EXHIBIT 3

MANUAL

FCC ID #: N4O-CYE2

Cye is a breakthrough, personal robot with a versatility, performance and price as astonishing as its Y2K design. Because Cye is controlled through a simple graphic user interface on any PC, it's accessible to a whole range of users: People who enjoy the fun offered by remote controlled devices The technologically curious with very basic point and click PC skills. People searching for inexpensive, cyberage solutions to tasks at home or in the office. Hobbyists or serious developers who can create their own Cye software or hardware accessories.

Cye is a fun remote control device

Take Cye out of the box, plug it's home base into your PC com port and 110 volt outlet, load the "Map and Zap" software into your PC and click open the Mapping window. The image on your screen will show what the robot and the space around it would look like if viewed from above. The robot icon appears surrounded by an indistinct grayish background-as though Cye were in a dense fog. Click the robot icon and drag it around the screen using your mouse or joystick. As you do this, the real Cye will move on the floor, mirroring the movement and direction of the robot icon on the screen.

Playing with Cye in this way is similar to playing with any remote control car, boat, or plane. But unlike conventional devices, Cye is not just moving around space: It is actually exploring and learning its environment. Wherever it moves, Cye reports back to the PC where it is finding obstacles, and where it is finding free space. Gradually, patches of fog on the screen clear up. The places where Cye finds obstacles are marked as black areas. The places where Cye finds free space become clear, white areas on the screen.

Cye is a mapping tool

The ability to record what it encounters in this way makes possible a second level of usage: mapping entire environments in precise detail. To do this, you are not confined to the dragging the robot icon across the screen. You can also use the point-and-click mapping tools on the menu bar. By using the pencil and the eraser tools, you can mark areas on the screen map as "clear"or "filled." This saves time and effort, since you don't have to drag the robot icon around the screen to establish these things.

Once the basic map is completed, you can use the point-and-click labeling tools on the menu bar to mark different places Cye needs to be aware of. You can use the "Danger" tool to rope off areas on the screen map - such as stairways - that you don't want Cye to enter. You can use the "Hot Point" tool to mark and type in the name of destinations - like the dining area or the kitchen - that you may want the robot to go to later. You can use the "Check Point" tool to show Cye where there are straight sections of wall it can use to update its position. You can use the "Vacuum Patch" tool to designate rectangular areas you may want the robot to vacuum. If you double click on a vacuum patch, you can specify which corner the robot should enter and whether the zig zag pattern Cye follows should be horizontal or vertical. This enables you to create a path that won't cause the vacuum to run over it's cord. At any time, you can click in this patch and the robot will execute it, cruising through it's zig zag pattern. If you have attached any upright vacuum to Cye using the vacuum attachment, Cye will pull the appliance through this pattern and vacuum your floor. You can set up a series of these patches using the "FlowZap" tool (see below) and get Cye to vacuum your entire house.

Cye is a programmable robot

You can save the map of Cye's world and use it to guide Cye around obstacles, race around the room, or drive a ball into any goal or target area you establish. But you can also use it enable the third and what is probably the most exciting level of usage: making Cye perform a whole range of tasks any time you specify.

To do this requires no more than basic point-and-click, drag- and-drop, type-a-word-or-a-number-in-an-open-window computer routines. You simply open the Flow-Zap window and, in a few seconds you can set up a job for Cye to carry out. For example, to get it to wake you up, you can create a simple, four-step do-list that says: "Wait till 6:30 AM." "Go to my bedroom." "Sing National Anthem." "Go to home base." You drag-and-drop the basic routines from a menu bar. Since you created the map with the "hot points" on it, the names of the destinations are available for selecting on pull down menus, as are all other major options. The only elements you must type in yourself are the specific times you want events to take place.

Just as simply and quickly, you can command Cye to execute a great variety of tasks in your home and business. You can make a do-list that instructs Cye to execute the path of one of the vacuum patches you have mapped at 5:00, then check in at a check point you have create to eliminate any positioning error that may have accumulated, then move on to the next patch, check in again, and so on until you have vacuumed your entire house. Of course you will have to lay out these patches carefully to avoid getting your vacuum cleaner's cord tangled up in your furniture, but that is up to you.

