

HP SERIES-II RECEIVER MODULE DESIGN GUIDE

DESCRIPTION:

The HP Series-II receiver module is designed for the cost-effective, high-performance wireless transfer of analog or digital data, in the popular 902-928MHz band. The receiver offers eight selectable channels and, when paired with an HP Series-II transmitter, is capable of receiving analog and digital information for distances up to 1000 feet (under optimum conditions). The receiver employs an advanced microprocessor-controlled synthesized architecture. Like all Linx modules, the HP Series-II requires no tuning and in most cases no external RF components (except an antenna), making integration straightforward even for engineers lacking previous RF experience.

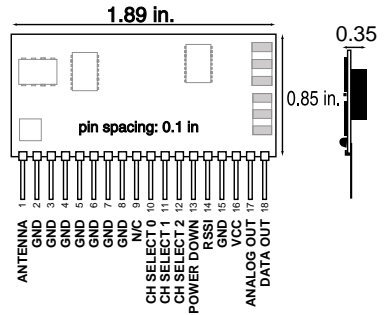


Figure 1: Physical Package

FEATURES:

- 8 Binary Selectable Reception Frequencies
- Exceptional Sensitivity (-95dBm @ 10⁻⁵ BER typical)
- High Serial Data Rate (50Kbps max.)
- Direct Serial Interface
- Fully Qualified Data Output
- Wide-Range Audio-Capable Analog Output (50Hz-25KHz)
- Cost-Effective
- No External RF Components Required (Except Antenna)
- Manufacturing-Friendly SIP-Style Packaging
- Precision-Synthesized Frequency Reference
- Wide Supply Range (2.7-16V DC)
- Receive Signal Strength (RSSI) and Powerdown Pins
- No Production Tuning

APPLICATIONS INCLUDE:

- Continuous Data Transfer
- Home/Industrial Automation
- Wireless Networking
- Remote Control
- Remote Access
- Remote Monitoring/Telemetry
- Fire/Security Alarms
- Long-Range RFID
- High-Quality Wireless Audio
- Analog Signal Transfer
- General Wire Elimination

ORDERING INFORMATION

PART #	DESCRIPTION
MDEV-900-HP-II	Evaluation Kit 900 MHz
TXM-900-HP-II	Transmitter 900 MHz
RXM-900-HP-II	Receiver 900 MHz

SPECIFICATIONS

ABOUT THESE MEASUREMENTS

The performance parameters listed below are based on module operation at 25°C from a 5VDC supply unless otherwise noted. It is recommended all ground pins be connected to the ground-plane. The pin marked N/C has no physical connection and is designed only to add support.

Parameter	Designation	Min.	Typical	Max.	Units	Notes
Input Voltage	V _{CC}	2.7	–	16.0	Volts	–
Supply Current	I _{CC}	16	18	20	mA	1
Sleep Current	I _{SLP}	–	–	50	µA	–
Data output:						
Logic low	V _{DOL}	GND	–	0.5	VDC	–
Logic high	V _{DOH}	V _{CC} -0.3	–	V _{CC}	VDC	–
RF input impedance	R _{IN}	–	50	–	Ohms	–
Receive frequency	F _C	903.37	–	921.37	MHz	2
Noise Bandwidth	N _{3DB}	–	280	–	KHz	–
Data Bandwidth		300	–	50,000	Bps	–
Audio Bandwidth		50	–	25,000	Hz	–
Sensitivity		-92	-95	-100	dBm	3
DC Modulation Sensitivity		-88	–	–	dBm	4
RSSI:						
Dynamic Range		60	70	80	dB	–
Gain	G _{RSSI}	–	24	–	mV/dB	–
Voltage/No Carrier		–	–	1.6	mV	–
Spurious Emissions		–	–	-45	dBm	–
Interference Rejection:						
Half F _C Spurious		–	60	–	dB	–
F _C ±1MHz		–	20	–	dB	–

Figure 2: Specifications table

Notes:

1. Over full operating voltage
2. Depends on CS0 - CS2 voltage levels
3. For 10⁻⁵ BER @ 9600 bps
4. Minimum input power level to ensure that data output can hold a DC level

Absolute Maximum Ratings:			
Supply voltage Vcc	-0.3	to	18 VDC
Operating temperature	0°C	to	+70°C
Storage temperature	-45°C	to	+85°C
Soldering temperature	+260°C for 15 sec.		
RF input, pin 1	0 dBm		
NOTE Exceeding any of the limits of this section may lead to permanent damage to the device. Furthermore, extended operation at these maximum ratings may reduce the life of this device.			

Figure 3: Maximum ratings table

TYPICAL PERFORMANCE GRAPHS

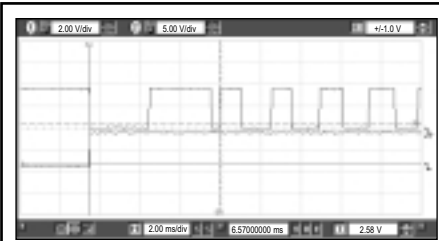


Figure 4: Receiver Turn-on Time

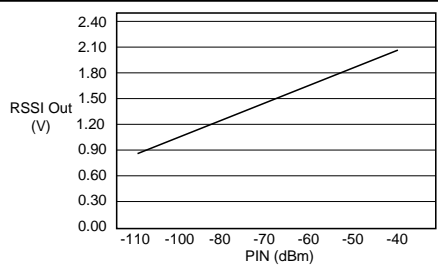


Figure 5: Receiver RSSI

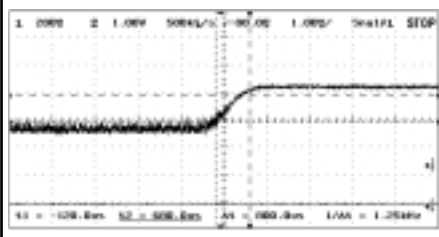


Figure 6: RSSI Response Time

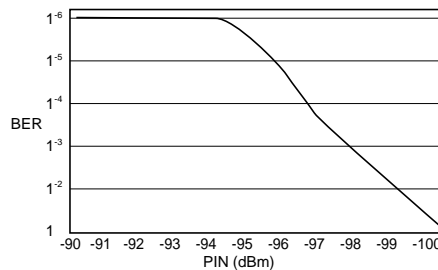
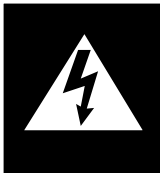


Figure 7: BER vs. Input Power (typical)



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.

PHYSICAL PACKAGING

The receiver is packaged as a hybrid through-hole SIP-style module with 18 pins spaced at .1" intervals. Baseband components occupy the rear of the board while high-frequency components are grouped on the front. Pin 1 is on the far left of the board when viewed from the front.

