain tun-over-normal production tolerances of external components. Guaranteed by design, not tested in production.

Parameter	Condition	Min	Typ	Max	Unit
Digital / Control Section					
Calibration Time	**Note 9**, ASK data rate 20kbps		25		ms
Power Amplifier Output Hold Off Time from STBY	**Note 10**, STDBY transition from LOW to HIGH Crystal, ESR < 20Ω		6		ms
Transmitter Stabilization Time from STBY	From External Reference (500mVpp)		10		ms
	Crystal, ESR < 20Ω		19		ms
Maximum Data Rate – ASK modulation	Duty cycle of the modulating signal = 50%	**20**			kbits/s
V_{STBY} Enable voltage		**$0.75V_{DD}$**	$0.6V_{DD}$		V
STBY Sink Current	$I_{STBY} = V_{DD}$		5	**6.5**	µA
ASK pin	V_{IH}, input high voltage	**$0.8V_{DD}$**			V
	V_{IL}, input low voltage			**$0.2V_{DD}$**	V
ASK input current	ASK = 0V, 5.0V input current	–10	0.1	10	µA

Note 9. When the device is first powered up or it loses power momentarily, it goes into the calibration mode to tune up the transmit antenna.

Note 10. After the release of the STDBY, the device requires an initialization time to settle the REFOSC and the internal PLL. The first MARK state (ASK HIGH) after exit from STDBY needs to be longer than the initialization time. After that, highs and lows in the ASK pin callibrates the output RF stage. See Figures 2, 3, and 4.

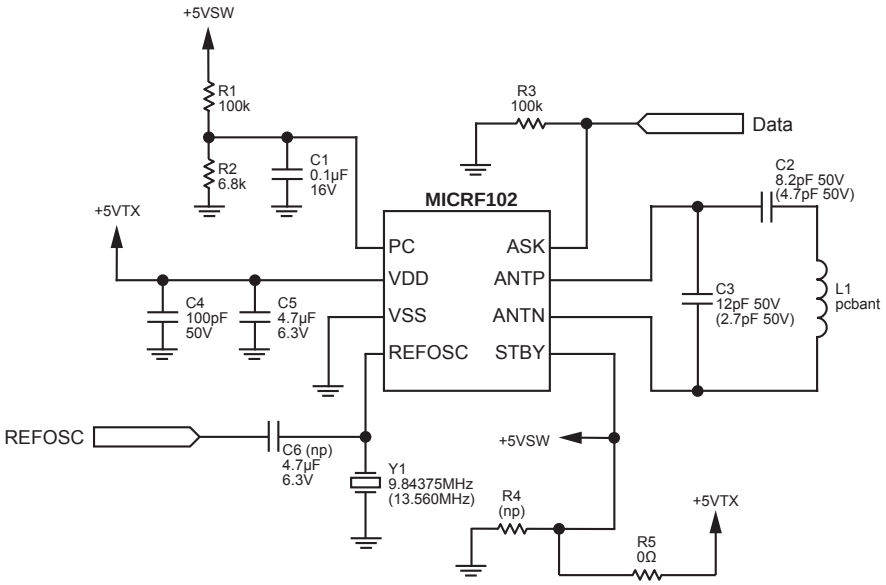


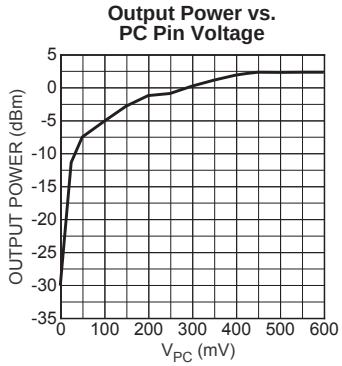
Figure 1.