You can create a do-list that runs Cye and its wagon into the dining area at 7:00PM; waits to be nudged before carrying dirty dishes into the kitchen; returns to the dining area when nudged to continue clearing; goes back-and-forth as many times as you instruct; and then returns to its home base.

In a business environment, by using the same simple point and click, and drag-and-drop commands, you can create a do-list that enables Cye to collect and distribute up to 10 lbs. of mail, supplies, or other material to any number of people or locations you specify.

You can instruct Cye to carry out amusing and entertaining tasks and routines. You can even create a do-list that will get a soccer ball into a net, no matter where you place the ball at the start.

Cye is a Hobbyist's and a Developer's dream

Cye comes with an RJ 45 connector accessible just in front of Cye's LED. This 8 pin connector has a relay driving output, a 5 volt input, and a 12 volt and 5 volt power supply. With these signals, hobbyists can manipulate muscle wires, read sensor inputs, turn on lights or sirens, or whatever else they might imagine. The input can be read and the state of the output set right from the Flow Zap window as part of the users program. So Cye could easily be programmed to do such things as go to the family room, rotate 45 degrees, and fire a nerf gun rigged with muscle wires. The wagon has a convenient holder for mounting popular 2"x4" hobby boxes.

For developers, the Cye hardware and software is completely open facilitating development of both new software applications for manipulating the robot and for creating hardware that attaches to it. Communication from the user's PC to Cye is handled through an OCX server which can be accessed from any Visual Basic or C programming environment on the user's PC. Using the OCX, developers can create their own application for Cye because the entire Cye hardware command set is exposed. This includes everything from "go to Cartesian X, Y" to "set PWM duty cycle on wheel A to value X", to "what is your battery level now?" Altogether, there are 35 commands to the robot and 20 messages from the robot that are included in this protocol.

In addition, the radio receive and transmit signals are exposed on the RJ connector. Probotics Inc. will provide the C code for the communications protocol for anyone wishing to communicate to their own remote microprocessor board through Cye's radio link. Cye has a unique address and only responds to messages sent to this address. Additional hardware mounted to Cye and connected through the RJ45 connector can have another address and share the radio link with the robot.

Breakthrough technologies

The technologies behind Cye's versatility, performance and ease of use are as innovative as its striking, distinctive design.

The threshold issue that mobile robots have to wrestle with is finding a way to keep track of precisely where they are in their environment.

Probotics founder and chief guru, Henry Thorne, solved this challenge in a remarkably simple manner: he developed a group of 5 patented technologies that make the age-old navigation system known as "ded-reckoning" accurate in dealing with the distortions and errors created by slippage and other problems of traction produced by the robot as it travels. In fact, Thorne's technology is more accurate and ten times less expensive than GPS, the leading currently available positioning technology.

Not surprisingly, he calls his technology FunDR-functional ded-reckoning. Following the standard ded-reckoning Formula, 500 times per second, Cye calculates its location based on its previous position, its current speed, and the direction it is traveling.

The accuracy and reliability of the calculations is the result of design, construction and software innovations. Cye's entire carriage is suspended on two wheels with projecting tips, 1/16 of an inch wide. This keeps Cye's points of contact with the floor as well as the external forces on the robot to a minimum. The wheels themselves are made of stiff plastic in a bicycle sprocket configuration, with a layer of very sticky urethane on the tips for good gripping. With this design, the amount of slip on any surface is minimized, while the pivot point - crucial in monitoring Cye's location - is perfectly defined.

Every 10th of an inch, Cye calculates the extent of any wheel slippage that may be taking place, and immediately compensates for it by slightly over-rotating the appropriate wheel. To eliminate any error that may accumulate in Cye's calculations, Cye goes to the checkpoints established by the user when creating the map of Cye's environment. At these checkpoints, Cye verifies its position and updates it if necessary.

