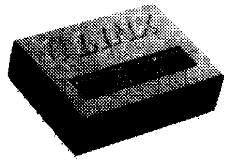
HIGH-PERFORMANCE
SC SERIES
PRE-CERTIFIED
RF TRANSCEIVER



SC SERIES TRANSCEIVER MODULE DESIGN GUIDE

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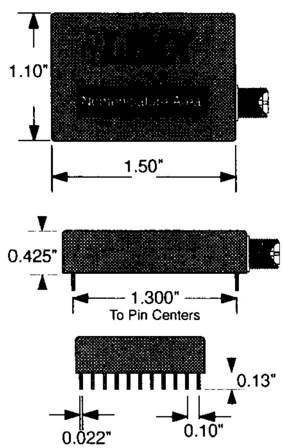
DESCRIPTION:

The TC-XXX-SC-PQ transceiver module is designed for the cost-effective, bi-directional transfer of wireless information. The transceiver is completely self-contained and requires no external RF components. The PQ version of the SC has been previously qualified as a modular product when used with the appropriate proprietary antennas. This greatly reduces the time to market and cost of product introduction. The Transceiver utilizes an advanced synthesized superhet architecture and has direct interface for analog or digital information, fully qualified UART-compatible data output, RSSI, low power consumption, wide operational voltage, on-board TX/RX switch, SAW front-end filter, and many other useful features. Fast turnaround times, along with the support for data rates to 33.6Kbps, make the transceiver suitable for a wide range of applications.



PACKAGE OUTLINE

FEATURES

- Precision crystal-controlled synthesized architecture
- Transparent serial input
- UART-compatible data output
- Built-in data squelching
- High data-rate: 33,600bps
- Can transmit intercom-quality audio
- Single antenna ready (No TX/RX switch required)
- Output power and harmonics are compatible with FCC regulations
- Differential LO dramatically reduces unintended radiation
- Output power can be programmed with an external resistor
- Good sensitivity (-92dBm typical at 10^{-5} BER)
- SAW filter on front-end for superior out-of-band rejection
- Received signal strength indication
- Fast start-up and turnaround time
- Wide input voltage range (2.7 to 16 VDC)
- Very low power consumption (as low as 12 mA)
- Power-down mode – 50µA max (V_{CC} @ 5V)

APPLICATIONS

- **Small Area Networks**
- **Wireless RS:232/485 Modems**
- **Telemetry**
- **Data Collection**
- **Home/Industrial Automation**
- **Long-Range RFID**
- **Robotics**

ORDERING INFORMATION

PART #	DESCRIPTION
TC-XXX-SC	SC Series Transceiver
XXX=433.92, 868, 916MHz	

PERFORMANCE DATA TC-XXX-SC

ABOUT THESE MEASUREMENTS

The performance parameters listed below are based on module operation at 25°C from a 5VDC supply unless otherwise noted.

TRANSMIT SECTION Parameter	Designation	Min	Typ	Max	Units	Notes
Center Frequency	Fc		SEE TABLE 1		MHz	
Fc Tolerance		50		+50	ppm	
Output Power	Po	-5	-3	+1	dBm	1,2
Output Power Control Range			12		dB	1,3
Harmonic Emissions	Ph		-43		dBc	
Spurious Emissions	compatible with FCC part 15					
Frequency Deviation		90	100	120	KHz	4
Data Modulation Bandwidth		.2		17	KHz	4
Audio Modulation Bandwidth		.2		17	KHz	8
Modulation Voltage						
Digital		0		3	VDC	
Analog		0		1	V P-P	12
RECEIVE SECTION						
LO Frequency	Flo		SEE TABLE 1		MHz	
Flo Tolerance		-50		+50	ppm	
Local Oscillator Feedthru			-50		dBm	1
Spurious Emissions	compatible with FCC part 15					
Receive Sensitivity		-94	-92	-90	dBm	5
DC Modulation Sensitivity			-86		dBm	7
Data Slicer Bandwidth		.2		17	KHz	4
Audio Bandwidth		.2		17	KHz	6,8
Audio Level			200		mVp-p	8
RSSI DC Output Range			.5 to 2.5		V	8
RSSI Gain	Grssi		25		mV/dB	8
RSSI Dynamic Range			80		dB	8
ANTENNA PORT						
Input Impedance			50		ohms	8
Input VSWR			1.5:1			8
TIMING						
Power-on to Valid Receive			10		ms	8, 9
Power-on to Valid Transmit			3	5	ms	8, 9
RX to Valid TX Switching			2.5	6	ms	8
TX to Valid RX Switching			3.5	4	ms	8
Minimum Off-Time			10		ms	8
POWER SUPPLY						
Operating Voltage	VCC (pin 10)	2.7		16	VDC	
Current Consumption	Icc					
TX Mode		12		29	mA	3
RX Mode		10	12	15	mA	
Sleep Mode			50		uA	11
ENVIRONMENTAL						
Operational Temp.		0		70	°C	