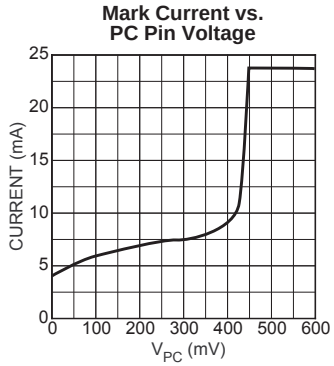
Frequency (MHz)	Antenna Polarity	Height (meters)	Azimuth (0-360)	EMI Meter Reading (dBµV/m)	Duty Cycle Correction (dB)	Corrected Reading (dBµV/m)	Corrected Reading (µV/m)	15:231b Limit (dBµV/m)	Margin (dB)
434.03	V	2.5	140	64.2	5.4	58.8	871.00	80.8	22
868.5	V	1	150	53.1	5.4	47.7	242.70	60.8	33.1
434.03	H	1	150	76.1	5.4	70.7	3427.80	80.8	10.1
868.5	H	1.5	295	60.1	5.4	54.7	543.30	60.8	26.1
1302	V	1	195	41.1	5.4	35.7	61.00	54	18.3
1736	V	1	280	51.3	5.4	45.9	197.20	60.8	14.9
1302	H	2.5	110	49.4	5.4	44	158.50	54	10
1736	H	1	113	44.5	5.4	39.2	91.20	60.8	21.6

Note. Higher order harmonics were found to be below the noise floor of the receiving system for testing.

Table 1. Transmitted Power Measurement with Transmitted Frequency 433.92MHz, FCC Limits and Compliance

Typical Characteristics





RF Output Callibration Time

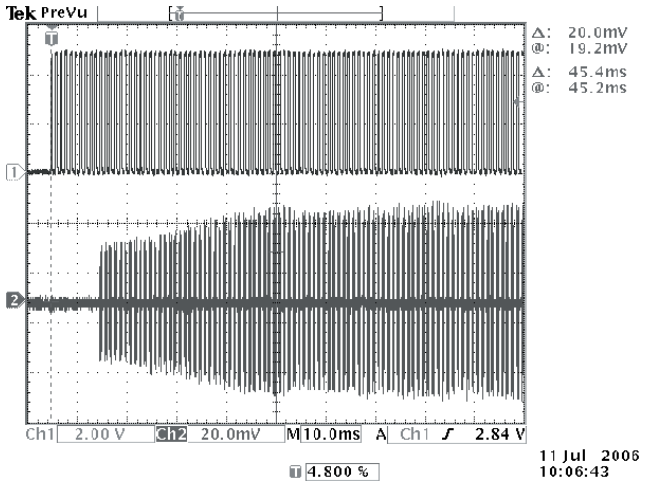


Figure 2. RF Out CAL Time Example (45ms)
Ch 1 - ASK Pin, 1ms Period
Ch 2 RF Field

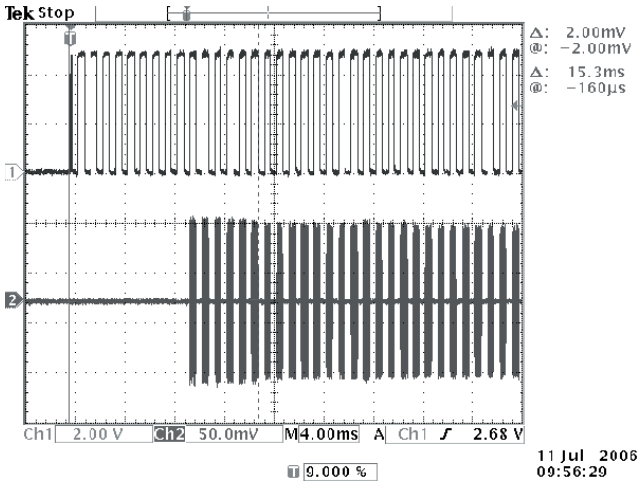


Figure 3. RF Out CAL Time Example from Standby cycle (15ms)
Ch 1 - ASK Pin, 1ms Period
Ch 2 RF Field