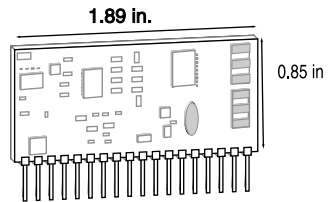


Figure 8: Physical package

PRODUCTION CONSIDERATIONS

The SIP module may be installed using hand- or wave-solder techniques. The module should not be subjected to reflow. If the module is subject to production wash cycles, adequate drying time should be allowed prior to power-up. If the wash cycle introduces contaminants, the module's performance may be adversely affected.

HP-II RECEIVER MANUAL TIMING CONSIDERATIONS

There are five major timing considerations the engineer must be aware of when designing with the HP Series-II receiver. These are shown in figure 8A below, and are labeled T_1 through T_5 .

Parameter	Description	Min.	Max.
T_1	Carrier turn-on settling time		5 mSec
T_2	Max time between data output transitions		33 mSec
T_3	Max Channel Change Time (Time to Valid Data)		10 mSec
T_4	Receiver Turn-on Time		12 mSec
T_5	Receiver Off Time	1 mSec	

Figure 8A: Time Considerations Table

T_1

While the HP-II transmitter is turned off (i.e., the receiver is not receiving a carrier), the receiver's output is squelched. When the HP-II transmitter is turned on, there is a finite time between the power-up of the transmitter and the transmitter being on-channel. This is known as the transmitter power-up time.

Once the transmitter is on-channel, its CTS line goes high indicating that the transmitter is ready to send data. However, at this time the receiver is not ready to receive data. It takes some time for the receiver to settle once the CTS pin on the transmitter is high. This time is shown in figure 8A as T_1 .

In short, T_1 is the maximum time required for the data output of the receiver to be valid once the transmitter's CTS pin goes high. This assumes that the receiver is already powered up.

T_2

The minimum baud rate of the HP-II receiver is 300 baud, assuming that the serial data is 10 bits, including a start and stop bit, each of opposite polarity. Therefore, even if the data itself was all 1's or all 0's, the start and stop bit would create a transition every 10 bits (or once every 33mSec). If a transition does not occur in the 33mSec time, and the power level presented at the receiver's RF input is above the DC modulation sensitivity, the data output will go high and remain high until the next byte. Once the minimum baud rate has been violated, though, the first byte transmitted after the delay will be in error if any of the lower 4 bits are 0's.

The designer must either guarantee that there will never be a delay of more than 33mSec between transitions on the transmitter's data input pin or must always send a 255 (or FF hex) following a delay of more than 33mSec. See applications note AN-00160 for more information.

T_3 - T_5 are self-explanatory

PIN DESCRIPTIONS:

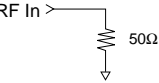

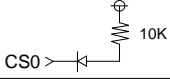
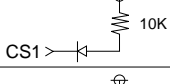
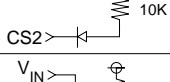
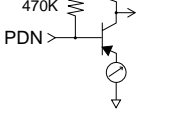
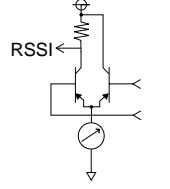

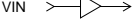
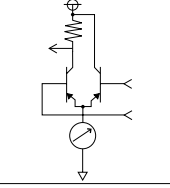
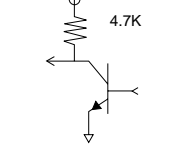
PIN#	Name	Equivalent CTK	Description
1	RF Input/ Antenna Input		50-ohm RF Input
2-8	Gnd		Analog Ground
9	N/C		No Connection
10	CS0		Channel Select 0
11	CS1		Channel Select 1
12	CS2		Channel Select 2
13	PDN		Power down (Active Low)
14	RSSI		Received Signal Strength Indicator
15	Gnd		Digital Ground
16	VCC		Voltage Input 2.7-16V
17	Analog Out		1V p-p Analog Output
18	Data Out		Digital Data Output

Figure 9: Pin functions and equivalent circuits

THEORY OF OPERATION

The HP-II-RXM is a high-performance, eight-channel, dual-conversion superhet FM receiver capable of receiving analog or digital data.

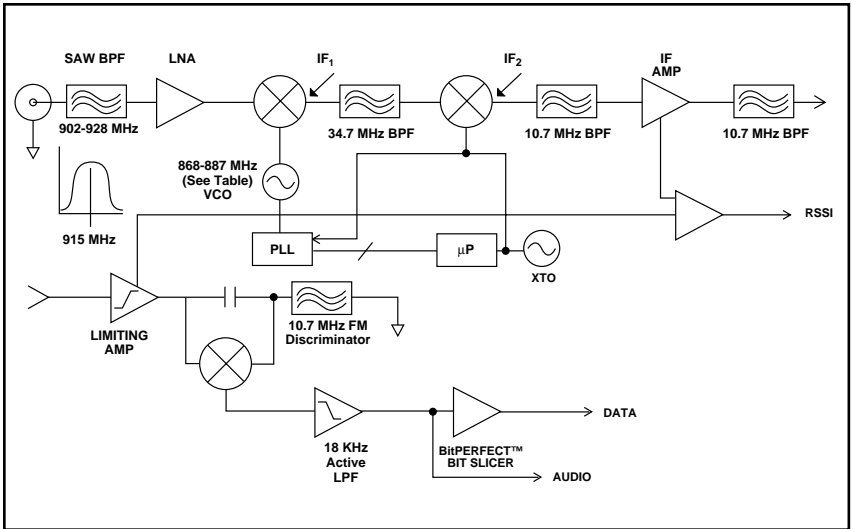


Figure 10: HP Series-II Receiver Block Diagram

Digital information is modulated at the transmitter using FSK (frequency shift keying), the binary form of frequency modulation. FSK offers significant advantages over AM-based modulation methods, i.e., increased noise immunity and the ability of the receiver to “capture” in the presence of multiple signals. These advantages will be particularly appreciated in crowded bands like those in which the HP-II operates. While FSK modulation is not the most bandwidth-efficient manner of modulating digital data, it is an excellent choice for reliable, low-cost, low-power RF products such as the HP Series-II.

To transmit analog information the module employs FM modulation. In this mode, simple to complex waveforms can be introduced at the transmitter’s data pin and recovered with minimal distortion at the receiver’s analog output pin.

The user-supplied antenna is connected at pin 1 (see Figure 1). The HP-II-RXM RF port is matched to 50 ohms to support interface to commonly available antennas such as those manufactured by Linx.

The RF signal coming in from the antenna is filtered by a SAW (surface acoustic wave) filter. The purpose of the SAW BPF is to attenuate unwanted RF energy (i.e., not in the 902-928 MHz band) that is present at the antenna. A SAW device provides significantly steeper roll-off and higher out-of-band attenuation than other filter types such as an LC bandpass.

Once filtered by the SAW, the signal is then amplified by a Low-Noise Amplifier (LNA) to increase the receiver sensitivity and lower the overall noise figure of the receiver. After the LNA, the signal is mixed with a synthesized local oscillator to perform the first frequency conversion.

