LINX TECHNOLOGIES

WIRELESS MADE SIMPLE

HIGH-PERFORMANCE
RF MODULE
RXM-900-HP3

HP SERIES-3 RECEIVER MODULE DESIGN GUIDE

DESCRIPTION:

The HP-3 RF receiver module is the third generation of the popular HP Series and offers complete compatibility and numerous enhancements over previous generations. Like its predecessors, the HP-3 is designed for the cost-effective, high-performance wireless transfer of analog or digital information in the popular 902-928MHz band. All HP-3 series modules continue to feature eight parallel selectable channels but versions are also available which add serial selection of 100 channels. To ensure reliable performance, the receiver employs FM/FSK demodulation and an advanced dual-conversion microprocessor-controlled synthesized architecture. The receiver is pin- and footprint-compatible with all previous generations but its overall physical size has been reduced. Both SMD and pinned packages are now available. When paired with an HP-3 transmitter, a reliable link is created for transferring analog and digital information up to 1000 ft. (under optimal conditions). Like all Linx modules, the HP-3 requires no tuning or additional RF components (except an antenna), making integration straightforward even for engineers without prior RF experience.

FEATURES:

- 8 Parallel/100 Serial (PS Versions) User-Selectable Channels
- Precision Frequency Synthesized Architecture
- SAW Filter For Superior Out-of-Band Rejection
- FM/FSK Demodulation For Outstanding Performance and Noise Immunity
- Exceptional Sensitivity (-100 dBm typical)
- Wide-Range Analog Capability Including Audio (50Hz-28kHz)
- Transparent Serial Data Output (56Kbps max.)
- Direct Serial Interface
- Receive Signal Strength (RSSI) and Powerdown Lines
- Cost-Effective
- Pinned or SMD Packaging
- Wide Supply Range (2.8-13V DC)
- Extended Temperature Range (-30°C to +85°C)
- No Production Tuning or External RF Components Required (Except Antenna)
- Compatible With Previous HP Series Modules

APPLICATIONS INCLUDE:

- General Wire Elimination
- Wireless Data Transfer
- Wireless Analog / Audio
- Home / Industrial Automation
- Wireless Networks
- Remote Control
- Remote Access
- Remote Monitoring / Telemetry
- Alarm / Security Systems
- Long-Range RFID
- MIDI Links
- Voice/Music / Intercom Links

ORDERING INFORMATION

PART #	DESCRIPTION
RXM-900-HP3-PPO	HP-3 Receiver (PINNED 8 CH only)
RXM-900-HP3-PPS	HP-3 Receiver (PINNED 8p /100s CH)
RXM-900-HP3-SPO	HP-3 Receiver (SMD 8 CH only)
RXM-900-HP3-SPS	HP-3 Receiver (SMD 8p /100s CH)
MDEV-900-HP3-PPS	Development Kit 900MHz (Pinned Pkg.)
MDEV-900-HP3-SPS	Development Kit 900MHz (SMD Pkg.)

Revised 6/10/03

SPECIFICATIONS

ABOUT THESE MEASUREMENTS

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

Parameter	Designation	Min.	Typical	Max.	Units	Notes
POWER SUPPLY						
Input Voltage	V_{CC}	2.8	–	13.0	VDC	–
Supply Current	I_{CC}	16	19	21	mA	1
Power-Down Current	I_{PDN}	–	5.6	10	µA	–
RECEIVE SECTION						
Receive Frequency Range	F_C	902.62	–	927.62	MHz	4
Channel Spacing		–	250	–	kHz	4
Center Frequency Accuracy		-50		+50	kHz	
First IF Frequency		–	34.7	–	MHz	–
Second IF Frequency		–	10.7	–	MHz	–
Noise Bandwidth	N_{3DB}	–	280	–	kHz	–
Data Bandwidth		100	–	56,000	Bps	–
Analog/Audio Bandwidth		50	–	28,000	Hz	–
Analog/Audio Output Level		0.8	1.1	2.0	Vac	5
Data output:						
Logic low		GND	–	0.5	VDC	2
Logic high		V_{CC}-.3	–	V_{CC}	VDC	2
Data Output Impedance		–	17	–	kOhms	–
Data Output Source Current		–	230	–	µA	3
Receiver Sensitivity		-94	-100	-107	dBm	6,7,8
RSSI:						
Dynamic Range		60	70	80	dB	–
Gain		–	24	–	mV/dB	–
Voltage/No Carrier		–	–	1.6	V	–
Spurious Emissions		–	-57	–	dBm	–
Interference Rejection:						
F_C±1MHz		–	54	–	dB	–
F_C±5MHz		–	57	–	dB	–
ANTENNA PORT						
RF input impedance	R_{IN}	–	50	–	Ohms	–
TIMING						
Max time between transitions	T_1	–	–	20	mSec	10
Max Channel-ChangeTime	T_2	–	–	1.5	mSec	10
Receiver Turn-on Time (Via PDN)	T_3	–	–	3	mSec	10
Receiver Turn-on Time (Via V_{CC})	T_4	–	–	7	mSec	10
ENVIRONMENTAL						
Operational Temperature		-30		+85	°C	

Figure 1: Specifications Table

Notes:

1. Over entire operating voltage range
2. No load
3. With 1-volt output drop
4. Serial Mode
5. With 1kHz Sine @ 115kHz transmitter deviation
6. For 10^{-5} @ 9,600 BPS
7. At specified center frequency
8. Units are not rejected for better than maximum sensitivity
9. Minimum input power level to ensure that data output can hold a DC level
10. See page 14

***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.**

Absolute Maximum Ratings:

Supply voltage Vcc	-0.3	to	13	VDC
Voltage on any digital input pin (regardless of supply)	-0.3	to	13	VDC
Maximum RF input power		+10 dB		
Operating temperature	-30°C	to	+85°C	
Storage temperature	-45°C	to	+85°C	
Soldering temperature		+260°C for 15 sec.		