Price

Not the least remarkable feature of Cye is its price. At $629, it offers some features only available for hundreds of dollars more, and unique capabilities unavailable until now at any price. Primarily, cost has been removed by utilizing the processing power of the user's existing PC to reduce the hardware requirements in the robot.

Additionally, numerous innovations in the mechanical and electrical design made this low-cost, high-quality product possible. Instead of expensive shaft encoders, the gear motor cooling fans double as encoders by running them through low-cost slotted optics. There are no wiring harnesses because everything - including the motors, battery, radio and antenna - is mounted directly to the central circuit board. The home base contacts double as the circuit board mounting bolts. Instead of expensive NI-CAD batteries, sealed lead acid batteries are used because the extra weight helps make the ded-reckoning calculations more accurate. A single dual H bridge driver chip drives both motors. Low cost high speed CMOS circuitry is used throughout. A single 16-bit micro-controller serves as the brains of the robot while also capturing analog inputs such as motor current and battery level and performing all timing functions. There are no moving parts other than the wheel on one end of the motor and the cooling fan on the other.

Extensive support available

At every level of usage, using Cye is highly intuitive and a joy to work and play with. For all but the fourth level of usage, the only computer skills the user has to have are basic select-and drag, point-an-click, drag-and-drop, and typing routines familiar to even the greenest PC novice.

Nonetheless, Cye comes with extensive support. In addition to a manual and help-file, users can consult a Probotics web site where they will find the general techniques for mapping and other operations presented using a unique LAYGo (Learn as you go) format that anticipates and presents relevant information as the user requires it. The site also includes an FAQ and a direct E-mail feature that can be used to forward any questions directly to Probotics technical support.

Specs

Cye is 16" X 10" X 5" and weighs 6 lbs. It operates from any PC with a Pentium 133 MHz chip or higher. Cye communicates to and from the PC 10 times per second via an FCC approved 900 MHz radio link. Its 2.9 amp hour rechargeable batteries will power Cye for 20 hours when idle. 4 hours when driving around on light carpet; 30 minutes when pulling the vacuum on light carpet; and 20 minutes when pulling a heavy vacuum through medium carpet with a half-inch sponge pad underneath.

Accessories

You can buy a wagon accessory, a vacuum attachment accessory, and a switched-outlet accessory. The wagon lets you carry goods around your home or business.

The vacuum accessory allows you to snap any upright vacuum cleaner onto Cye. Cye can pull around any upright vacuum on any carpets up to medium-thickness.

The switched-outlet accessory lets you pull an extension cord around and turn on or turn off an outlet powered by the extension cord.

Radio and Television Interference Statement

The equipment described in this manual generates and uses radio frequency energy. If it is not installed and used properly, that is in strict accordance with the manufacturer's instruction, it may cause interference to radio and television reception.

This equipment has been tested and complies with the limits for a Class B Digital Device in accordance with the specifications in Part 15 of the FCC Rules. These rules are designed to provide reasonable protection against such interference in a residential installation. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause interference to radio or TV reception, which can be determined by turning the equipment on and off, the user is encouraged to try to correct the interference by one or more of the following measures:

* Reorient the receiving antenna.
* Relocate the computer with respect to the receiver.
* Move the computer away from the receiver.
* Plug the computer into a different outlet so that computer and receiver are on different branch circuits.

If necessary, the user should consult the dealer or an experienced radio/TV technician for additional suggestions. The user may find the following booklet, prepared by the Federal Communications Commissions, helpful: *How to Identify and Resolve Radio and TV Interference Problems*. This booklet is available from the U.S. Government Printing Office, Washington, DC 20402.

WARNING

This equipment has been certified to comply with the limits for a Class B Digital Device under Part 15 of the FCC Rules. Only peripherals (modems, printers, etc.) certified to comply with the Class B limits may be attached to this computer. Operation with non-certified peripherals is likely to result in interference to radio and TV reception. Any changes or modifications to this equipment not expressly approved by the manufacturer could void the user's authority to operate this equipment.