The first IF frequency is 34.7 MHz. This frequency is achieved by setting the synthesizer frequency to a value that is lower than the incoming RF energy from the antenna.

A high-performance IF receiver strip is used to perform the second conversion and the FM demodulation. The IF strip takes the 34.7 MHz frequency from the first conversion, mixes it with a high-precision 24.0 MHz crystal oscillator-generated frequency to produce the second IF of 10.7 MHz, and amplifies it in preparation for FM demodulation.

FM demodulation is achieved with an on-board gilbert multiplier. The output of the IF strip is a demodulated waveform that, after filtering, very closely resembles the original waveform used to modulate the transmitter.

A high-performance, active low-pass filter cleans up the audio signal, removing all of the unwanted noise from the FM demodulation process. The output of this filter is provided to the audio output pin and to the BitPERFECT bit slicer, which uses proprietary methods to support a wide dynamic range of modulation rates (300 bps to 50Kbps) with no prerequisites for waveform duty cycle.

An on-board micro-controller is used to manage receiver functions and to provide a simple interface to external circuitry. The micro-controller performs the following functions:

- FREQUENCY SYNTHESIZER PROGRAMMING: The micro-controller reads the three-channel select input lines and programs the frequency synthesizer registers to the proper values for a given channel. This frees the user from complex programming requirements and allows for manual channel selection via switches in product designs where a microprocessor is not used.
- BASEBAND DATA QUALIFICATION: The micro-controller monitors the signal quality and squelches the data output when the signal is not strong enough for accurate data detection. This prevents noise on the data output pin during low-signal or no-signal conditions.

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 HP Series-II 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.

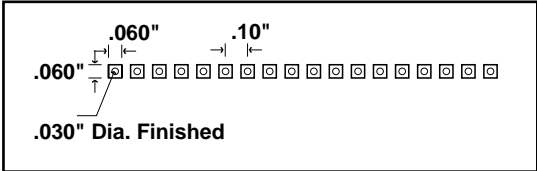


Figure 11: Suggested PCB Footprint

Figure 11 shows the suggested PCB footprint for the HP Series-II receiver.

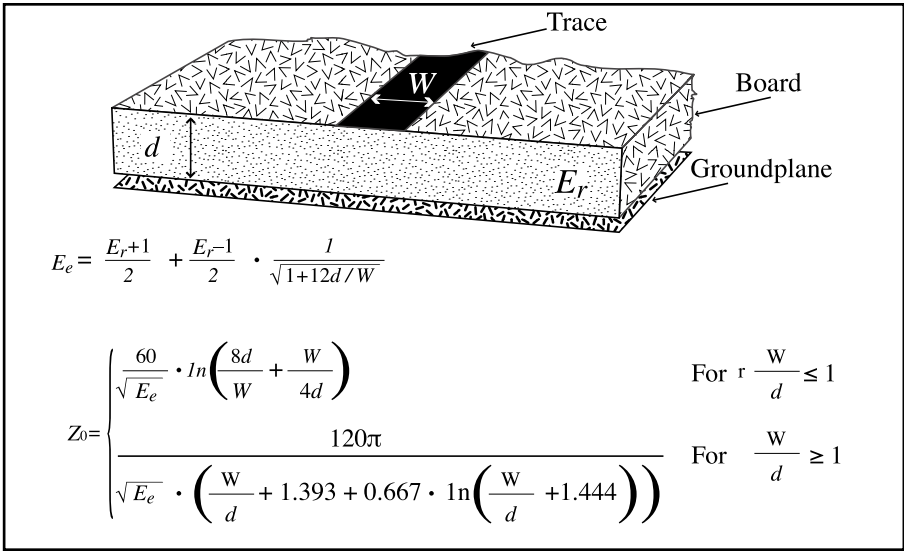
A ground-plane (as large as possible) should be placed directly under the HP-II receiver. This ground-plane can also be critical to the performance of your antenna.

The HP-II receiver 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 HP-II receiver.

If the receiver is to be mounted parallel to the board, it should be laid over so that the side with the crystal is closest to the PC board and the RF side is facing away from the PC board.

The trace from the receiver to the antenna should be kept as short as possible. A simple trace is suitable for runs up to 1/4 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 shown below.

MICROSTRIP DETAILS



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 12: Microstrip formulas (E_r = Dielectric constant of PCB material)

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.

The HP-II-RXM 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 fig. 13.

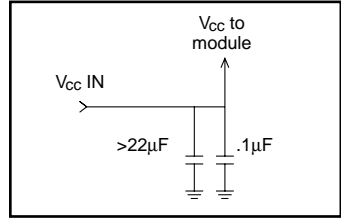


Figure 13: Suggested supply filter

POWER UP SEQUENCE

The HP-II-RXM is controlled by an on-board microprocessor. When power is applied, a start-up sequence is executed. At the end of the start-up sequence, the receiver is ready to receive data.

Figure 14 shows the start-up sequence. This sequence is executed when power is applied to the VCC pin or when the PDN pin is cycled from low to high.

On power-up, the microprocessor reads the external channel-selection lines and sets the frequency synthesizer to the appropriate channel. Once the frequency synthesizer has locked on to the selected channel's frequency, the receiver is ready to accept data.

Figure 4 on Pg. 3 shows the typical turn-on response time for an HP Series-II receiver. The response time was measured by connecting the module's RF input to a signal generator which is set to the proper channel frequency with an output power of -80dBm and FM modulated at 50kHz deviation with a 1kHz square wave. You will notice that the data output remains squelched until the internal start-up procedure has been executed and the receiver is ready to receive data.

The HP-II-RXM can be put into an ultra-low-current (<50uA) power-down mode by holding the PDN pin low. If the PDN pin is left floating or held high, the receiver will turn fully on. In power-down mode, the receiver is completely shut down. Thus, the RSSI circuit CANNOT be used to monitor for channel activity.

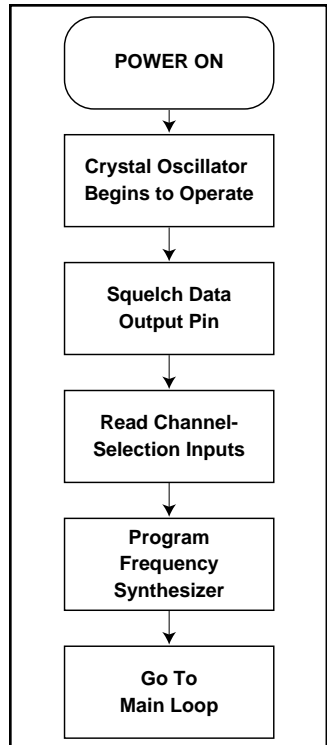


Figure 14: Start-up sequence

NOTE: READ THIS IF YOU ARE GOING TO PERIODICALLY POWER-DOWN RECEIVER!!

A common method of reducing receiver power consumption is to turn the receiver off via the PDN pin for some time interval and wake the receiver periodically to check for the presence of a transmitted signal. In order to implement this method with an HP-II receiver successfully, there are some timing requirements the user must observe when powering up the receiver to check for channel activity.