Figure 2: Maximum Ratings Table

TYPICAL PERFORMANCE GRAPHS

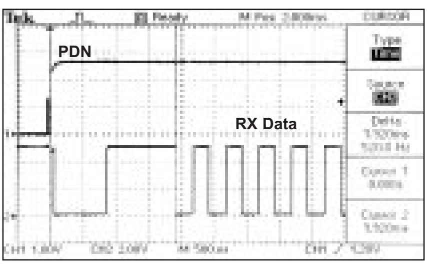


Figure 3: RX Enabled to Valid Data

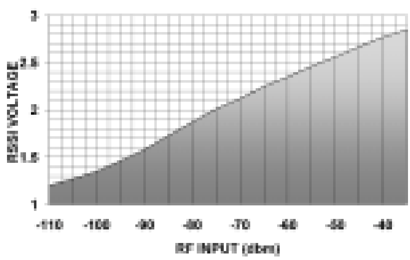


Figure 4: Receiver RSSI

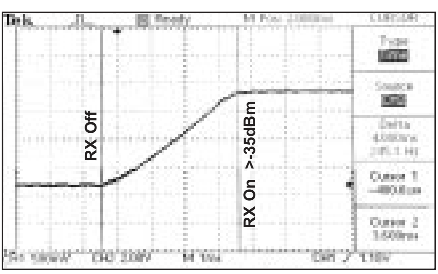


Figure 5: Worst Case RSSI Response Time

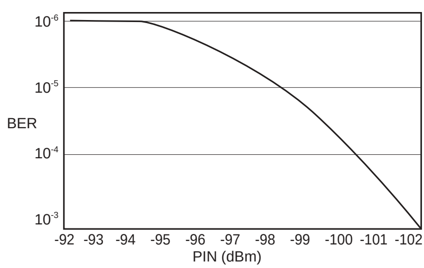


Figure 6: BER vs. Input Power (typical)

CAUTION

This product incorporates 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.

PIN DESCRIPTIONS

It is recommended all ground pins be connected to the groundplane. Pins marked N/C have no physical connection, and are designed only to add support.

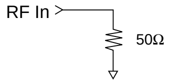
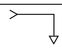
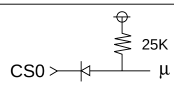
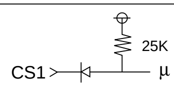
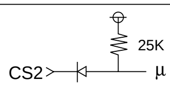
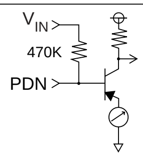
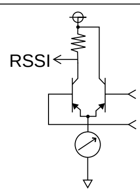
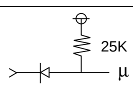
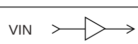
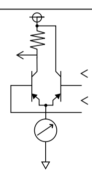
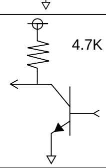
PIN#	Name	Equivalent CTK	Description
1	RF Input/ Antenna Input		50-ohm RF Input
2-8	Gnd		Analog Ground
9	N/C		No Connection
10	CS0		Channel Select 0
11	CS1 / SS Clock		Channel Select 1 / Serial Select Clock
12	CS2 / SS Data		Channel Select 2 / Serial Select Data
13	PDN		Power Down (Active Low)
14	RSSI		Received Signal Strength Indicator
15	Gnd/Mode		Mode Select
16	VCC		Voltage Input 2.8-13V
17	Analog Out		1V p-p Analog Output
18	Data Out		Digital Data Output
19-36	N/C	SMD (Only)	No Connection

Figure 7: Pin Functions and Equivalent Circuits

PHYSICAL PACKAGING

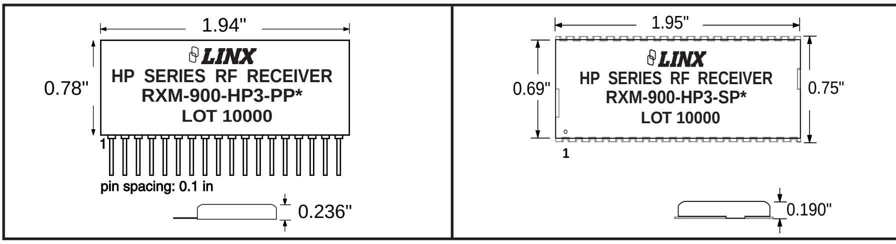


Figure 8: Receiver Physical Package

The receiver is available in two package styles. The pinned SIP style is designed for through-hole application and has 18 pins spaced at 0.1" intervals. Pin 1 is on the far left of the board when viewed from the front. The package may be inserted at right angles or bent to lie down (with the cover facing up) on the PCB. Avoid repeated bending of the pins as they will weaken and may break.

The surface mount version is housed in a 36-pad hybrid SMD package which has been designed to facilitate both hand and automated assembly. Castellation grooves have been provided for ease of hand soldering and inspection. Pin 1 is on the lower left when viewed as shown above.

RECOMMENDED PAD LAYOUT

The following drawings illustrate the recommended circuit-board footprints for the HP-3 series receiver modules. The ground plane layer is also an essential part of good layout. Be sure to review the physical layout recommendations and antenna guidelines contained elsewhere in this design guide.

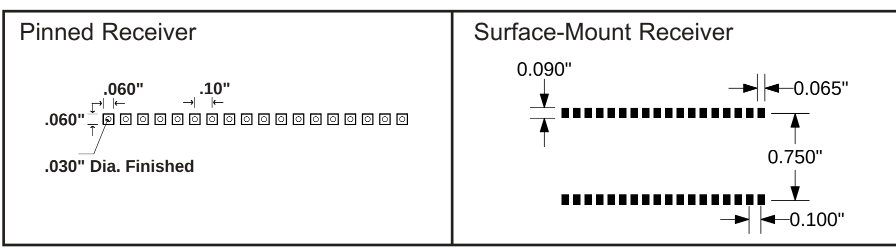


Figure 9: Suggested PCB Footprint

ENCAPSULATION NOTICE

In some applications the designer may wish to encapsulate the product's circuit board. Among the common reasons for doing so are environmental protection and security. The dielectric constant of encapsulation and potting materials varies and can adversely affect receiver performance. For this reason Linx does not recommend the encapsulation of our products and doing so will void all product warranties. It should be noted, however, that customers have reported success with a variety of encapsulation materials and techniques. Should you choose to encapsulate your product, careful testing should be conducted to determine the suitability of the chosen material.

PRODUCTION CONSIDERATIONS

Pinned Receiver Hand Assembly

The SIP module pins may be hand or wave-soldered. The module should not be subjected to reflow. Linx recommends wash-free manufacturing techniques. The modules are wash-resistant, but are not hermetically sealed. If a wash is used, a drying time, sufficient to allow the evaporation of any moisture which may have migrated into the module, must be allowed prior to applying electrical power. If the wash contains contaminants, receiver performance may be adversely affected even after drying.

SMD Receiver Hand Assembly

The SMD version is housed in a hybrid SMD package which has been designed to support hand or automated reflow techniques. The packages primary mounting surface is 36 pads located on the bottom of the module. Since these pads are inaccessible during mounting, plated castellations run up the sides of the module to facilitate solder wicking. This allows for very quick and efficient hand soldering for prototyping and small volume production.