REMARKS

To meet FCC requirements, shielded interface cables and power cords are required to connect the device to a personal computer, peripheral, or other Class B Certified device.

PERFORMANCE DATA TXM-900-HP

ABOUT THESE MEASUREMENTS

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

Parameter	Designation	Min.	Typical	Max.	Units	Notes
Input Voltage (Vcc)	V_{CC}	2.7	–	16.0	VDC	–
Supply current	I_{CC}	14	15	17	mA	–
Operating frequency	F_C	902	–	928	MHz	–
Overall frequency accuracy		-50	–	+50	KHz	–
Output Power		+2	+5	+7	dBm	–
Spurious Emissions		–	–	-50	dBc	–
Harmonic Emissions		–	–	-45	dBc	–
Occupied Bandwidth		–	32	–	KHz	–
P_{ON} to CTS High Time	T_{PON}	-	35	40	mSec	–
Minimum On	T_{MINON}	40	–	–	mSec	–
Minimum Off	T_{MINOFF}	300	–	–	mSec	–

Figure 2: Performance data table

Absolute Maximum Ratings:			
Supply voltage Vcc, using pin 7	-0.3	to	+18 VDC
Operating temperature	0°C	to	+70°C
Storage temperature	-45°C	to	+85°C
Soldering temperature	+260°C for 10 sec.		
Any input or output pin	-0.3	to	Vcc

***NOTE* Exceeding any of the limits of this section may lead to permanent damage of the device. Furthermore, extended operation at these maximum ratings may reduce the life of this device.**

Figure 3: Maximum ratings table

CAUTION

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

TYPICAL PERFORMANCE GRAPHS

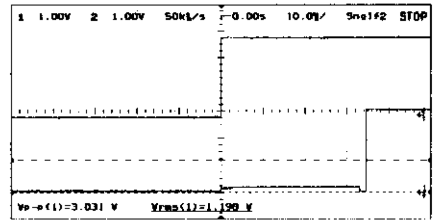


Figure 4: Power-On Timing

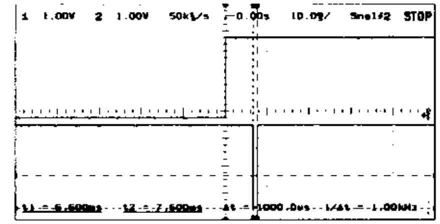


Figure 5: Channel Change Timing

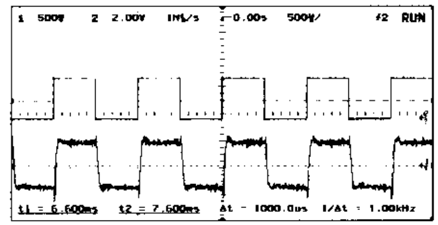


Figure 6: Modulation Linearity for Square Wave Input

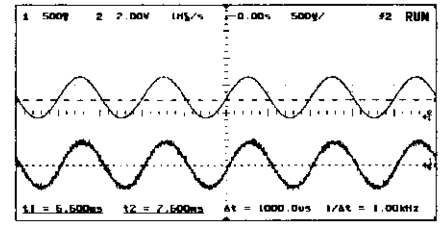


Figure 7: Modulation Linearity for Sine Wave Input

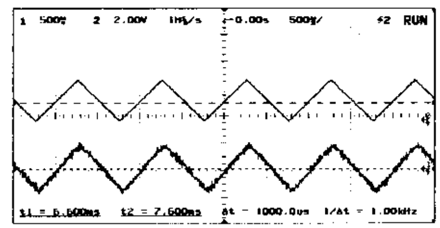


Figure 8: Modulation Linearity for Triangle Wave Input

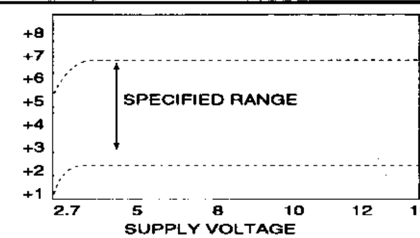


Figure 9: Output Power vs. Supply Voltage

PHYSICAL PACKAGING

The transmitter is packaged as a hybrid through-hole SIP-style module with 10 pins spaced at .1" intervals with a .3" gap between pins 2 & 3. Baseband components occupy the rear of the board while high-frequency components are grouped on the front.