NOTES:
1) Into a 50-ohm load
2) LVLADJ left open
3) Maximum power when LVLADJ open, minimum power when LVLADJ grounded
4) Pin 9 is modulated with a 3V square wave
5) For 10^{-5} BER at 9,600 baud
6) The audio bandwidth is determined by the needs of the data slicer. In audio applications, it is highly recommended that the user filter the audio using a low pass filter with a maximum cutoff of 5kHz
7) Minimum input power level to ensure that the output will hold a DC level
8) These parameters are only characterized and not tested
9) Measured from rising edge on /PDN
10) Measured from rising edge of carrier modulation on transmit side to valid data on receive side
11) VCC on pin 10 is 5V
12) AC Coupled

MODEL	Center Frequency TX	RX LO	UNITS
TC-433-SC	Not Released		MHz
TC-868-SC	Not Released		MHz
TC-916-SC	916.48	905.78	MHz

Table 1

CAUTION
This product incorporates numerous static-sensitive components. Always wear an ESD wrist strap and observe proper ESD handling procedures when working with this device. Failure to observe this precaution may result in module damage or failure.

TYPICAL PERFORMANCE GRAPHS

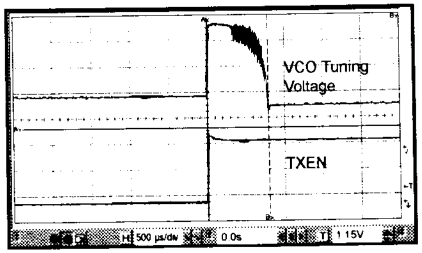


Figure 1: TXEN to PLL lock timing

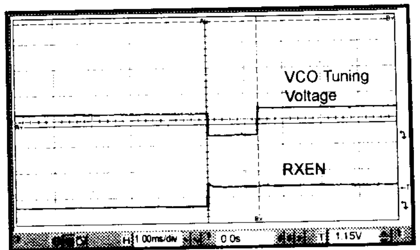


Figure 2: RXEN to PLL lock tuning

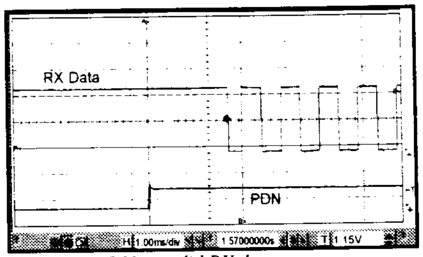


Figure 3: PDN to valid RX data

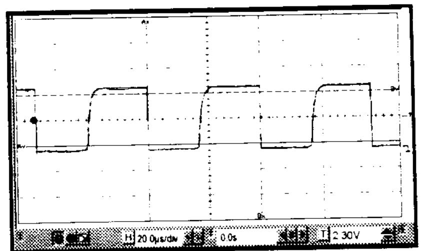


Figure 4: Receive Bit Symmetry @36.8Kbps

PIN DESCRIPTION

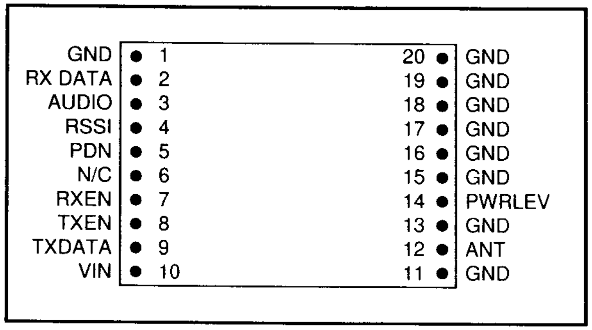


Figure 5: SC Series Pinouts (viewed looking down on top cover)