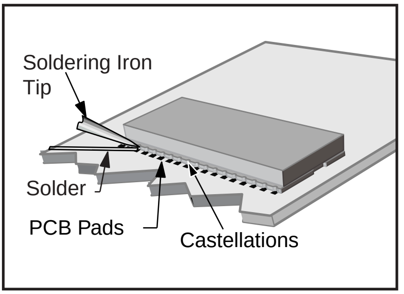


Figure 10: Soldering Technique

If the recommended pad placement has been followed, the pad on the board will extend slightly past the edge of the module. Touch both the PCB pad and the module castellation with a fine soldering tip. Tack one module corner first, then work around the remaining attachment points being careful not to exceed the solder times listed below.

Care should be taken, especially when hand-soldering, not to use excessive amounts of flux as it will wick under the module and potentially impair its function. In many cases, no-clean solder is the best choice. The modules are wash-resistant, but are not hermetically sealed. Linx recommends wash-free manufacturing techniques. If a wash is used, a drying time, sufficient to allow any moisture which may have migrated into the module to evaporate, must be allowed prior to applying electrical power. If the wash contains contaminants, receiver performance may be adversely affected even after drying.

Absolute Maximum Solder Times

Hand-Solder Temp. TX +225°C for 10 Sec.
Hand-Solder Temp. RX +225°C for 10 Sec.
Recommended Solder Melting Point +180°C
Reflow Oven: +220° Max. (See adjoining diagram)

SMD RECEIVER AUTOMATED ASSEMBLY GUIDELINES

For high-volume assembly, most users will want to auto-place the modules. The modules have been designed to maintain compatibility with most pick-and-place equipment, however, due to the module's hybrid nature certain aspects of the automated assembly process are far more critical than for other component types.

Following are brief discussions of the three primary areas where caution must be observed.

Reflow Temperature Profile

The single most critical stage in the automated assembly process is the reflow process. The reflow profile below should not be exceeded since excessive temperatures or transport times during reflow will irreparably damage the modules. Assembly personnel will need to pay careful attention to the oven's profile to ensure that it meets the requirements necessary to successfully reflow all components while remaining within the limits mandated by the modules themselves.

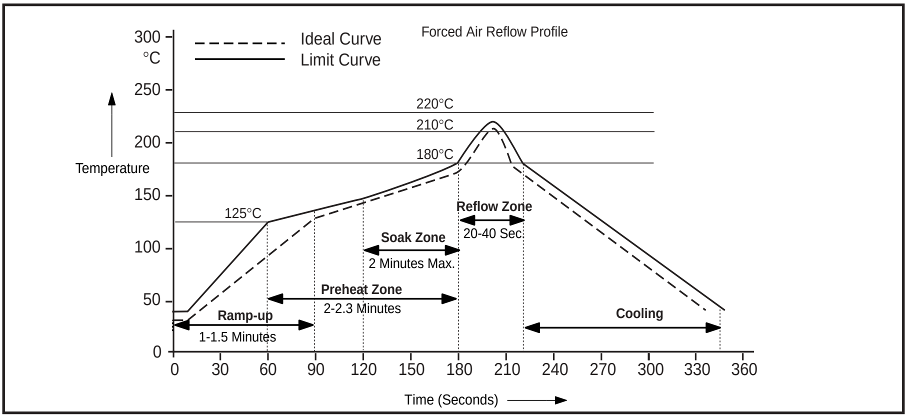


Figure 11: Maximum Reflow Profile

Shock During Reflow Transport

Since some internal module components may reflow along with the components placed on the board being assembled, it is imperative that the module not be subjected to shock or vibration during the time solder is liquidus.

Washability

The modules are wash-resistant, but are not hermetically sealed. Linx recommends wash-free manufacturing techniques, however, the modules can be subjected to a wash cycle provided that a drying time is allowed prior to applying electrical power to the parts. The drying time should be sufficient to allow any moisture which may have migrated into the module to evaporate, thus eliminating the potential for shorting damage during power-up or testing. If the wash cycle contains contaminants, receiver performance may be adversely affected, even after drying.

THEORY OF OPERATION

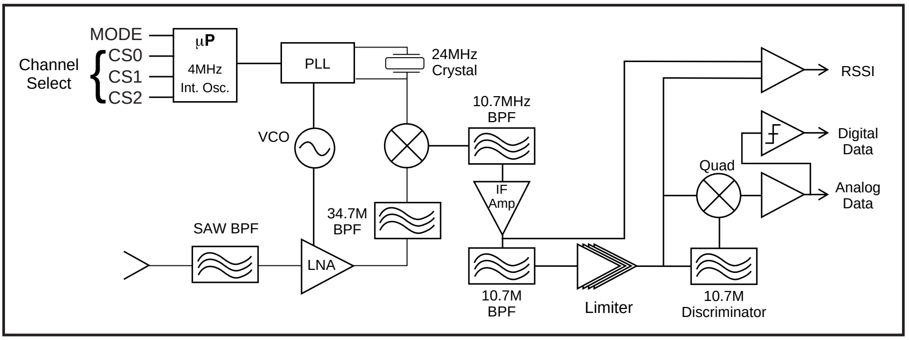


Figure 12: HP Series-3 Receiver Block Diagram

The HP-3 is a high-performance multi-channel, dual-conversion superhet receiver capable of recovering both analog (FM) and digital (FSK) information from a matching HP transmitter. FM/FSK modulation offers significant advantages over AM or OOK modulation methods including increased noise immunity and the receiver's ability to "capture" in the presence of multiple signals. This is especially helpful in crowded bands like those in which the HP-3 operates.

Let's take a brief look at each receiver section starting with the antenna. The single-ended RF port is matched to 50 ohms to support commonly available antennas such as those manufactured by Linx. The RF signal coming in from the antenna is filtered by a Surface Acoustic Wave (SAW) filter to attenuate unwanted RF energy (i.e., not in the 902-928MHz band). A SAW filter provides significantly higher performance than other filter types such as an LC bandpass.

Once filtered, the signal is 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 operating 34.7MHz below the incoming transmission frequency to produce the first Intermediate Frequency (IF).

The second conversion and FM demodulation is achieved by a high-performance IF strip which mixes the 34.7MHz first conversion frequency with 24.0MHz from a precision crystal oscillator. The resulting second IF of 10.7MHz is then highly amplified in preparation for demodulation.

A quadrature demodulator is used to recover the baseband signal from the carrier. The demodulated waveform is filtered, after which it closely resembles the original signal. The signal is routed to the analog output pin and the data slicer stage, which provides squared digital output via the data output pin. A key feature of the HP-3 is the transparency of its digital output which does not impose balancing or duty-cycle requirements within a range of 100 bps to 56Kbps.