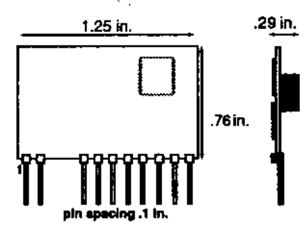


Figure 10: Physical package

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.

PIN DESCRIPTION

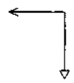
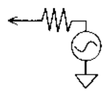
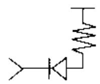
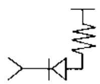
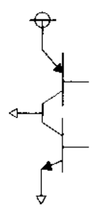
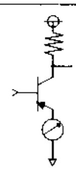
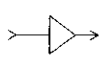
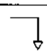
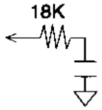
PIN#	PIN Name	Equivalent CTK	Description
1	Ground		50-ohm RF Input
2	RF/ANT Out		Analog Ground
3	CS0		Channel Select 0
4	CS1		Channel Select 1
5	CS2		Channel Select 2
6	CTS		Clear to Send Output
7	PDN		Power down (Active Low)
8	VCC		Voltage Input 2.7-10V
9	Gnd		Digital Ground
10	Analog In/Data In		Digital/Analog Input 0-3V 0-5V w/13K Series Resistor

Figure 11: Pin functions and equivalent circuits

THEORY OF OPERATION

The HP-TXM is a high-performance, eight-channel, FM transmitter capable of transmitting analog or digital data.

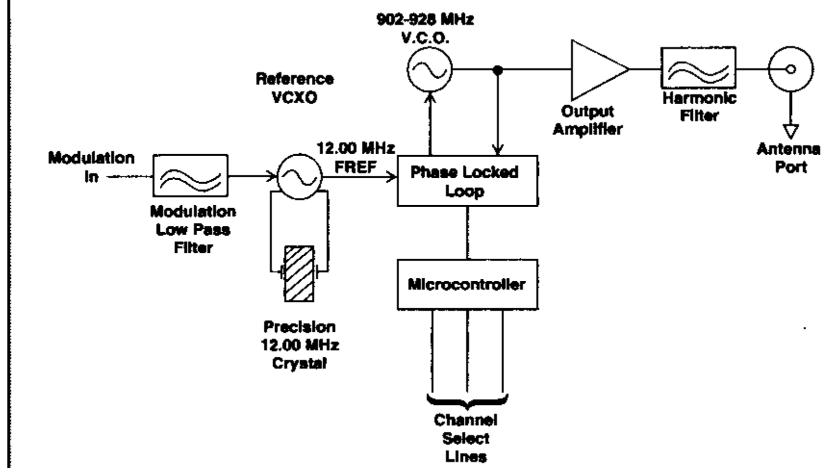


Figure 12: HP Series transmitter block diagram

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 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.

To transmit analog information the module reverts to 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 2 (see Figure 1). The HP series transmitters are designed to operate with a 50-ohm load.

An accurate 12.00MHz VCXO (voltage-controlled crystal oscillator) serves as the frequency reference for the transmitter. The modulation input pin is connected to the VCXO through a 25kHz two-pole low-pass filter. The low-pass filter is used to shape the incoming data and limit the transmission bandwidth to 25kHz.

The reference frequency is directly modulated. This method affords two benefits. First, it eliminates the need for a frequency conversion in the transmitter, reducing size, cost, and current consumption. Second, it allows the modulation to occur within the loop bandwidth of the frequency synthesizer allowing a wide modulation bandwidth of 50Hz to 25kHz.

The modulated 12.00MHz reference frequency is applied to the Phase-Locked-Loop (PLL). The PLL, combined with a 902-928MHz VCO, forms a stable frequency synthesizer that can be programmed to oscillate at a number of preset frequencies.