At power-up the receiver's on-board microprocessor will begin its start-up routine as detailed previously. A 12 mSec time period must be allotted to allow this routine to be completed. After 12 mSec, the data and RSSI circuits are fully qualified and reliable.

The off-period is determined by the discharge rate of the internal bypass capacitors. The capacitors must fully discharge to ensure that subsequent power-ups will reliably restart the microprocessor. This minimum time should be no less than 1 mSec. If the user is finding that the transmitter is not reliable starting up after power-up, this time should be increased.

CHANNEL SELECTION

The HP-II receiver module features eight user-selectable channels. The channel of operation is determined by the state of pins CS0-CS2. Figure 15 shows a channel-selection table based on the pins' states. The on-board microprocessor performs all PLL loading functions. This frees the user from complex programming requirements and allows for manual channel selection via switches in product designs where a microprocessor is not used.

CS2	CS1	CS0	Channel	Frequency
0	0	0	0	903.37
0	0	1	1	906.37
0	1	0	2	907.87
0	1	1	3	909.37
1	0	0	4	912.37
1	0	1	5	915.37
1	1	0	6	919.87
1	1	1	7	921.37

Figure 15: Channel-Selection Table

ANALOG OUTPUT

The analog output is derived after amplification in the BitPERFECT bit slicer. The analog output is valid from 50 Hz to 25 KHz, providing an AC signal of about 1V peak-to-peak. This output should not be used to drive a low-impedance load such as a speaker. In applications requiring direct drive into a speaker, such as the transmission of audio, a simple op-amp circuit like the one shown in Figure 16 can be used. In this circuit, the op-amp is used to act as an impedance converter.

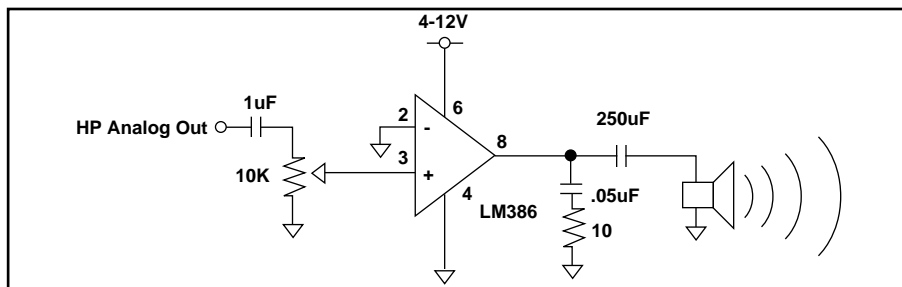


Figure 16: Audio Amplifier

THE DATA OUTPUT

Once a reliable RF link has been established, the challenge becomes how to effectively transfer data across it. While a properly designed RF link provides reliable data transfer under most conditions, there are still distinct differences from a wired link that must be addressed. Since the HP-II modules do not incorporate internal coding/decoding, a user has tremendous flexibility in how data is handled.

The data output is generated by an on-board open-collector comparator and swings from 0V (representing the reception of a logic "0") to VIN (representing a logic "1"). This output is capable of sinking 2 mA of current and presents a 4.7K source resistance when sourcing current. If additional current sourcing or sinking capacity is required, the user should use a buffer gate to service the additional loads.

When a carrier is not present, the data output is continuously high. Although the audio output of the receiver is pure noise, an internal squelch circuit is used to hold the data output low. The data output will "break squelch" anytime the RF energy present at the antenna input is strong enough to cause the RSSI voltage to rise above the factory-set squelch level. Typically, a receiver will only break squelch when a carrier is present on the desired frequency. However, strong signals at interfering frequencies can also cause the data output to break squelch.

When a carrier is present with no modulation, the data output will remain continuously high when the RF signal input level is above the DC Modulation Sensitivity. Note that the DC modulation sensitivity is higher than the data sensitivity of the receiver. The ability to maintain a DC level on the data output requires a higher SNR than is required to receive data. When the RF signal input level is below the DC modulation sensitivity but above the data sensitivity, the receiver's output will contain valid data when the incoming carrier is modulated. However, in this condition the receiver may not hold a continuous high level on the data output when the carrier is not being modulated.

This feature is unique to the HP Series-II and is designed to support direct operation with UARTs which require their input to be continuously marking (or high). The HP Series-II transmitters and receivers can be directly connected between two UARTs without the need for buffering or logical inversion.

Another area of consideration is that of data structure or protocol. If you are not familiar with the considerations for sending serial data in a wireless environment you will want to review Linx application note #00160 (Considerations for sending data with the HP Series-II). These issues should be clearly understood prior to commencing a significant design effort.

If you want to transfer simple control or status signals such as button presses or switch closures, and your product does not have a microprocessor on board your product or you wish to avoid protocol development, consider using an encoder and decoder IC set. These chips are available from a wide range of manufacturers including: Microchip (Keelock), Holtek, and Motorola. These chips take care of all encoding, error checking, and decoding functions and generally provide a number of data pins to which switches can be directly connected. In addition, address bits are usually provided for security and to allow the addressing of multiple receivers independently. These IC's are an excellent way to bring basic Remote Control/Status products quickly and inexpensively to market. Additionally, it is a simple task to interface with inexpensive microprocessors such as the Microchip PIC or one of many IR, remote control, DTMF, and modem IC's.