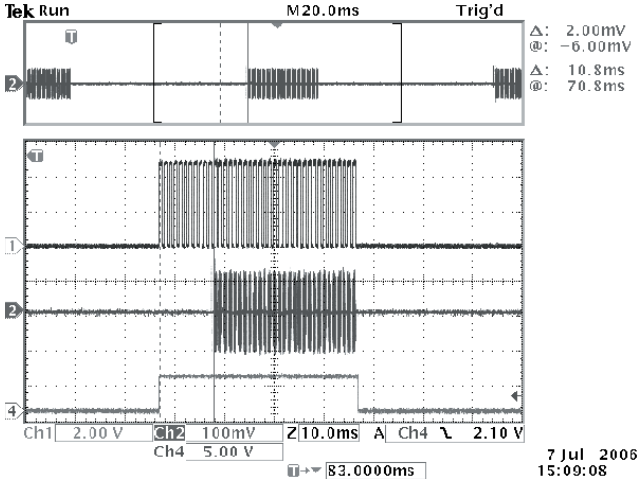
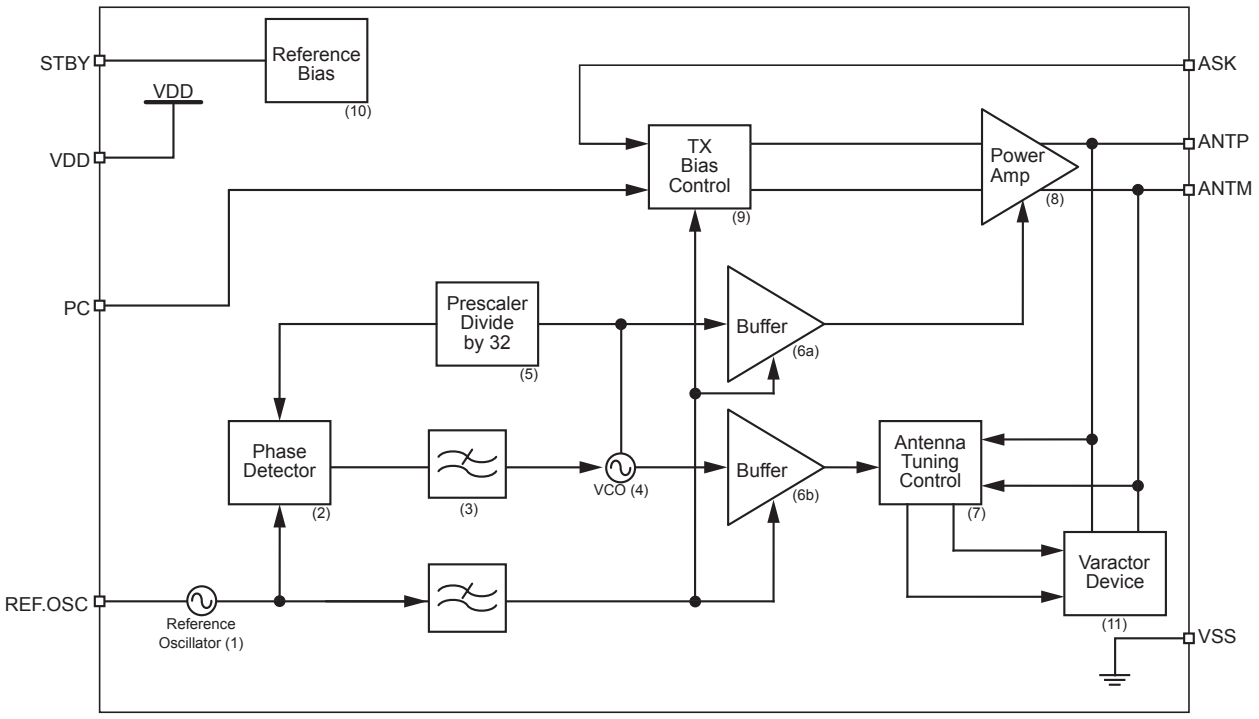


Figure 4. RF Out after shut down cycle example (11ms)
Ch 1 - ASK pin, 1ms period
Ch 2 RF Field, ch 4 - Standby Pin

Block Diagram



Functional Description

The block diagram illustrates the basic structure of the MICRF102. Identified in the figure are the principal functional blocks of the IC, namely the (1, 2, 3, 4, 5) UHF Synthesizer, (6a/b) Buffer, (7) Antenna tuner, (8) Power amplifier, (9) TX bias control, (10) Reference bias and, (11) Process tuner.