An on-board micro-controller manages receiver functions and greatly simplifies user interface. The micro-controller reads the channel-selection lines and programs the on-board synthesizer. This frees the designer from complex programming requirements and allows for manual or software channel selection. The micro-controller also monitors incoming signal strength and squelches the data output when the signal is not strong enough for accurate data detection.

BOARD LAYOUT CONSIDERATIONS

If you are familiar with RF you may be concerned about specialized layout requirements. Fortunately, by adhering carefully to a few basic design and layout rules, receiver integration is generally very straightforward.

Page 5 shows the suggested PCB footprint for the HP Series-3 receiver. A groundplane (as large as possible) should be placed on a lower layer of your PC board opposite the HP-3 receiver. This groundplane can also be critical to the performance of your antenna which will be discussed later in the manual.

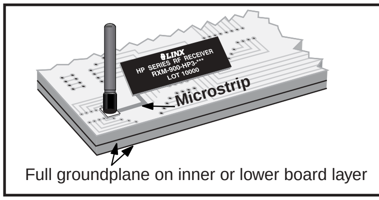


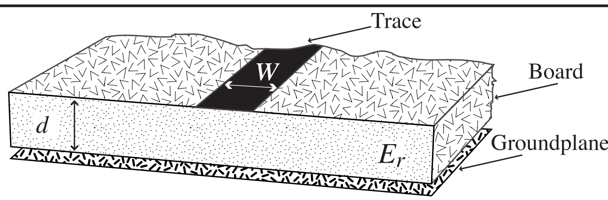
Figure 13: Groundplane Treatment

The HP-3 receiver should, as much as reasonably possible, be isolated from other components on your PCB. Specifically, high-frequency circuitry such as crystal oscillators should be kept as far away as possible from the HP-3 receiver.

If a pinned version of the receiver is to be mounted parallel to the board, it should be laid over so that the plastic cover faces away from the PC board.

Do not route PCB traces directly under SMD-packaged versions. The underside of the module has numerous signal-bearing traces and vias which could short or couple to traces on the product's circuit board.

The trace from the receiver to the antenna should be kept as short as possible. For runs greater than 1/4 inch use 50-ohm coax or a 50-ohm microstrip transmission line as shown below. Handy software for calculating microstrip lines is available on the Linx website (www.linxtechnologies.com).



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

$$Z_0 = \begin{cases} \dfrac{60}{\sqrt{E_e}} \cdot \ln\left(\dfrac{8d}{W} + \dfrac{W}{4d}\right) & \text{For } \dfrac{W}{d} \leq 1 \\[2ex] \dfrac{120\pi}{\sqrt{E_e} \cdot \left(\dfrac{W}{d} + 1.393 + 0.667 \cdot \ln\left(\dfrac{W}{d} + 1.444\right)\right)} & \text{For } \dfrac{W}{d} \geq 1 \end{cases}$$

Figure 14: Microstrip Formulas (E_r = Dielectric constant of PCB material)

Effective Dielectric Constant	Width/Height (W/d)	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

POWER SUPPLY

The user must provide a clean source of power to the receiver to ensure proper operation. Supply noise will reduce receiver sensitivity.

The HP-3 incorporates a precision low-dropout regulator on-board which allows operation over an input voltage range of 2.8 to 13 volts DC. Figure 15, shows a typical supply filter. This filter should be placed close to the module's supply lines. Its actual values will depend on the type and frequency of noise present in the user's product.

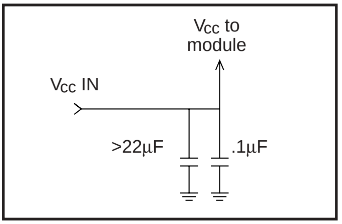


Figure 15: Typical Supply Filter

The HP-3 can be put into an ultra-low-current (<10µA) power-down mode by holding the PDN pin low. In power-down mode, the receiver is completely shut down. Thus, the RSSI circuit CANNOT be used to monitor for channel activity. If the PDN pin is left open or held high, the receiver will be fully on.

NOTE: WHEN PERIODICALLY POWERING-DOWN THE RECEIVER!

A common method of reducing power consumption is to turn off the receiver via the PDN pin and then wake it periodically to check for signal presence. During power-down the module is completely shut down. In order to wake the receiver successfully, allowance must be made for the start-up time requirements outlined elsewhere in this guide.

Remember the stated timing parameters assume a stable supply of 2.8 volts or greater. They do not include the charging times of external capacitance on the module's supply lines or the overhead of external software.

POWER-UP SEQUENCE

As previously mentioned, the HP-3 is controlled by an on-board microprocessor. When power is applied, the microprocessor executes the receiver start-up sequence, after which the receiver is ready to receive valid data.

Figure 16 shows the start-up sequence. This sequence is executed when power is applied to the VCC pin or when the PDN pin is taken 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 stabilized, the receiver is ready to accept data.

The typical turn-on response time for an HP Series-3 receiver is shown on page 3. The response time was measured by connecting the module's RF input to a signal generator set to the proper channel frequency with an output power of -92dBm and FM modulated at 115kHz deviation with a 1kHz square wave. The data output remains squelched until the internal start-up procedure has been executed.

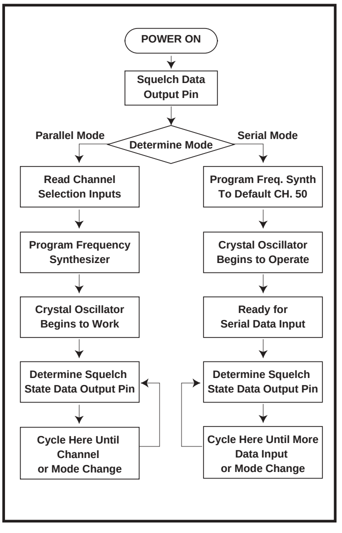


Figure 16: Start-Up Sequence

CHANNEL SELECTION

Parallel Selection

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

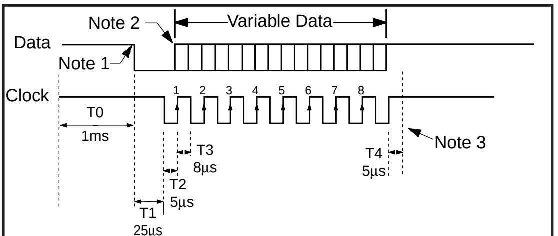
Figure 17: Parallel Channel Select Table

All HP-3 receiver models feature eight parallel selectable channels. Parallel mode is selected by grounding the mode pin. In this mode, channel selection is determined by the logic states of pins CS0-CS2 as shown in Figure 17. In this table a "0" represents ground and a "1" the positive supply. The on-board microprocessor performs all PLL loading functions eliminating external programming and allowing channel selection via DIP switches or a product's processor.