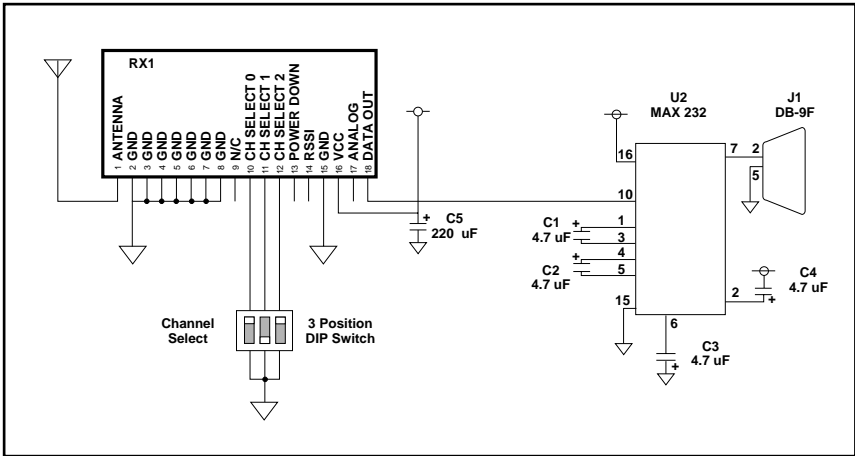


Figure 17: Typical Application - RS-232 Interface

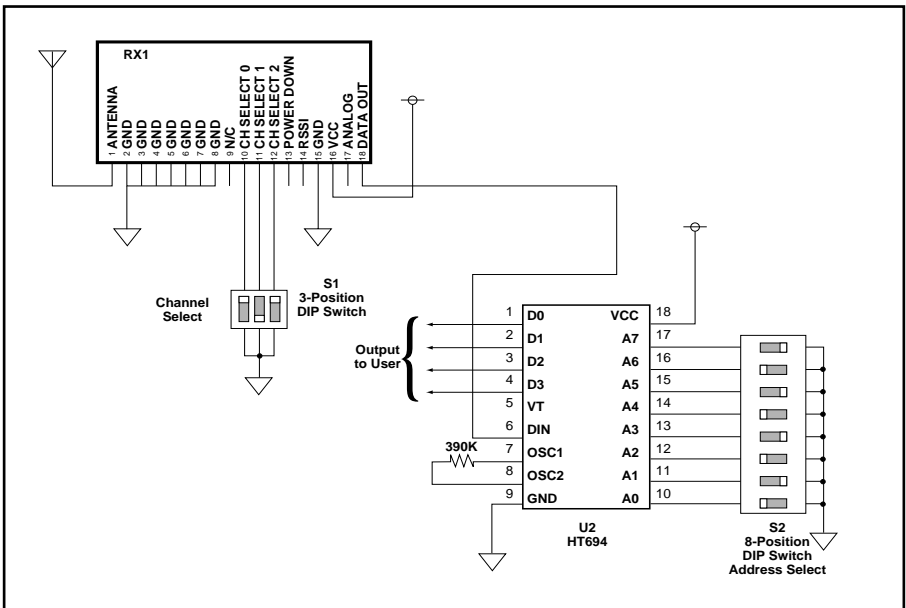


Figure 18: Typical Application - Remote-Control Receiver

PROXIMITY OPERATION

If modules are combined to form a transceiver they should be operated in half-duplex, meaning that only the transmitter or receiver is active at any time. When combined with certain high-gain antennas the HP-II transmitter can, in close proximity, exceed -10dBm power into the receiver. Since the receiver does not incorporate an AGC this can result in poor performance or complete shutdown of the receiver. This effect occurs when both the transmitter and receiver have the high-gain antennas connected and are in close proximity (1-5 feet) of each other.

RSSI CIRCUIT

The HP Series-II receivers are equipped with an on-board Received-Signal-Strength-Indicator (RSSI) circuit. RSSI is useful to check for channel occupation, and interference as well as signal strength determination.

The RSSI circuit provides a DC voltage which is logarithmically proportional to the incoming signal strength present at the RF input pin. The RSSI circuit has a voltage range of about 800mV to 2.5 V and a dynamic signal range of better than 60 dB.

Figure 5 on p. 3 shows the RSSI output versus input signal strength. This graph is a characterization only and is adapted from measurements made from a small sampling of receivers. The RSSI response is different for every FM-IF chip, and is therefore different for every HP Series-II receiver. Calibration parameters are stored on-board to compensate for this variation.

Figure 6 on p. 3 shows the RSSI response time with an input power of -80dBm. This graph basically shows how long it takes the RSSI voltage to respond to an instantaneous increase in output power. If the carrier is AM modulated, or OOK modulated (in the case of data), the RSSI pin can be used for demodulation.

NOTE: MAKING SIGNAL STRENGTH MEASUREMENTS WITH THE RSSI CIRCUIT

If your application requires that you accurately measure the incoming signal strength (distance measurement, for example), then you must calibrate the RSSI circuit on a receiver-by-receiver basis.

The calibration process is simple. Using a signal generator, inject a -40dBm unmodulated carrier into the receiver and measure the RSSI voltage. Repeat the same for an input signal level of -100dBm. This is known as a two-point "slope" calibration.

To determine the slope of the RSSI response, use the following equation:

$$M=60/(V_2-V_1)$$

Where M=slope in dB/volts

V1=the voltage measured at -100dBm

V2=the voltage measured at -40dBm

Using this slope, you can determine the signal strength for any RSSI voltage using the following formula:

$$SS=M * (V_1-V_m) +100dBm$$

Where SS=signal strength in dBm

M=previously determined slope

Vm=measured RSSI voltage

If you are using a microprocessor with an A/D converter, this process can easily be achieved in software. If not, it can also be achieved using standard analog measurement circuitry.

RECEIVER SENSITIVITY PERFORMANCE

The sensitivity of a receiver is critical to the overall range-performance of a wireless link. Among wireless manufacturers this measurement is particularly subject to specmanship due to the variety of methods and conditions under which sensitivity can be tested.

A hallmark of Linx designs is outstanding sensitivity, but more importantly our sensitivity specifications are based on harsh testing. The receiver sensitivity for the HP Series-II is specified for a given bit-error-rate (BER), which is measured using a pseudo-random bitstream generated by a bit-error-rate-tester (BERT). A sample of each lot of modules is tested for sensitivity, and therefore the quoted sensitivity is a characterization of the module, and not a guaranteed specification. The receiver sensitivity test setup used by Linx is shown in the figure below.

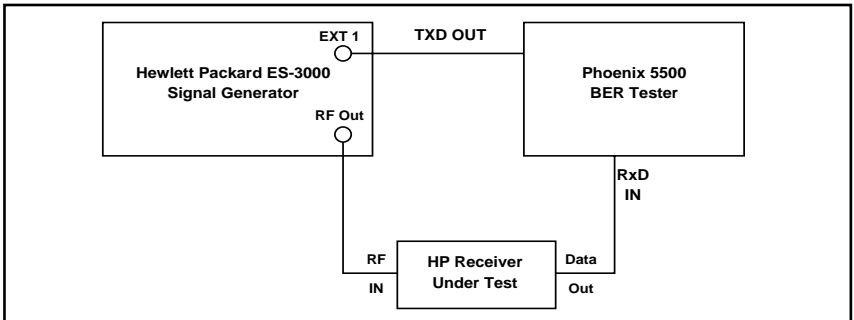


Figure 19: Sensitivity Test Setup

Figure 7 on page 3 shows the typical BER versus input power for the HP Series-II receivers. This graph can be used to determine the actual sensitivity you can attain for a given application. For instance, high-rate data communications would require a BER of $<1^{-5}$ where a low-rate data application with redundant data transmission may only require a BER of $<1^{-2}$.

Based on the sensitivity characterization of the HP-II receiver and the output power of the transmitter as legally allowed by the FCC, a path loss model can be used to show that the open field range of an HP-II link can exceed 1,000 feet. The actual ability of a particular product utilizing the HP Series-II receivers to attain this range-performance depends on many factors including:

- 1). Quality of receiving antenna
- 2). Actual path loss model (open field, inter-building, city, etc.)
- 3). Quality of power supply

The HP-II development kit you purchased contains two development boards that can be used to properly evaluate an HP-II data link's range-performance. If you have any difficulties duplicating the same range with your own product, you should carefully review all Linx documentation for hints on what the problem might be. If all else fails, contact Linx and discuss your design with an application engineer.