The UHF synthesizer generates the carrier frequency with quadrature outputs. The in-phase signal (I) is used to drive the PA and the quadrature signal (Q) is used to compare the antenna signal phase for antenna tuning purposes.

The Antenna tuner block senses the phase of the transmit signal at the antenna port and controls the varactor capacitor to tune the antenna.

The Power control unit senses the antenna signal and controls the PA bias current to regulate the antenna signal to the transmit power.

The Process tune circuit generates process independent bias currents for different blocks.

A PCB antenna loop coupled with a resonator and a resistor divider network are all the components required to construct a complete UHF transmitter for remote actuation applications such as automotive keyless entry.

Included within the IC is a differential varactor that serves as the tuning element to insure that the transmit frequency and antenna are aligned with the receiver over all supply and temperature variations.

Applications Information

Design Process

The MICRF102 transmitter design process is as follows:

1) Set the transmit frequency by providing the correct reference oscillator frequency.

2) Ensure antenna resonance at the transmit frequency by:

$$L_{ANT} = 0.2 \times Length \times \ln(Length/d - 1.6) \times 10^{-9} \times k$$

Where:

Length is the total antenna length in mm.

d is the trace width in mm.

k is a frequency correction factor.

L_{ANT} is the approximate antenna inductance in henries.

Note 1. The total inductance, however, will be a little greater than the L_{ANT} calculated due to parasitics. A 2nH should be added to the calculated value. The L_{ANT} formula is an approximated way to calculate the inductance of the antenna. The inductance value will vary however, depending on PCB material, thickness, ground plane, etc. The most precise way to measure is to use a RF network analyzer.

3) Calculate the total capacitance using the following equation.

$$C_T = \frac{1}{\left(4 \times \pi^2 \times f^2 \times L_{ANT}\right)}$$

Where:

C_T total capacitance in farads.

π = 3.1416.

f = carrier frequency in hertz.

L_{ANT} inductance of the antenna in henries.

4) Calculate the parallel and series capacitors, which will resonate the antenna.

4.1) Ideally for the MICRF102 the series and parallel capacitors should have the same value or as close as possible.

4.2) Start with a parallel capacitor value and plug in the following equation.

$$C_S = \frac{1}{\left(\frac{1}{C_T} - \frac{1}{\left(C_{VAR} + C_P\right)}\right)}$$

Where:

C_{VAR} is the center varactor capacitance (5pF for the MICRF102) in farads.

C_P is the parallel capacitor in farads.

C_S is the series capacitor in farads.

Repeat this calculation until C_S and C_P are very close and they can be found as regular 5% commercial values.

Note 2. Ideally, the antenna size should not be larger than the one shown in Figure 7. The bigger the antenna area, the higher the loaded Q in the antenna circuit will be. This will make it more difficult to match the parallel and series capacitors. Another point to take into consideration is the total AC rms current going through the internal varactor in the MICRF102. This current should not exceed 16mA rms. The parallel capacitor will absorb part of this current if the antenna dimensions are appropriate and not exaggerated larger than the one shown here.

Note 3. A strong indication that the right capacitor values have been selected is the mean current with a 1kHz signal in the ASK pin. Refer to the *"Electrical Characteristics"* for the current values.

Note 4. For much smaller antennas, place a blocking capacitor for the series capacitance (around 100pF to 220pF) and use the following formula for the parallel capacitance $C_T = C_P + C_{VAR}$. The blocking capacitor is needed to ensure that no dc current flows from one antenna pin to the other.

5) Set PC pin to the desired transmit power.

Reference Oscillator Selection

An external reference oscillator is required to set the transmit frequency. The transmit frequency will be 32 times the reference oscillator frequency.

$$f_{TX} = 32 \times f_{REFOSC}$$

Crystals or a signal generator can be used. Correct reference oscillator selection is critical to ensure operation. Crystals must be selected with an ESR of 20Ω or less. If a signal generator is used, the input amplitude must be greater than 200 mV_{PP} and less than 500 mV_{PP}.

Antenna Considerations

The MICRF102 is designed specifically to drive a loop antenna. It has a differential output designed to drive an inductive load. The output stage of the MICRF102 includes a varactor that is automatically tuned to the inductance of the antenna to ensure resonance at the transmit frequency.