PIN#	Pin Title	Description
1,11,13 15-20	Ground	Module Grounds Tie to Common Ground Plane
2	RXDATA	Recovered Data Output
3	AUDIO	Recovered Analog Output
4	RSSI	Received Signal Strength Indicator
5	PDN	Logic Low Powers Down The Transceiver
6	N/C	Not Implemented Do Not Connect
7	RXEN	Receiver Enable Pin Active High Pull Low When in TX
8	TXEN	Transmitter Enable Pin Active High Pull Low When in RX
9	TXDATA	Analog or Digital Content to be Transmitted
10	VIN	2.7-16VDC Supply
12	ANT	50Ω Antenna Port TX/RX Switched Inside Module
14	VIN	Open for Maximum Power Insert Resistor to Lower Over 12db Range

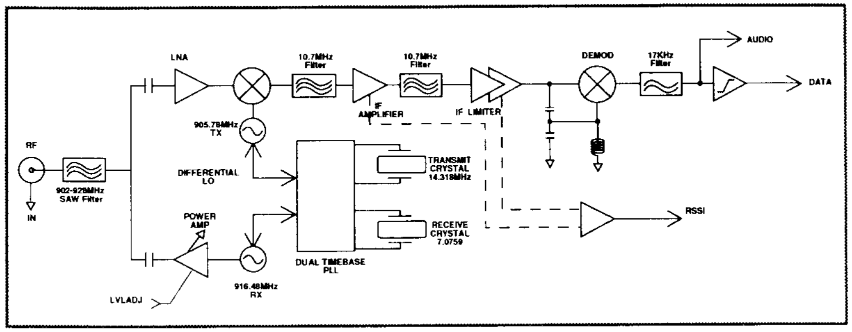


Figure 6: SC Series Block Diagram

DESCRIPTION

The TC-XXX-SC module is a single-channel, half-duplex digital/analog transceiver designed for wireless applications requiring range performance of <500 feet outside and <200 feet inside.

No external components (excluding an antenna) are required. The module incorporates on-board switch allowing the use of a single antenna. Linx offers a wide selection of antennas designed for use with the transceiver module.

The transmit section of the transceiver is capable of producing up to 1mW of output power while maintaining harmonics and spurious emissions within legal limits. The transmitter directly modulates the carrier with the baseband signal present at the TXDATA pin. If the signal is analog in nature, it will FM modulate the carrier. If this signal is a square-wave, then the transmitter modulation method becomes FSK with a peak deviation of +/-50kHz.

Note The TC-XXX-SC is designed to provide only intercom-quality audio. Excessive deviation will cause distortion in the reproduced audio on the receiver end. Please read the section "USING THE TC-XXX-SC FOR AUDIO APPLICATIONS" for more information.

The power amplifier can be adjusted with a 12dB adjustment range. To adjust the power, simply add an external resistor from the LVLADJ pin to ground. The value of this resistor will determine the output power. This is very useful to optimize a product during FCC testing.

The receive section of the transceiver is capable of recovering a signal as low as -92dBm (typical). The receiver operates in a single conversion superhet configuration, with an IF of 10.7 MHz. A quadrature demodulator is used to recover the baseband audio signal from the carrier. This audio signal is filtered and presented to the data slicer to reconstruct the digital waveforms used to modulate the transmitter.

The transceiver is half-duplex. Therefore, it can only be operated in one mode at a time: either transmit mode or receive mode. When transmitting, the receiver is powered down. Likewise, the transmitter is powered down in receive mode.

The transceiver has an on-board voltage regulator that regulates the internal VCC to 3.0V. This allows a wide operating voltage range of 2.7V to 16V. At 2.7V, the internal regulator acts as a saturated switch, directly passing voltage through to the internal electronics. The /PDN pin can be used to put the transceiver into a low-current sleep mode (<50uA).