ANTENNA CONSIDERATIONS

The choice of antennas is one of the most critical and often overlooked design considerations. The range, performance, and legality of an RF link is critically dependent upon the type of antenna employed. Proper design and matching of an antenna is a complex task requiring sophisticated test equipment and a strong background in principles of RF propagation. While adequate antenna performance can often be obtained by trial and error methods, you may also want to consider utilizing a professionally designed antenna such as those offered by Linx. Our low-cost antenna line is designed to ensure maximum performance and compliance with Part 15 attachment requirements. The purpose of the following sections is to give you a basic idea of some of the considerations involved in the design and selection of antennas. For a more comprehensive discussion please review Linx applications note #00500 "Antennas: Design, Application, Performance".

THE TRANSMITTER ANTENNA

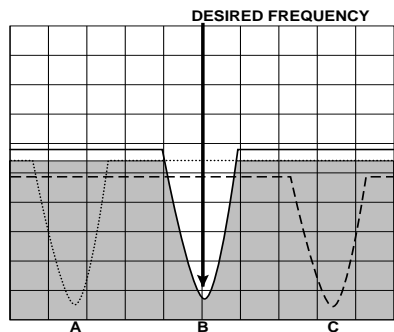
The transmitter antenna allows RF energy to be efficiently radiated from the output stage into free space. In modular designs such as the HP, a transmitter's output power is often slightly higher than the legal limit. This allows a designer to utilize an inefficient antenna in order to achieve full legal power while meeting size, cost, or cosmetic objectives. For this reason a transmitter's antenna can generally be less efficient than the antenna used on the receiver.

THE RECEIVER ANTENNA

A receiving antenna should give its optimum performance at the frequency or in the band for which a receiver was designed, and capture as little as possible of other off-frequency signals. The efficiency of the receiver's antenna is critical to maximizing range-performance. Unlike the transmitter antenna, where legal operation may mandate a reduction in antenna efficiency or attenuation, the receiver's antenna should be optimized as much as is practical.

It is usually best to utilize a basic quarter-wave whip for your initial concept evaluation. Once the prototype product is operating satisfactorily, a production antenna should be selected to meet the cost, size and cosmetic requirements of the product.

Maximum antenna efficiency is always obtained when the antenna is at resonance. If the antenna is too short, capacitive reactance is present; if it is too long, inductive reactance will be present. The indicator of resonance is the minimum point in the VSWR curve. You will see from the following example that antenna (A) is resonant at too low a frequency, indicating excessive length, while antenna (C) is resonant at too high a frequency, indicating the antenna is too short. Antenna (B), however, is "just right."



Antenna resonance should not be confused with antenna impedance. The difference between resonance and impedance is most easily understood by considering the value of VSWR at its lowest point. The lowest point of VSWR indicates the antenna is resonant, but the value of that low point is determined by the quality of the match between the antenna, the transmission line, and the device it is attached to.

To fully appreciate the importance of an antenna that is both resonant and matched consider that an antenna with a VSWR of 1.5 will effectively transmit approximately 95% of its power while an antenna with a VSWR of 10 will only transmit about 30%. (See pg. 23)

GENERAL ANTENNA RULES

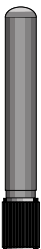
The following general rules should help in maximizing antenna performance:

1. Proximity to objects such as a user's hand or body, or metal objects will cause an antenna to detune. For this reason the antenna shaft and tip should be positioned as far away from such objects as possible.
2. Optimum performance will be obtained from a 1/4- or 1/2-wave straight whip mounted at a right angle to the ground-plane. In many cases this isn't desirable for practical or ergonomic reasons; thus, an alternative antenna style such as a helical, loop, patch, or base-loaded whip may be utilized.
3. If an internal antenna is to be used, keep it away from other metal components, particularly large items like transformers, batteries, and PCB tracks and ground-planes. In many cases, the space around the antenna is as important as the antenna itself.
4. In many antenna designs, particularly 1/4-wave whips, the ground-plane acts as a counterpoise, forming, in essence, a 1/2-wave dipole. For this reason adequate ground-plane area is essential. As a general rule the ground-plane to be used as counterpoise should have a surface area \geq the overall length of the 1/4-wave radiating element.
5. Remove the antenna as far as possible from potential interference sources. Any frequency of sufficient amplitude to enter the receiver's front end will reduce system range, cause increased bit errors, and can even prevent reception entirely. There are many possible sources of internally generated interference. Switching power supplies, oscillators, even relays can also be significant sources of potential interference. Here again, the single best weapon against such problems is attention to placement and layout. Filter the module's power supply with a high-frequency bypass capacitor. Place adequate ground-plane under all potential sources of noise. Shield noisy board areas whenever practical.
6. In some applications it is advantageous to place the receiver and its antenna away from the main equipment. This avoids interference problems and allows the antenna to be oriented for optimum RF performance. Always use 50 Ω coax such as RG-174 for the remote feed.

ANTENNA STYLES

From a coat hanger to a tuned Yagi, there are literally hundreds of antenna styles and variations that can be employed. Following is a brief discussion of the styles most commonly utilized in compact RF designs. The selection chart broadly categorizes key areas of antenna performance. In reviewing this section it is important to recognize that each antenna style will produce widely varying results based on the specific design execution and optimization. Additional information can be found in Linx application notes #00500, #00100, #00125 and #00140.

Whip Style



1/4-wave wire lengths for HP frequencies:
902-928MHz = 3.06"

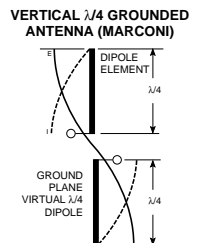
A whip-style antenna provides exceptional performance and is easy to integrate. A low-cost whip is generally made of a wire or rod while more expensive whip designs are encapsulated in rubber or plastic to improve appearance and minimize the potential for damage to the antenna element. A whip is often combined with a helical winding to reduce the overall length. This technique is commonly referred to as "base loading".

Every frequency has a physical length that it occupies in space. That length is referred to as the *wavelength* and is theoretically determined by two factors: 1) the frequency itself and 2) the speed of propagation. The wavelength of the frequency to be received or transmitted determines an antenna's length. Since an antenna has a dielectric constant greater than that of free space, the velocity of a wave on the antenna is slower. This fact, along with several other factors, has led antenna designers to accept the formula below as an accurate starting point for determining the physical length of a half-wave antenna. The resultant length may be divided in half for a quarter wave.

$$L = \frac{234}{F \text{ MHz}}$$

Where:
L = length in feet of quarter-wave length
F = operating frequency in megahertz

Because of its compact length, a popular antenna style for Part 15 applications is the 1/4-wave whip. It is important to note that in order to operate effectively the 1/4 wave must radiate against a ground-plane. The ground-plane can be a metal case or ground area on a PCB of at least equivalent area to the antenna's surface. The ground-plane acts as a counterpoise, in essence forming an effective half-wave dipole as illustrated.