Serial Selection

In addition to the parallel mode, PS versions of the HP-3 also feature 100 serially selectable channels. The serial mode is entered when the mode pin is left open or held high. In this condition CS1 and CS2 become a synchronous serial port with CS1 serving as the clock line and CS2 as the data line. The module is easily programmed by sending and latching the binary number (0-100) of the desired channel (*see page 22 for channel selection table*). With no additional effort the module's on-board microprocessor handles the complex PLL loading functions.

The serial mode is straightforward, however, minimum timings and bit order must be followed. Loading is initiated by taking the clock line high and the data line low as shown. The eight-bit channel number is then clocked in one bit at a time with the LSB first.



(T0) Minimum time between packets or prior to data startup ....1mS min.
(T1) Data-LO/Clock-HI to Data-LO/Clock-LO ....25µS min.
(T2) Clock-LO to Clock-HI ....5µS min.
(T3) Clock-HI to Clock-LO ....8µS min.
(T4) Data-HI/Clock-HI ....5µS min.
Total Packet Time..157µS min.

Figure 18: PLL Serial Data Timing Table

There is no maximum time for this process, only the minimum times which must be observed. After the eighth bit both the clock and data lines should be taken high to trigger the automatic data latch. A typical software routine can complete the loading sequence in under 200uS. A sample routine is available on the Linx website.

NOTE: When the module is powered up in the serial mode it will self program to channel 50 until programmed by user software. This allows testing apart from external programming and prevents out-of-band operation. When programmed properly the dwell time on this default channel can be less than 200uS. Channel 50 is not counted as a usable channel since data errors may occur as transmitters also default to channel 50 on startup. If a loading error occurs, such as a channel number >100 or a timing problem, the receiver will default to serial channel 0. This is useful for debugging as it verifies serial port activity.

ANALOG OUTPUT

The HP-3 series is optimized for the transmission of serial data, however, it can also be used very effectively to send a variety of analog signals including audio. The ability of the HP-3 to send combinations of audio and data opens new areas of opportunity for creative design.

The analog output is valid from 50 Hz to 28 kHz, providing an AC signal of about 1V peak-to-peak. This is a high impedance output and not suitable for directly driving low-impedance loads, such as a speaker. In applications where a low impedance load is to be driven a buffer circuit should always be used. For example, in the case of a speaker, a simple op-amp circuit like the one shown below can be used to act as an impedance converter.

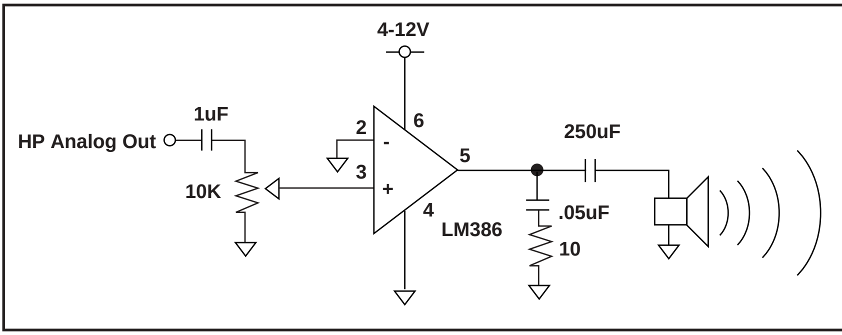


Figure 19: Audio Buffer Amplifier

The transmitter's modulation voltage is critical, since it determines the carrier deviation and distortion. The transmitter input level should be adjusted to achieve the optimum results for your application in your circuit. Please refer to the transmitter data guide for full details.

When used for audio, the analog output of the receiver should be filtered and buffered to obtain maximum sound quality. For voice, a 3-4kHz low-pass filter is often employed. For broader-range sources such as music, a 12-17kHz cutoff may be more appropriate. In applications which require high-quality audio, a compandor may be used to further improve SNR. The HP-3 is capable of providing audio quality comparable to a radio or intercom. For applications where truly high fidelity audio is required, the HP-3 will probably not be the best choice and a device optimized for audio should be utilized.

THE DATA OUTPUT

The data output pin provides recovered digital data. It is an open collector output with an internal 4.7K pull-up. When an RF transmission is not present, or when the received signal strength is too low to ensure proper demodulation, the data output is squelched continuous high. This feature supports direct operation with UARTs which require their input to be continuously marking (or high). An HP-3 transmitter and receiver can be directly connected between two UARTs without the need for buffering or logical inversion. It should be noted that the squelch level is set just over the receiver's internal noise threshold. Any external RF activity above that threshold will "break squelch" and produce hashing on the data output. While the data output will be reliably squelched in low-noise environments, the designer should always plan for the potential of hashing.

DATA CONSIDERATIONS

Once an RF link has been established, the challenge becomes how to effectively transfer information across it. For simple control or status signals such as button presses or switch closures, consider using an encoder and decoder IC set. These chips are available from several manufacturers including Linx, Microchip, Holtek, and Motorola. These chips take care of all encoding, error checking, and decoding functions. They generally provide a number of inputs to which switches can be directly connected, and address or security bits to prevent unintentional activation. These IC's are an excellent way to avoid protocol development and bring basic remote control/status products quickly and inexpensively to market.

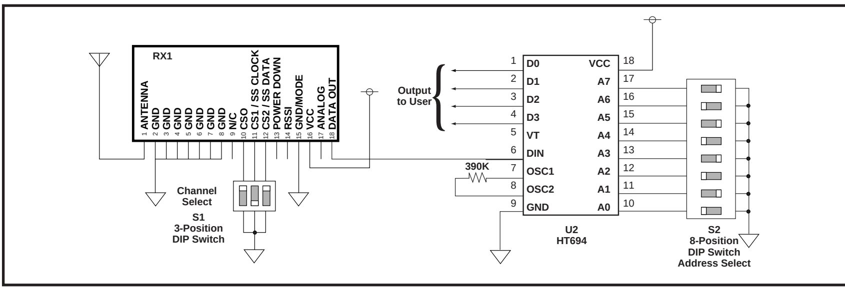


Figure 20: Typical Application - Remote-Control Receiver

In most applications the modules will be interfaced to a microprocessor. A UART may be employed or an output pin of the microprocessor "bit-banged" to create a data stream. While many RF solutions impose complex formatting and balancing requirements, the HP-3 series was designed to be as transparent as possible. The HP-3 does not encode or packetize the data in any manner. This transparency gives the designer tremendous flexibility in the structure of a protocol. Of course the performance and reliability of the link are dependent on the quality of external software and hardware. To properly apply the receiver, it is critical to understand the differences between a wired and a wireless environment. At each point in the system there are timing and data-corruption issues that should be understood and accounted for. The following section provides a brief overview of these issues.