TRANSMITTER OPERATION

The transmitter is a wide-band FM transmitter capable of generating 1mW of output power into a 50-ohm load.

The transmitter is comprised of a LO and crystal-controlled frequency synthesizer. The frequency synthesizer phase locks the LO to a precision crystal to achieve a high-Q, low phase-noise oscillator.

FM modulation is achieved by varying a reactance in series with the reference crystal. By modulating the transmitter in this manner, a wide modulation bandwidth is achieved. If the transmitter were modulated at the LO, the frequency synthesizer would track out any modulation within the bandwidth of the loop filter (this is a common limitation of most synthesized FM transmitters).

The transmitter is designed to give a peak deviation of +/-50kHz with a 3V square wave input. For 5V systems, we recommend adding a 3.0K resistor in series with the TXDATA pin.

The output amplifier can be externally adjusted to control the output power from -12dBm to 0dBm. The LVLADJ pin is used to control the amplifier. When the LVLADJ pin is at 3V, power is at its max and the transmitter will draw 25mA typically. When LVLADJ is at 0V, power is at its minimum and the transmitter will draw 12mA typically.

An internal 1K pull-up resistor is used to pull LVLADJ to about 2.7V when the transceiver is in transmit mode. To adjust the transmit power, simply place a resistor from the LVLADJ pin to ground to form a voltage divider. Linx recommends placing pads for this resistor whether you intend to use it or not. It will be useful if the power has to be reduced to comply with applicable regulations.

There are two timing parameters that are important to consider when designing with the transceiver: *Start-Up time* and *RX-to-TX time*. The value for each is listed under "Performance Specifications" section of this document. Please make sure that you have a current data sheet prior to designing with the Transceiver.

The start-up time is measured as the time from the /PDN pin going high to the transmitter being ready to transmit data.

The RX-to-TX time is measured as the time from the TXEN pin going high to the transmitter being ready to transmit data.

It is important to note that TXEN and RXEN should never be high at the same time. This will invalidate the timing parameters and may cause illegal emissions from the transceiver.

RECEIVER OPERATION

The receiver is configured as a single conversion superhet FM receiver with a baseband bandwidth of 17kHz.

Low level RF signals are filtered at the front end by a SAW band-pass filter. This filter reduces the signal levels of interfering transmitters such as pager towers and cell phones.

The filtered signal is amplified and down-converted to the 10.7 MHz IF using a

highly-integrated RF IC.

The LO used for the receiver mixer is the same one used for the transmitter. It is a differential LO with very low emissions to ensure compliance with FCC regulations. It is phase-locked to a precision crystal reference by the frequency synthesizer to form a high-Q, low phase-noise oscillator.

The 10.7 MHz IF is amplified, filtered, and finally demodulated to recover the audio baseband signal transmitted by the transmitter.

The audio output is filtered using a 3rd order active low-pass filter. A proprietary data slicer is used to recover the CMOS voltage levels from the audio signal.

When the transmitter is on but not being modulated, or when the received signal strength is too low to ensure proper demodulation, the data output is squelched to a continuous high state. This ensures compatibility with common serial UART's.

The data slicer is capable of recreating squared waveforms in the 400Hz to 17kHz band, giving a data-rate bandwidth of 4800 baud to 33.6kBaud.

There are two timing parameters that are important to consider when designing with the transceiver: start-up time and TX-to-RX time.

The start-up time is measured as the time from the /PDN pin going high to the receiver's data output being valid. The typical value for this time is about 10msec.

The TX-to-RX time is measured as the time from the RXEN pin going high to the receiver's data output being valid. The typical value for this time is about 7mSec.

It is important to note that TXEN and RXEN should never be high at the same time. This will invalidate the timing parameters and may cause illegal emissions from the transceiver.

POWER CONSIDERATIONS

POWER SUPPLY

The user must provide a clean source of power to the receiver to ensure proper operation. In an FM receiver, power-supply noise will manifest itself as AM and FM noise in the receiver circuitry, reducing the overall sensitivity of the receiver. Providing a good power supply for the module is a designer's first line of defense in the battle for receiver sensitivity.