There are many manufacturers providing high-quality whip antennas. It is important to remember, however, that Part 15 requires a permanent attachment or attachment with a unique or not commonly available connector. This rules out the use of whips employing standard connectors such as BNC's.

Helical Style



A helical is a wire coil usually wound from steel, copper or brass. This antenna is very efficient given its small size. The helical is an excellent choice for products requiring good range-performance and a concealed internal antenna element. Care must be exercised in placement, however, as a helical detunes badly when located in proximity with other conductive objects. Because a helical has a high "Q" factor its bandwidth is very narrow and inter-coil spacing has a pronounced effect on antenna performance. For this reason it is usually best to utilize a premade helical which has been professionally optimized to achieve maximum performance.



Loop Style



A loop or track-style antenna is usually printed directly on the PCB making it the most cost-effective of antenna styles. There are many different styles and shapes of loops which can be utilized, including spirals and rectangles. A loop has excellent immunity to proximity detuning (i.e., a user's body) and is easily concealed inside products which have a plastic case. Despite these advantages a loop is difficult to match and tune without expensive RF test equipment. An improperly designed loop will have a very high SWR and may induce harmonics. For this reason a helical or whip style is usually a better choice for applications requiring maximum range-performance. For

products where cost or size is critical, a designer will generally want to have a loop professionally designed and optimized.

HP Antenna Selection Chart

PARAMETER	LOOP	HELICAL	WHIP
Ultimate performance	●	●●	●●●
Ease of design setup	●	●●	●●●
Size	●●	●●●	●
Immunity to proximity effects	●●●	●●	●
HP-II Range (open ground to similar antenna)	400 ft.	600 ft.	1,000+ ft.
	●=FAIR	●●=GOOD	●●●=EXCELLENT

ANTENNA SHARING

Many times when a transmitter and receiver module are combined to form a transceiver the designer will find it advantageous for the modules to share a single antenna. To accomplish this an antenna switch must be used to provide isolation between each of the modules. There are a wide variety of antenna switches available which are cost-effective and straightforward to use. Among the most

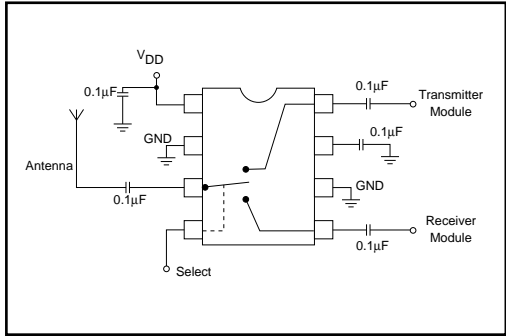
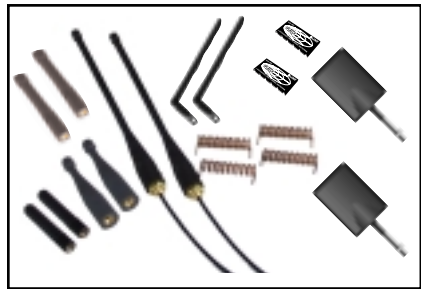


Figure 20: Typical Antenna Switch

popular are switches from Alpha, Motorola, Philips, TriQuint, and NEC. Look for an antenna switch that has high isolation and low loss at the desired frequency of operation. Generally, the TX or RX status of a switch will be controlled by a product's microprocessor, but selection may also be made manually by the user. In some cases where the characteristics of the TX and RX antennas need to be different or switch losses are unacceptable the designer may find it more practical to utilize two discrete antennas.

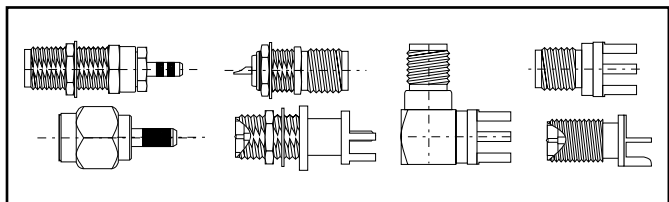
LINX ANTENNA OPTIONS

Linx offers a full line of antennas which are optimized for the frequencies at which our modules operate. The antennas are cost-effectively priced in volume and designed to maximize the performance of your product. For complete details, visit the Linx website at www.linxtechnologies.com, or contact the Linx literature department at (800)736-6677.



LINX CONNECTOR OPTIONS

The FCC requires that antennas designed for use on Part 15 products be either permanently attached, or utilize a unique and proprietary connector not available to the general public. Linx offers a full line of connectors designed to comply with these requirements. To insure the continued compliance of these connectors, details are not available on our website. However, complete connector specifications may be obtained by contacting the Linx literature department at (800)736-6677.



Part 15-Compliant Connectors

LEGAL CONSIDERATIONS

NOTE: HP Series-II Modules are designed as component devices which require external components to function. The modules are intended to allow for full Part 15 compliance; however, they are not approved by the FCC or any other agency worldwide. The purchaser understands that approvals may be required prior to the sale or operation of the device, and agrees to utilize the component in keeping with all laws governing its operation in the country of operation.

When working with RF, a clear distinction must be made between what is technically possible and what is legally acceptable in the country where operation is intended. Many manufacturers have avoided incorporating RF into their products as a result of uncertainty and even fear of the approval and certification process. Here at Linx our desire is not only to expedite the design process, but also to assist you in achieving a clear idea of what is involved in obtaining the necessary approvals to legally market your completed product.

In the United States the approval process is actually quite straightforward. The regulations governing RF devices and the enforcement of them are the responsibility of the Federal Communications Commission. The regulations are contained in the Code of Federal Regulations (CFR), Title 47. Title 47 is made up of numerous volumes; however, all regulations applicable to this module are contained in volume 0-19. It is strongly recommended that a copy be obtained from the Government Printing Office in Washington, or from your local government book store. Excerpts of applicable sections are included with Linx evaluation kits or may be obtained from the Linx Technologies web site (www.linxtechnologies.com). In brief, these rules require that any device which intentionally radiates RF energy be approved, that is, tested, for compliance and issued a unique identification number. This is a relatively painless process. Linx offers full EMC pre-compliance testing in our HP/Emco-equipped test center. Final compliance testing is then performed by one of the many independent testing laboratories across the country. Many labs can also provide other certifications the product may require at the same time, such as UL, CLASS A/B, etc. Once your completed product has passed, you will be issued an ID number which is then clearly placed on each product manufactured.