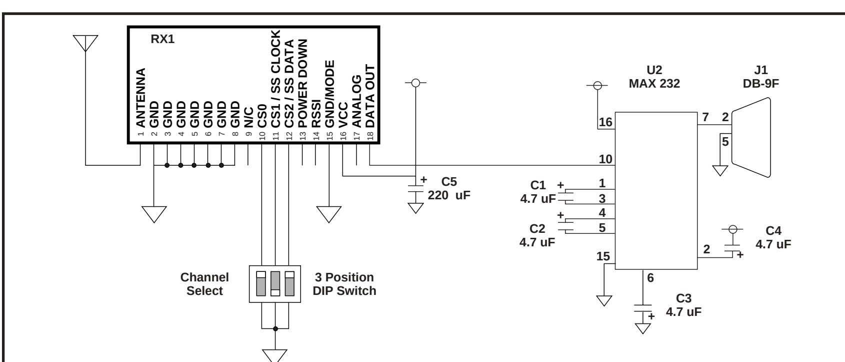


Figure 21: Typical Application - RS-232 Interface

TIMING CONSIDERATIONS

There are four major timing considerations the engineer must be aware of when designing with the HP-3 Series receiver. These are shown in the table below.

Parameter	Description	Max.
T_1	Max time between data output transitions	20mSec
T_2	Max Channel-Change Time (Time to Valid Data)	1.5mSec
T_3	Receiver Turn-on Time (Via PDN)	3mSec
T_4	Receiver Turn-on Time (Via V_{CC})	7mSec

T1 is the maximum amount of time that can elapse without a data transition. Data must always be considered in both the analog and the digital domain. Because the data stream is asynchronous and no particular format is imposed, it is possible for the data to meet the receiver's baud-rate requirement yet violate the analog frequency parameters. For example, if a 255 (0FF hex) were sent continuously the receiver would view the data as a DC level. The receiver would hold that level until a transition was required to meet the minimum frequency requirement. If no transition occurred, data integrity could not be guaranteed. Thus, while no particular structure or balancing requirement is imposed, the designer must ensure that both analog and digital signals meet the required transition specification.

T2 is the worst-case time needed for a powered-up module to switch between channels after a valid channel selection. This time does not include external overhead for loading a desired channel in the serial channel-selection mode.

T3 is the time to receiver-readiness from the PDN pin going high. Receiver readiness is determined by valid data at the RXDATA pin. (This assumes an incoming data stream and the presence of stable supply on Vcc pin).

T4 is the time to receiver-readiness from the application of Vcc. Receiver readiness is determined by valid data at the RXDATA pin. (This assumes an incoming data stream and the PDN pin is high or open).

PROTOCOL CONSIDERATIONS

As previously indicated, the module's transparency allows for virtually unlimited protocol types and techniques. This section is meant only to illustrate general issues a designer should address to ensure product reliability in the field. Your application may call for or benefit from an entirely different protocol structure.

It is a good idea to structure the data being sent into small packets so that errors can be managed without affecting large amounts of data. Packets should be transmitted without space between bytes. When using a UART the following packet format is often followed:

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

The UART sync-byte is used to ensure that the start-bit for the start-byte will be correctly detected. It is a single byte with a value of 255 (0FF hex). A start-byte often follows the sync-byte to intelligently qualify the data-packet which will follow. Detection of the start-byte would be performed by the computer or microcontroller connected to the receiver.

PROTOCOL CONSIDERATIONS (CONT.)

The procedure here is protocol-dependent, but to illustrate let's consider the packet format outlined above being sent to a UART. A UART interprets the start-bit of a byte as a 1-0 transition. When the incoming data is 101010, or hash, it is hard to actually find the start bit. This problem is solved by the UART sync-byte. The purpose of the sync-byte is to create a high marking period of at least a byte-length so that the start bit of the following start-byte can be correctly recognized.

The start-byte is used by the receiving computer or microcontroller to intelligently identify the beginning of a data packet. The start-byte value 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 many other ways to organize protocol if this proves impractical.

There is always a possibility of bursting errors from interference or changing signal conditions causing corruption of the data packet, so some form of error checking should be employed. A simple checksum or CRC could be used. Once an error is detected the protocol designer may wish to simply discard the corrupt data or develop a scheme for correcting it or requesting its retransmission.

INTERFERENCE CONSIDERATIONS

It must be recognized that many bands are widely used, and the potential for conflict with other unwanted sources of RF is very real. All RF products are at risk from interference but its effects can be minimized by better understanding its characteristics.

Interference can manifest itself in many ways. Low-level interference will produce noise and hashing on the output and reduce the link's overall range. Thanks to the capture properties of an FM system, the receiver will still function when an intended signal is present at a higher level than the interference.

Another type of interference can be caused by higher-powered devices such as hopping spread-spectrum devices. Since these devices move rapidly from frequency to frequency they will usually cause short, intense losses of information. Such errors are referred to as bursting errors and will generally be dealt with through protocol.

High-level interference is caused by products sharing the same frequency or from near-band high-power devices. Fortunately, this type of interference is less common than those mentioned previously, but in severe cases can prevent all useful function of the affected device. It is in these cases that the frequency agility offered by the HP is especially useful.

Although technically it is not interference, multipath is also a factor to be understood. Multipath is a term used to refer to the signal cancellation effects that occur when RF waves arrive at the receiver in different phase relationships. This is particularly a factor in interior environments where objects provide many different reflection paths. Multipath results in lowered signal levels at the receiver and thus shorter useful distances for the link.

RSSI OUTPUT

HP-3 Series receivers are equipped with Received-Signal-Strength-Indication (RSSI). The RSSI output is a DC voltage proportional to the incoming signal strength. The output has many valuable uses including interference assessment, signal strength indication, external squelching, and transmitter presence indication.The RSSI circuit has a voltage range of about 800mV to 2.5V and a dynamic signal range of greater than 60dB.

Figure 4 on page 3 shows the RSSI output versus input signal strength. This graph is a characterization only. The RSSI response and level vary from module to module. For many applications this slight variation is acceptable but when highly accurate measurement of the incoming signal strength is required your product must be calibrated on a receiver-by-receiver basis.