A high-Q loop antenna should be accurately designed to set the center frequency of the resonant circuit at the desired transmit frequency. Any deviation from the desired frequency will reduce the transmitted power. The loop itself is an inductive element. The inductance of a typical PCB-trace antenna is determined by the size of the loop, the width of the antenna traces, PCB thickness and location of the ground plane. The tolerance of the inductance is set by the manufacturing tolerances and will vary depending upon how the PCB is manufactured.

The MICRF102 features automatic tuning. The MICRF102 automatically tunes itself to the antenna, eliminating the need for manual tuning in production. It also dynamically adapts to changes in impedance in operation and compensates for the hand-effect.

Automatic Antenna Tuning

The output stage of the MICRF102 consists of a variable capacitor (varactor) with a nominal value of 5.0pF tunable over a range of 3pF to 7pF. The MICRF102 monitors the phase of the signal on the output of the power amplifier and automatically tunes the resonant circuit by setting the varactor value at the correct capacitance to achieve resonance.

In the simplest implementation, the inductance of the loop antenna should be chosen such that the nominal value is

resonant at 5pF, the nominal mid-range value of the MICRF102 output stage varactor.

Using the equation:

$$L = \frac{1}{4\pi^2 f^2 C}$$

If the inductance of the antenna cannot be set at the nominal value determined by the above equation, a capacitor can be added in parallel or series with the antenna. In this case, the varactor internal to the MICRF102 acts to trim the total capacitance value.

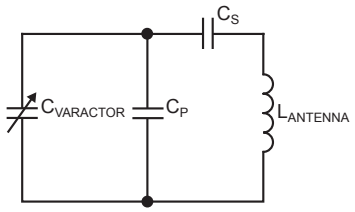


Figure 5.

Supply Bypassing

Correct supply bypassing is essential. A 4.7µF capacitor in parallel with a 100pF capacitor is recommended.

The MICRF102 is susceptible to supply-line ripple, if supply regulation is poor or bypassing is inadequate, spurs will be evident in the transmit spectrum.

Transmit Power

The transmit power specified in this datasheet is normalized to a load of 50Ohm. The antenna efficiency will determine the actual radiated power. Good antenna design will yield transmit power in the range of 67dBµV/m to 80dBµV/m at 3 meters.

The PC pin on the MICRF102 is used to set the transmit power. The differential voltage on the output of the PA (power amplifier) is proportional to the voltage at the PC pin.

With more than 0.35V on the PC pin the output amplifier becomes current limited. At this point, further increase in the PC pin voltage will not increase the RF output power in the antenna pins. Low power consumption is achieved by decreasing the voltage in the PC pin, also reducing the RF output power and maximum range.

Output Blanking

When the device is first powered up, or after a momentary loss of power, the output is automatically blanked (disabled). This feature ensures RF transmission only occurs under controlled conditions when the synthesizer is fully operational, plus preventing unintentional transmission at an undesired frequency. Output blanking is key to guaranteeing compliance with UHF regulations by ensuring transmission only occurs in the intended frequency band.

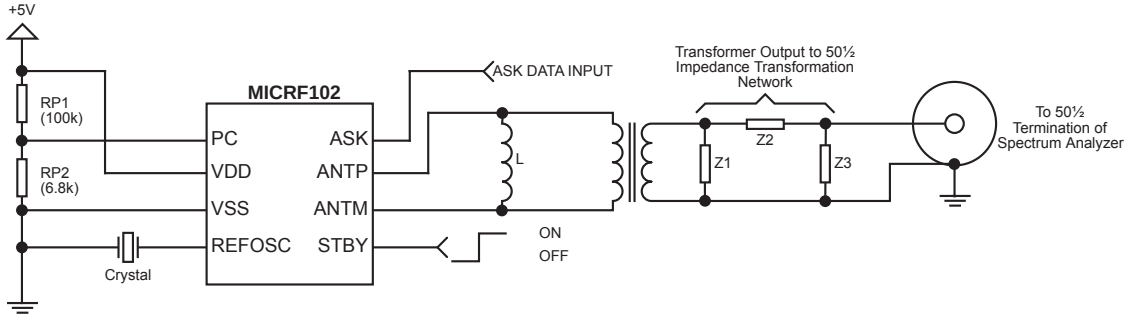


Figure 6. Application Test Circuit For Specification Verification

Design Examples

Complete reference designs including gerber files can be downloaded from Micrel's website at: www.micrel.com/product-info/qwikradio.shtml.