Questions regarding interpretations of the Part 2 and Part 15 rules or measurement procedures used to test intentional radiators, such as the HP-II modules, for compliance with the Part 15 technical standards, should be addressed to:

Federal Communications Commission
Equipment Authorization Division
Customer Service Branch, MS 1300F2
7435 Oakland Mills Road
Columbia, MD 21046

Tel: (301) 725-1585 / Fax: (301) 344-2050 E-Mail: labinfo@fcc.gov

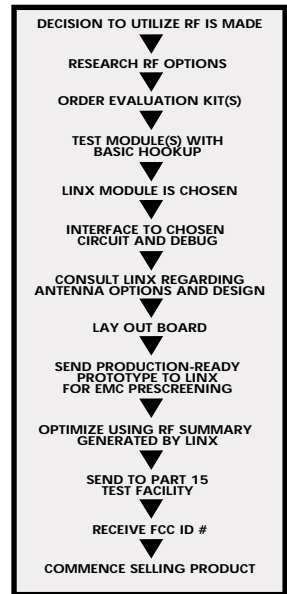
International approvals are slightly more complex, although many modules are designed to allow all international standards to be met. If you are considering the export of your product abroad, you should contact Linx Technologies to determine the specific suitability of the module to your application.

All Linx modules are designed with the approval process in mind and thus much of the frustration that is typically experienced with a discrete design is eliminated. Approval is still dependent on many factors such as the choice of antennas, correct use of the frequency selected, and physical packaging. While some extra cost and design effort are required to address these issues, the additional usefulness and profitability added to a product by RF makes the effort more than worthwhile.

SURVIVING AN RF IMPLEMENTATION

Adding an RF stage brings an exciting new dimension to any product. It also means that additional effort and commitment will be needed to bring the product successfully to market. By utilizing premade RF modules, such as the HP-II Series-II, the design and approval process will be greatly simplified. It is still important, however, to have an objective view of the steps necessary to insure a successful RF integration. Since the capabilities of each customer vary widely it is difficult to recommend one particular design path, but most projects follow steps similar to those shown at the right.

In reviewing this sample design path you may notice that Linx offers a variety of services, such as antenna design, and FCC prequalification, that are unusual for a high-volume component manufacturer. These services, along with an exceptional level of technical support, are offered because we recognize that RF is a complex science requiring the highest caliber of products and support. "Wireless Made Simple" is more than just a motto, it's our commitment. By choosing Linx as your RF partner and taking advantage of the resources we offer, you will not only survive implementing RF, but you may even find the process enjoyable.



TYPICAL STEPS FOR IMPLEMENTING RF

HELPFUL APPLICATION NOTES FROM LINX

It is not the intention of this manual to address in depth many of the issues that should be considered to ensure that the modules function correctly and deliver the maximum possible performance. As you proceed with your design you may wish to obtain one or more of the following application notes, which address in depth key areas of RF design and application of Linx products.

NOTE #	LINX APPLICATION NOTE TITLE
00500	Antennas: Design, Application, Performance
00130	Modulation techniques for low-cost RF data links
00126	Considerations for operation in the 902 Mhz to 928 Mhz band
00100	RF 101: Information for the RF challenged
00140	The FCC Road: Part 15 from concept to approval
00150	Use and design of T-Attenuation Pads
00110	Understanding the performance specifications of receivers
00160	Considerations for sending data with the HP Series-II

Power Conversion Tables For 50Ω System

dBm	mW	dBmV	mVRMS	mVp	mVpp
-50	0.000	-3.0	0.7	1.0	2.0
-45	0.000	2.0	1.3	1.8	3.6
-40	0.000	7.0	2.2	3.2	6.3
-35	0.000	12.0	4.0	5.6	11.2
-30	0.001	17.0	7.1	10.0	20.0
-25	0.003	22.0	12.6	17.8	35.6
-20	0.010	27.0	22.4	31.6	63.2
-15	0.032	32.0	39.8	56.2	112.5
-10	0.100	37.0	70.7	100.0	200.0
-5	0.316	42.0	125.7	177.8	355.7
0	1.000	47.0	223.6	316.2	632.5
1	1.259	48.0	250.9	354.8	709.6
2	1.585	49.0	281.5	398.1	796.2
3	1.995	50.0	315.9	446.7	893.4
4	2.512	51.0	354.4	501.2	1002.4
5	3.162	52.0	397.6	562.3	1124.7
6	3.981	53.0	446.2	631.0	1261.9
7	5.012	54.0	500.6	707.9	1415.9
8	6.310	55.0	561.7	794.3	1588.7
9	7.943	56.0	630.2	891.3	1782.5
10	10.000	57.0	707.1	1000.0	2000.0
11	12.589	58.0	793.4	1122.0	2244.0
12	15.849	59.0	890.2	1258.9	2517.9
13	19.953	60.0	998.8	1412.5	2825.1
14	25.119	61.0	1120.7	1584.9	3169.8
15	31.623	62.0	1257.4	1778.3	3556.6
16	39.811	63.0	1410.9	1995.3	3990.5
17	50.119	64.0	1583.0	2238.7	4477.4
18	63.096	65.0	1776.2	2511.9	5023.8
19	79.433	66.0	1992.9	2818.4	5636.8
20	100.000	67.0	2236.1	3162.3	6324.6
21	125.893	68.0	2508.9	3548.1	7096.3
22	158.489	69.0	2815.0	3981.1	7962.1
23	199.526	70.0	3158.5	4466.8	8933.7
24	251.189	71.0	3543.9	5011.9	10023.7
25	316.228	72.0	3976.4	5623.4	11246.8
26	398.107	73.0	4461.5	6309.6	12619.1
27	501.187	74.0	5005.9	7079.5	14158.9
28	630.957	75.0	5616.7	7943.3	15886.6
29	794.328	76.0	6302.1	8912.5	17825.0
30	1000.000	77.0	7071.1	10000.0	20000.0

MISMATCH CONVERSION TABLE

VSWR	Insertion Loss (dB)	Power Transmitted (%)	Power Reflected (%)
17.391	-6.87	20.57%	79.43%
11.610	-5.35	29.21%	70.79%
8.724	-4.33	36.90%	63.10%
6.997	-3.59	43.77%	56.23%
5.848	-3.02	49.88%	50.12%
5.030	-2.57	55.33%	44.67%
4.419	-2.20	60.19%	39.81%
3.946	-1.90	64.52%	35.48%
3.570	-1.65	68.38%	31.62%
3.010	-1.26	74.88%	25.12%
2.615	-0.97	80.05%	19.95%
2.323	-0.75	84.15%	15.85%
2.100	-0.58	87.41%	12.59%
1.925	-0.46	90.00%	10.00%
1.433	-0.14	96.84%	3.16%
1.222	-0.04	99.00%	1.00%
1.119	-0.01	99.68%	0.32%
1.065	0.00	99.90%	0.10%
1.034	0.00	99.97%	0.03%
1.020	0.00	99.99%	0.01%

NOTES:



WIRELESS MADE SIMPLE

U.S. CORPORATE HEADQUARTERS:

LINX TECHNOLOGIES, INC.

575 S.E. ASHLEY PLACE
GRANTS PASS, OR 97526

Phone: (541) 471-6256

FAX: (541) 471-6251

<http://www.linxtechnologies.com>

Disclaimer

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