Figure 5 on page 3 shows the worst case RSSI response time. This graph shows how long it takes the RSSI voltage leval without RF present to respond to an incomi8 CH onlyng signal. The RSSI pin can also be used for demodulation of AM or OOK modulated carriers.

A spectrum analyzer is the primary tool of the RF engineer for assessing interference sources and levels, but is complex and costly. Fortunately, the RSSI voltage output can also be used to determine the presence and strength of interference during the development process or for display to the end user.

RECEIVER SENSITIVITY

The sensitivity of a receiver is critical to the overall range-performance of a wireless link. A sensitivity specification is almost meaningless unless accompanied by a bit-error-rate (BER). Receiver sensitivity is often measured using a pseudo-random bitstream generated by a bit-error-rate-tester (BERT). A typical receiver sensitivity test setup is shown in Figure 22.

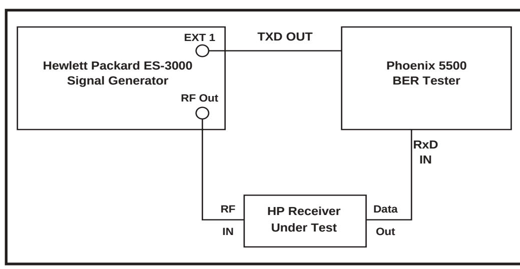


Figure 22: Sensitivity Test Setup

A path loss model can be used to show that the open field range of a FCC-compliant link can exceed 1,000 feet. The actual ability of a product to attain this range-performance depends on many factors including:

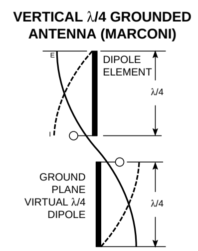
1) *Transmitter characteristics*
2) *Quality of receiving antenna*
3) *Actual operating environment (open field, inter-building, city, etc.)*
4) *Ambient RF conditions / Interference level*
5) *Protocol structure / Data rate*
6) *Quality of layout / Level of circuit and power supply noise*

The HP-3 development kit contains two development boards that can be used to evaluate the HP-3's range-performance. If you have any difficulties attaining the same range with your own product, you should carefully review all Linx documentation for ideas of what the problem might be. If all else fails, contact Linx and discuss your design with an application engineer.

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 groundplane. 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 and the corresponding sacrifice in performance accepted.
3. If an internal antenna is used, keep it away from other metal components, particularly large items like transformers, batteries, and PCB tracks and groundplanes. 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 groundplane acts as a counterpoise, forming, in essence, a 1/2-wave dipole. For this reason adequate groundplane area is essential. The groundplane can be a metal case or ground-fill on the circuit board. Ideally, the groundplane to be used as counterpoise should have a surface area ≥ the overall length of the 1/4-wave radiating element and be oriented at a 90° angle. Such an orientation is often not practical due to size and configuration constraints. In these instances a designer must make the best use of the area available to create as much groundplane in proximity to the base of the antenna as possible. In instances where the antenna is remotely located or the antenna is not in close proximity to a circuit board plane or grounded metal case, a small metal plate may be fabricated to maximize antenna performance.



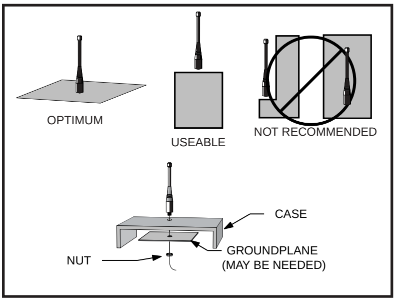


Figure 23: Antenna Orientations

5. Remove the antenna as far as possible from potential interference sources such as switching power supplies, oscillators, motors and relays. Remember, 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 groundplane 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 50Ω coax such as RG-174 for the remote feed.

ANTENNA CONSIDERATIONS

The choice of antennas is one of the most critical and often overlooked design considerations. The range, performance, and legality of the receiver is critically dependent on the antenna utilized. While adequate antenna performance can often be obtained by trial and error methods, professionally designed antennas, such as those offered by Linx, can provide superior performance, repeatability and legal compliance. For complete details on the Linx antenna line, visit the Linx website at www.linxtechnologies.com, or call (800)736-6677.

Figure 23: Linx Antennas

The following sections look at some of the basic considerations involved in the design and selection of antennas. For a more comprehensive discussion please refer to Linx applications note #00500 "Antennas: Design, Application, Performance".

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. In cases where the antenna needs to be removable, Linx offers a full line of connectors designed to comply with these requirements.

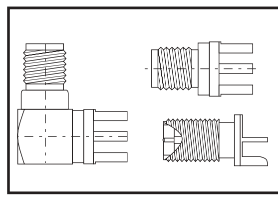


Figure 24: Linx Connectors

ANTENNA SHARING

In cases where a transmitter and receiver module are combined to form a transceiver it is often advantageous to share a single antenna. To accomplish this an antenna switch must be used to provide isolation between the modules. There is a wide variety of antenna switches available which are cost-effective and straight-forward to use. Among the most popular are switches from Alpha 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 it may be more appropriate to utilize two discrete antennas.

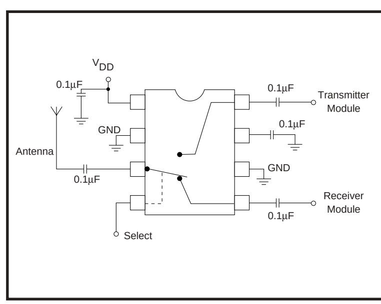


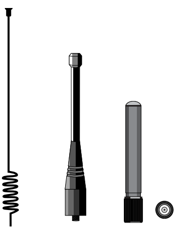
Figure 25: Typical Antenna Switch

COMMON ANTENNA STYLES

The antenna is a critical and often overlooked component which has a significant effect on the overall range, performance and legality of an RF link. There are hundreds of antenna styles that can be successfully employed with the HP-3 Series. Following is a brief discussion of the most commonly utilized styles.

Whip Style

A whip-style monopole antenna provides outstanding overall performance and stability. A low-cost whip can be easily fabricated from wire or rod, but most product designers opt for the consistent performance and cosmetic appeal of a professionally made model. To meet this need, Linx offers a wide variety of straight and reduced-height whip-style antennas in permanent and connectorized mounting styles.