Antenna Characteristics

In this design, the desired loop inductance value is determined according to the table below.

Freq. (MHz)	R (Ω)	XL (Ω)	Ind (nH)	Q (XL/R)	K
300	1.7	84.5	44.8	39.72	0.83
315	2.34	89.3	45.1	39.65	0.85
390	3.2	161	47.4	52.00	0.90
434	2.1	136	50.0	78.33	0.96

The reference design, shown in Figure 7, has an antenna meeting this requirement.

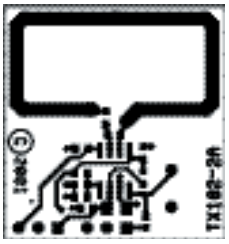


Figure 7. Demo Board PCB.

Loop antennas are often considered highly directional. In fact small loop antennas can achieve transmit patterns close in performance to a Dipole antenna. The radiation pattern below is the theoretical radiation pattern for the antenna, as shown in Figure 8.

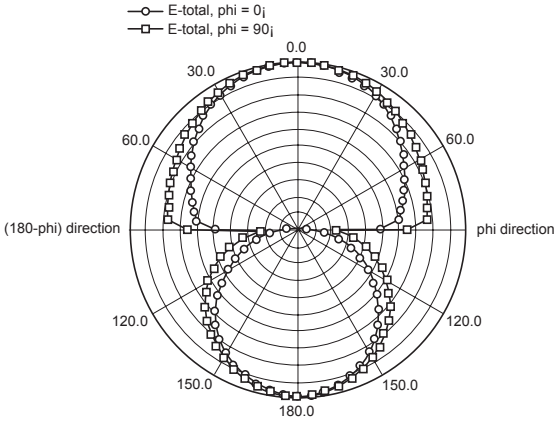


Figure 8. Polar Elevation Pattern at 315MHz.

The 0 degree plot is the radiation pattern in the plane of the transmitter PCB, the 90 degree plot represents the plane perpendicular to the PCB. Micrel's evaluation of the performance of the board in Figure 8 indicates an even more uniform radiation pattern that the theoretical plot shown here.

Supply Bypassing

Supply bypassing consists of three capacitors; C3 = 4.7µF, C4 = 0.1µFand C5 = 100pF

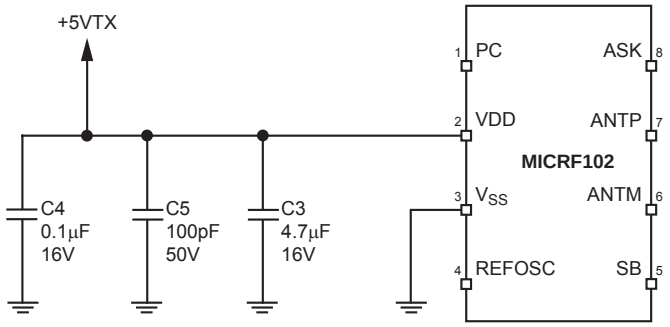


Figure 9. Supply Bypassing

Example to Calculate C_S and C_P Antenna Inductance Calculation

Length_mils = 2815

dmils = 70

k = 0.85

$$\text{Length} = \frac{(\text{Length_mils} \times 25.4)}{1000} \qquad \text{d} = \frac{(\text{dmils} \times 25.4)}{1000}$$

$$\text{Length} = 71.501 \qquad \text{d} = 1.778$$

$$L = 0.2 \times \text{Length} \times \ln\left(\frac{\text{Length}}{d} - 1.6\right) \times 10^{-9} \times k$$

$$L = 44 \times 10^{-9}$$

Where Length and d are in mm and L is in H;

Where k is a constant dependent on PCB material, copper thickness, etc.