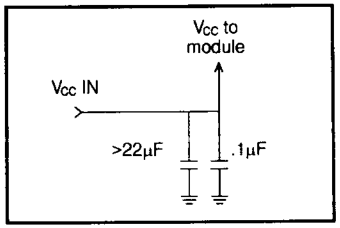


Figure 7: Suggested supply filter

The TC-XXX-SC incorporates a precision Low-Dropout Regulator on-board which allows the module to operate over an input voltage range of 2.7 to 16 volts DC. The module's power-supply line should have low ESR bypass capacitors configured as shown in figure 7.

BOARD LAYOUT CONSIDERATIONS

If you are at all familiar with RF devices, you may be concerned about specialized layout requirements. Fortunately, because of the care taken by Linx in the layout of the module's PCB, integrating an TC-XXX-SC receiver into your design is very straightforward. By adhering carefully to a few basic design and layout rules, you can enjoy a trouble-free path to RF success.

Figure 8 shows the suggested PCB footprint for the SC Series transceiver.

A ground-plane (as large as possible) should be placed directly under the SC Transceiver. This ground-plane can also be critical to the performance of your antenna.

The SC should, as much as reasonably possible, be isolated from all other components on your PCB. Specifically, high-frequency circuitry such as crystal oscillators should be kept as far away as possible from the module.

The trace from the receiver to the antenna should be kept as short as possible. A simple trace is suitable for runs up to 1/8 inch for antennas with wide bandwidth characteristics. For longer runs or to avoid detuning a high-Q narrow bandwidth antenna such as a helical, use a 50-ohm coax or 50-ohm microstrip transmission line as described in the following section.

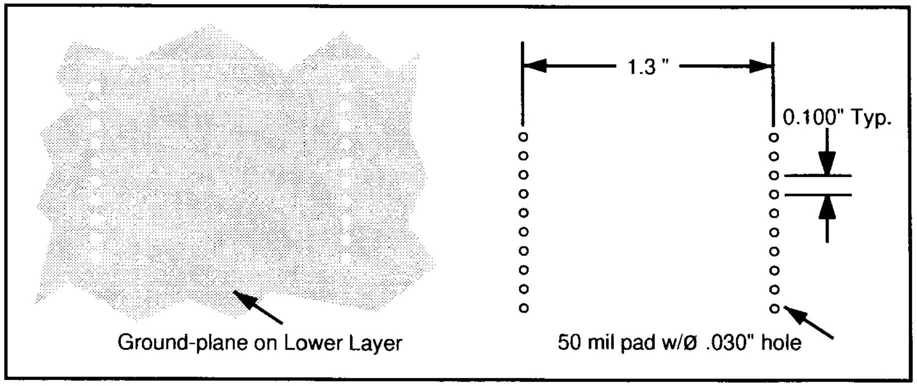
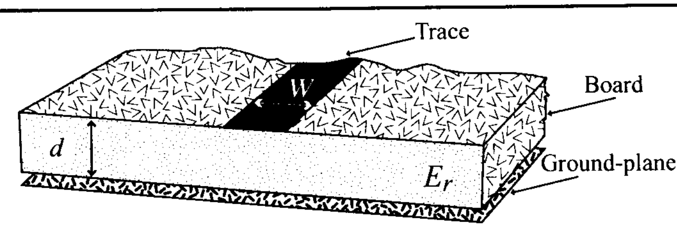


Figure 8: Recommended PCB layout

MICROSTRIP DETAILS

A transmission line is a medium whereby RF energy is transferred from one place to another with minimal loss. This is a critical factor, particularly in high-frequency products like the SC because the trace leading to the module's antenna can effectively contribute to the length of the antenna, changing its resonant bandwidth. In order to minimize loss and detuning, some form of transmission line between the antenna and the module is needed, unless the antenna connection can be made in close proximity: <1/8 in. to the module. One common form of transmission line is coax cable, another is the *microstrip*. The term refers to a PCB trace running over a ground-plane which is designed to serve as a transmission line between the module and the antenna. The width is based on the desired characteristic impedance, the thickness of the PCB, and its dielectric constant. The correct trace width can be easily calculated using the information on the next page.