The wavelength of the operational frequency determines an antenna's overall length. Since a full wavelength is often quite long, a partial 1/4-wave antenna is normally employed. Its size and natural radiation resistance make it well-matched to Linx modules. The approximate length for a straight 1/4-wave antenna can be easily found using the formula below. It is also possible to reduce the overall height of the antenna by using a helical winding; therefore, the physical appearance is not always an indicator of the antenna's frequency.

1/4-wave wire length frequencies:
433MHz = 6.5"
868MHz = 3.24"
902-928MHz = 3.06"

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

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

Example:

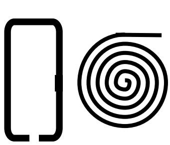
$$\frac{234}{916\text{MHz}} = .255$$

.255 x 12" = 3.06"

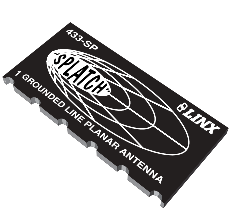
Specialty Styles

Linx offers a wide variety of specialized antenna styles and variations. Many of these styles utilize helical elements to reduce the overall antenna size while maintaining reasonable performance. A helical antenna's bandwidth is often quite narrow and the antenna can detune in proximity to other objects, so care must be exercised in layout and placement.

Loop Style



A loop- or trace-style antenna is normally printed directly on a product's PCB. The element can be made self-resonant or externally resonated with discrete components but its actual layout is product specific. Despite its cost advantages, PCB antenna styles are generally inefficient and are very sensitive to changes in layout or substrate. In addition, printed styles are difficult to engineer, requiring the use of expensive equipment including a network analyzer. An improperly designed loop will have a high SWR at the desired frequency which can introduce instability in the RF stages.



Linx offers low-cost planar and chip antennas which mount directly to a product's PCB. These tiny antennas do not require testing and provide excellent performance in light of their compact size. They offer a preferable alternative to the often problematic "printed" antenna.

LEGAL CONSIDERATIONS

NOTE: HP-3 Series modules are intended to allow for full Part-15 compliance; however, they are not approved by the FCC or any other agency worldwide. This is because the module's performance and legality may be affected by external factors specific to a user's application. The purchaser understands that testing and approvals of a finished product may be required prior to the sale or operation of the device, and agrees to utilize the component in keeping with all laws governing their use 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 (FCC). 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-3 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

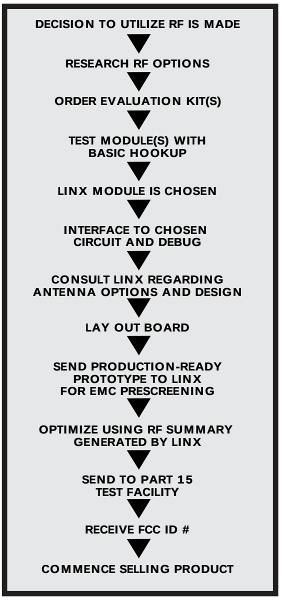
International approvals are slightly more complex, although many modules are designed to allow all international standards to be met. If you are considering the export of your product abroad, you should contact Linx Technologies to determine the specific suitability of the module to your application.

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 factors such as the choice of antennas, correct use of the frequency selected, and physical layout. 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

The addition of wireless capabilities 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 an RF module, such as the HP-3, the design and approval process will be greatly simplified. It is still important, however, to have an objective view of the steps necessary to ensure 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. These applications notes are available on-line at www.linxtechnologies.com or by contacting the Linx literature department.

NOTE #	LINX APPLICATION NOTE TITLE
00100	RF 101: Information for the RF challenged
00126	Considerations for operation in the 902MHz to 928MHz band
00130	Modulation techniques for low-cost RF data links
00140	The FCC Road: Part 15 from concept to approval
00150	Use and design of T-attenuation pads
00155	Serial loading techniques for the HP-3 Series (PS Versions)
00161	Considerations for sending data with the HP-3 Series
00500	Antennas: Design, Application, Performance

SERIAL CHANNEL SELECTION TABLE

CHANNEL	TX FREQUENCY	RX LO	CHANNEL	TX FREQUENCY	RX LO
0	902.62	867.92	51	915.37	880.67
1	902.87	868.17	52	915.62	880.92
2	903.12	868.42	53	915.87	881.17
3	903.37	868.67	54	916.12	881.42
4	903.62	868.92	55	916.37	881.67
5	903.87	869.17	56	916.62	881.92
6	904.12	869.42	57	916.87	882.17
7	904.37	869.67	58	917.12	882.42
8	904.62	869.92	59	917.37	882.67
9	904.87	870.17	60	917.62	882.92
10	905.12	870.42	61	917.87	883.17
11	905.37	870.67	62	918.12	883.42
12	905.62	870.92	63	918.37	883.67
13	905.87	871.17	64	918.62	883.92
14	906.12	871.42	65	918.87	884.17
15	906.37	871.67	66	919.12	884.42
16	906.62	871.92	67	919.37	884.67
17	906.87	872.17	68	919.62	884.92
18	907.12	872.42	69	919.87	885.17
19	907.37	872.67	70	920.12	885.42
20	907.62	872.92	71	920.37	885.67
21	907.87	873.17	72	920.62	885.92
22	908.12	873.42	73	920.87	886.17
23	908.37	873.67	74	921.12	886.42
24	908.62	873.92	75	921.37	886.67
25	908.87	874.17	76	921.62	886.92
26	909.12	874.42	77	921.87	887.17
27	909.37	874.67	78	922.12	887.42
28	909.62	874.92	79	922.37	887.67
29	909.87	875.17	80	922.62	887.92
30	910.12	875.42	81	922.87	888.17
31	910.37	875.67	82	923.12	888.42
32	910.62	875.92	83	923.37	888.67
33	910.87	876.17	84	923.62	888.92
34	911.12	876.42	85	923.87	889.17
35	911.37	876.67	86	924.12	889.42
36	911.62	876.92	87	924.37	889.67
37	911.87	877.17	88	924.62	889.92
38	912.12	877.42	89	924.87	890.17
39	912.37	877.67	90	925.12	890.42
40	912.62	877.92	91	925.37	890.67
41	912.87	878.17	92	925.62	890.92
42	913.12	878.42	93	925.87	891.17
43	913.37	878.67	94	926.12	891.42
44	913.62	878.92	95	926.37	891.67
45	913.87	879.17	96	926.62	891.92
46	914.12	879.42	97	926.87	892.17
47	914.37	879.67	98	927.12	892.42
48	914.62	879.92	99	927.37	892.67
49	914.87	880.17	100	927.62	892.92
50*	915.12	880.42	(shaded) = Also available in Parallel Mode		

**This channel is not counted as it is the Serial Mode default channel (see page 11)*

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

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