An on-board micro-controller reads the channel-selection lines and programs the PLL to the desired channel frequency. The micro-controller also monitors the status of the PLL and indicates when the transmitter is stable and ready to transmit data by asserting the CTS line high.

A buffer amplifier is used to isolate the VCO from the antenna and to increase the output power of the transmitter. The output of the buffer amplifier is connected to a LPF which is used to suppress harmonic emissions. Since the harmonic LPF is designed for a 50-ohm load, all harmonic specifications are provided as such.

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 transmitter 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.

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

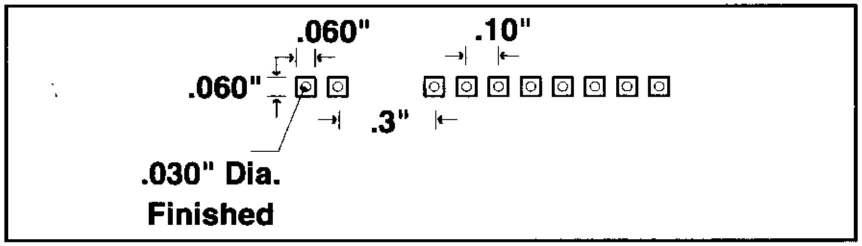


Figure 13: HP Series transmitter footprint

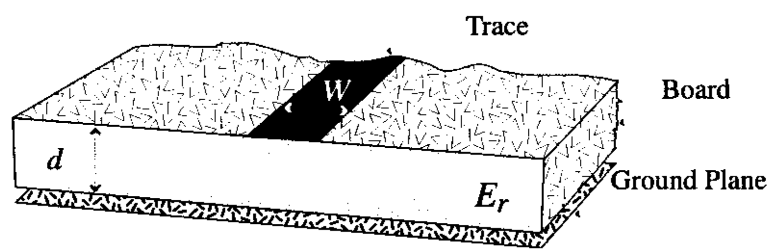
The HP transmitter should, as much as reasonably possible, be isolated from all other components on your PCB. Specifically, high-frequency circuitry such as crystal oscillators should be kept as far away as possible from the transmitter module.

If the transmitter must be mounted vertically, it should be laid over so that the side with the crystal is closest to the user's 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 narrow bandwidth antenna such as a helical, use a 50-ohm coax or 50-ohm microstrip transmission line as shown in Figure 14.

MICROSTRIP DETAILS

A transmission line is a medium whereby RF energy is transferred from one place to another with minimal loss. This is a critical factor, particularly in high-frequency products like the HP because the trace leading to the module's antenna can effectively contribute to the length of the antenna changing its resonant bandwidth. In order to minimize loss and detuning, some form of transmission line between the antenna is needed unless the antenna connection can be made in close proximity; <1/4 in. to the module. One common form of transmission line is coax cable, another is the *microstrip*. The term refers to a PCB trace running over a ground plane which is designed to serve as a transmission line between the module and the antenna. The width is based on the desired characteristic impedance, the thickness of the PCB, and its dielectric constant. The correct trace width can be easily calculated using the information below.



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

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

Figure 14: Microstrip formulas (Er = Dielectric constant of pc board material)

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

POWER CONSIDERATIONS

The user must provide a clean source of power to the transmitter module in order to ensure proper operation. The transmitter 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 a 150uF tantalum and a .1uF ceramic capacitor to ground, in order to bypass both low-frequency and high-frequency noise.

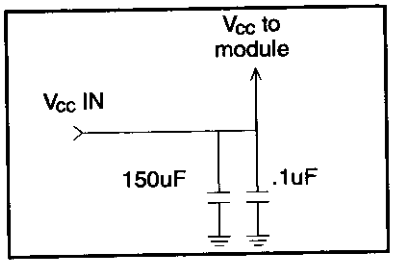


Figure 15: Suggested supply filter

POWER-UP

The HP-TXM 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 transmitter is ready to transmit 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 cycled from low to high.