$$E_e = \frac{E_r+1}{2} + \frac{E_r-1}{2} \cdot \frac{1}{\sqrt{1+12d/W}}$$

$$Z_0 = \begin{cases} \frac{60}{\sqrt{E_e}} \cdot \ln\left(\frac{8d}{W} + \frac{W}{4d}\right) & \text{For } \frac{W}{d} \le 1 \\ \frac{120\pi}{\sqrt{E_e} \cdot \left(\frac{W}{d} + 1.393 + 0.667 \cdot \ln\left(\frac{W}{d} + 1.444\right)\right)} & \text{For } \frac{W}{d} \ge 1 \end{cases}$$

Dielectric Constant	Width/Height (W/d)	Effective Dielectric Constant	Characteristic Impedance
4.8	1.8	3.59	50.0
4	2	3.07	51.0
2.55	3	2.12	48.0

Figure 9: Microstrip formulas (Er = Dielectric constant of pc board material)

A SYSTEM'S DESIGN APPROACH

To properly apply the transceiver, the designer must take a "systems" view of the communications link.

In this communication system, there are a transmitter, an antenna, free space, an antenna, and a receiver. At every point in this system, there are timing and data corruption issues that must be fully understood and accounted for.

It is important to note that the TC-XXX-SC does not encode or packetize the data in any manner. This transparency eliminates the issues of variable latency common to traditional radio modems and gives the designer tremendous flexibility in the structure of protocol. A drawback to this approach is that the performance and reliability of the link is in part determined by the quality of external software and hardware. It is critical that all project engineers have a full understanding and respect for the differences that exist between a wired and a wireless environment. The following section briefly outlines the typical flow of events in a link incorporating SC series modules. There are many alternative methodologies but it is intended to illustrate some of the considerations previously mentioned.

The SC series is a half-duplex transceiver. This means that the transceiver itself can only act as a transmitter or a receiver at any given time, but never both. Designing a system with a half-duplex transceiver is a little more challenging because of the timing requirements when shifting between transmit and receive modes. In a typical system, the operation will be as follows:

1) Switch to transmit mode

The transceiver is placed in transmit mode by bringing TXEN high and RXEN low. The PDN pin must be open or pulled to VCC. Once the transceiver is placed in transmit mode, it will start the VCXO (voltage controlled crystal oscillator) and begin trying to phase-lock the main carrier to the VCXO.

2) Wait for transmitter to stabilize

This step is necessary to allow the transmitter time to stabilize. Lock will normally be accomplished in 4-5mSec after which time the transmitter is ready to begin sending data.

3) Transmit a packet

Packets should be transmitted so that there is no space between bytes. The following packet format should be followed:

[uart sync byte] [start byte] [packet data]

The UART sync byte is used to ensure that the start-bit for the start byte will be accurately detected. It is a single byte with a value of 0FF hex.

The start byte indicates the beginning of the packet. The detection of the start byte would be performed by the computer or microcontroller connected to the transceiver.

4) Switch to receive mode

The transceiver is placed in receive mode by bringing RXEN high and TXEN low. The PDN pin must be open or pulled to VCC. Once the transceiver is placed in receive mode, it will start the crystal oscillator and begin trying to phase-lock the LO to the crystal.

5) Wait for receiver to stabilize

This step is necessary to allow the receiver time to stabilize. When the LO is phase-locked and the data slicer peak detectors are stable, the transceiver is ready to receive valid data. This will normally take 7-10mSec.

6) Receive a packet

The pre-amble serves to set up the data slicer, but can confuse the UART. The UART interprets the start-bit of a byte as a 1-0 transition. When the incoming data is 101010... it is hard to know which 1-0 transition actually marks the start bit. This problem is solved by the UART Sync Byte. It will cause the bit pattern to look like this:

...010101 0111111111. The space indicates the beginning of the UART Sync byte. If the UART were to interpret the last 1-0 transition as a start-bit, it would receive the following byte: 1011111111. The remaining 1's would be ignored and the start-bit of the start byte would be correctly recognized.