MICRF102 Series Capacitor Calculation:

$f = 315 \times 10^6$

$L = 46 \times 10^{-9}$

$C_{VAR} = 5 \times 10^{-12}$

$C_P = 12 \times 10^{-12}$

$$C_T = \frac{1}{4 \times \pi^2 \times f^2 \times L}$$

$$C_T = 2.587 \times 10^{-12}$$

$$C_{SERIES} = \frac{1}{\frac{1}{C_T} - \frac{1}{C_{VAR}}}$$

$$C_{SERIES} = 8.2 \times 10^{-12}$$

MICRF102 Series Capacitor Calculation:

$f = 433.92 \times 10^6$

$L = 52 \times 10^{-9}$

$C_{VAR} = 5 \times 10^{-12}$

$C_P = 2.7 \times 10^{-12}$

$$C_T = \frac{1}{4 \times \pi^2 \times f^2 \times L}$$

$$C_T = 2.587 \times 10^{-12}$$

$$C_{SERIES} = \frac{1}{\frac{1}{C_T} - \frac{1}{C_{VAR} + C_P}}$$

$$C_{SERIES} = 3.9 \times 10^{-12}$$

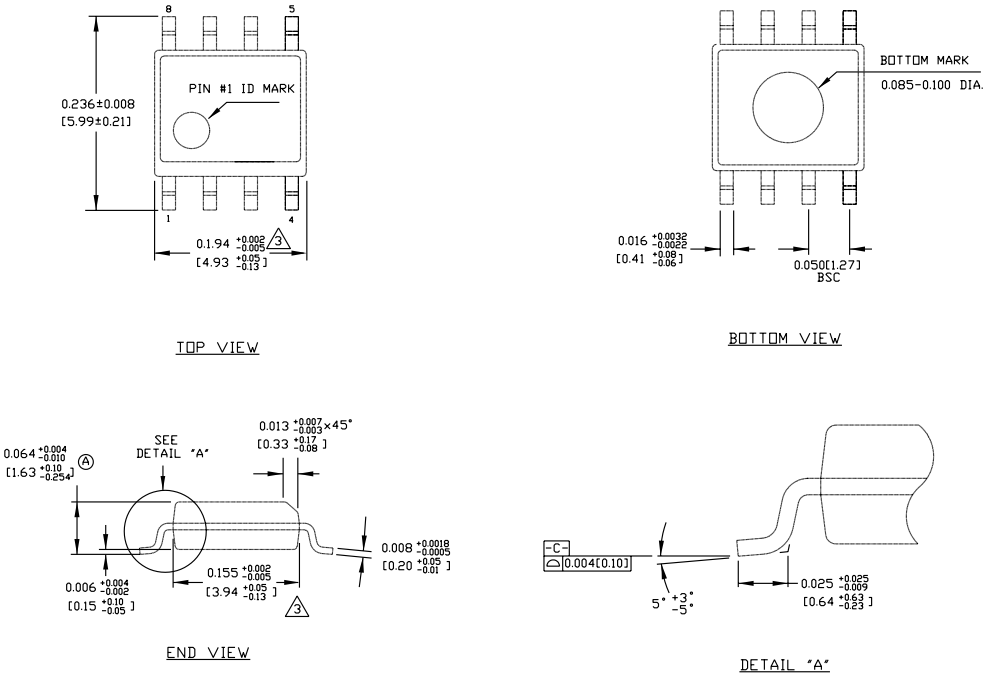
$L1 = 52 \times 10^{-9}$

f1 = 433.92 ¥ 10^6

$$C_{T1} = \frac{1}{4 \times \pi^2 \times f^2 \times L1}$$

$$C_{T1} = 2.587 \times 10^{-12}$$

Package Information



NOTES:
1. DIMENSIONS ARE IN INCHES[MM].
2. CONTROLLING DIMENSION: INCHES.
3. DIMENSION DOES NOT INCLUDE MOLD FLASH OR PROTRUSIONS, EITHER OF WHICH SHALL NOT EXCEED 0.010[0.25] PER SIDE.

8-Pin SOIC (M)

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