The start byte is used by the receiving computer or microcontroller to detect the beginning of a valid packet. In reality, there may actually be two start bytes. In any case, the start byte should be chosen so that it does not appear in the data

stream. Otherwise, a receiver may "wake up" in the middle of a packet and interpret data in the packet as a valid start byte. There are other, more complicated ways to organize the protocol if this restriction cannot be met.

There is a possibility of bursting errors corrupting the data packet, so we recommend that some form of error checking be embedded in the data packet. A simple checksum or CRC could be used.

When used for half-duplex communications, the microcontroller will basically run through the steps in order and then return back to step 1, flipping back and forth between transmit and receive modes. In this case, the designer must take into account the timing considerations of both the transmitting and receiving sides. The preceding flow description is very simplistic and is for illustration purposes only. The systems designer should carefully think through protocol issues to ensure reliability under field conditions.

USING THE TC-XXX-SC FOR AUDIO APPLICATIONS

The SC series is optimized for the transmission of serial data; however, it can also be used to send a variety of simple and complex analog signals including audio. For application requiring high-quality audio the SC series may not be an appropriate choice. For applications requiring "intercom quality" audio, or a combination of audio and data, the SC modules bear strong consideration.

The audio source should provide a 1V P-P waveform and should be AC-coupled into the TXDATA pin. It should be bandwidth-limited to 3-5kHz. Figure 10 shows a sample circuit. Distortion can occur if the TXDATA pin is overdriven. The actual level of the input waveform should be adjusted to achieve the desired results in your circuit.

The RXAUDIO output of the transceiver should be filtered to 3-5kHz using a low-pass filter. The circuit in figure 11 shows an example of a 5kHz low-pass filter.

The SNR of the audio will depend on the bandwidth you select. The higher the SNR, the less "crackling" you will hear in the background. For the best SNR, choose a filter cutoff of 3kHz. Obviously, this will limit the audio frequency range that can be transmitted. If a higher frequency range is required, the cutoff can be raised to a value up to 8kHz or so, with a degradation in SNR.

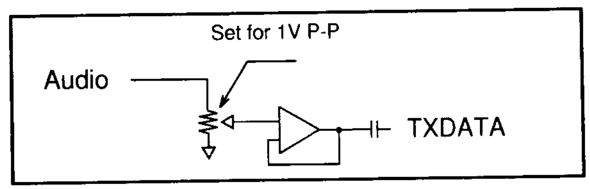


Figure 10

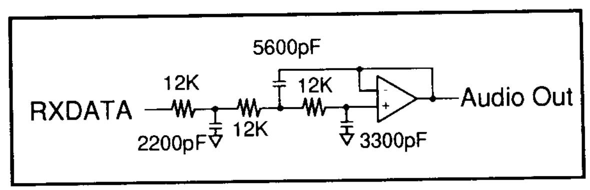


Figure 11

LEGAL CONSIDERATIONS

The TR-916-SC module has been previously tested and received further certification as a modular product. The pre-certified status of the module is valid only if all of the following are observed:

- No modifications to the module may be made.
- The module must utilize Linx RH or CW series antennas. These antennas utilize non-standard connectors and were the antennas utilized for device approval.
- The pre-certified status applies only to the RF module. The user must determine if additional certification or testing is required for peripheral components or the users market.
- If the transceivers own label is not visible when installed inside another device then the device must display an external label referring to the enclosed module. The exterior label should appear as follows:

This device contains a previously certified RF Transceiver module FCC ID:OJM-TR-916-SC

The products instruction manual must display the following statement:

INSTRUCTION TO THE USER

This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to Part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses and can radiate radio frequency energy and if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

Reorient or relocate the receiving antenna.

Increase the separation between the equipment and receiver.

Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.

Consult the dealer or an experienced radio/TV technician for help.

This equipment has been certified to comply with the limits for a class B computing device, pursuant to FCC Rules. In order to maintain compliance with FCC regulations, shielded cables must be used with this equipment. Operation with non-approved equipment or unshielded cables is likely to result in interference to radio and TV reception. The user is cautioned that changes and modifications made to the equipment without the approval of manufacturer could void the user's authority to operate this equipment.

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