After power-up, the microprocessor waits for a period of about 12mSec to allow the 12.0 MHz crystal oscillator to complete its start-up cycle before turning on the rest of the circuit.

Once the initial power-on delay has been executed, the on-board microprocessor reads the external channel-selection lines and sets the frequency synthesizer to the appropriate channel. Figure 4 on p. 3 shows the typical turn-on response time for an HP series transmitter. When the frequency synthesizer has locked on to the proper channel frequency, the circuit is ready to accept data. This is acknowledged by the CTS line transitioning high.

The transmitter is then ready to accept modulated data from a user's circuit.

The HP-TXM can be put into an ultra-low-current (<10uA) power-down mode by holding the PDN pin low. This removes all power from the transmitter's circuitry. If PDN is left floating or held high, the transmitter will wake up and begin normal operation. No transmitter functions work when PDN is low.

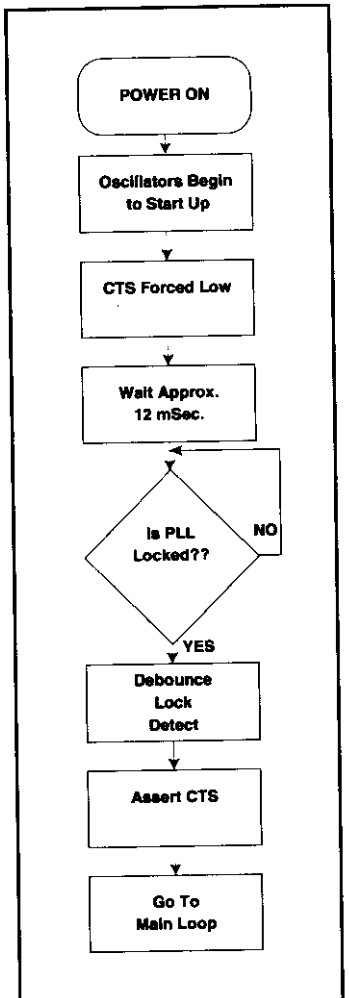


Figure 16: Start-up sequence

NOTE: READ THIS IF YOU ARE GOING TO PERIODICALLY POWER DOWN THE TRANSMITTER!!

There are some timing requirements the user must observe when periodically powering-up the transmitter.

The on-period is determined by the start-up procedure and forces the user to leave the transmitter on for no less than 40 mSec. After 40 mSec, the transmitter is stable and ready to transmit data.

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 300 mSec. If the user is finding that the transmitter is not reliable starting-up after power-up, this time should be increased.

CTS OUTPUT

The **C**lear-**T**o-**S**end output is used to indicate to the user's circuitry when the transmitter is ready to accept data. This pin can be monitored to allow transmission to begin immediately upon the transmitter's synthesizer locking on frequency.

In a typical application, a micro-controller will raise the PDN line high (powering-up the transmitter) and begin to monitor the CTS line. When the CTS line goes high, the micro-controller would start sending data.

In applications where CTS is not used, i.e., an extra I/O pin is not available, the user's circuit should wait a minimum of 50mSec (which includes a 10mSec buffer) after raising the PDN pin high before transmitting any data.

In applications where remote-control encoders are used, the data is being sent redundantly and there is no need to monitor the CTS pin or to wait a fixed time.

CHANNEL SELECTION

The HP transmitter module features eight user-selectable channels. The channel of operation is determined by the state of pins CS0-CS2. Figure 17 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	903.3
0	0	1	1	906.3
0	1	0	2	907.8
0	1	1	3	909.3
1	0	0	4	912.3
1	0	1	5	915.3
1	1	0	6	919.8
1	1	1	7	921.3

Figure 17: Channel Selection Table

INPUTTING DIGITAL DATA

The data input pin may be directly connected to virtually any digital peripheral including microcontrollers, encoders, and UARTs. The data input has been optimized for NRZ serial data that swings from ground (0V) to 3V.The VCXO is modulated by the voltage swing on this pin.

For applications where the peripheral's output swings to 5V, a 13K resistor should be added in series with the data-in pin.

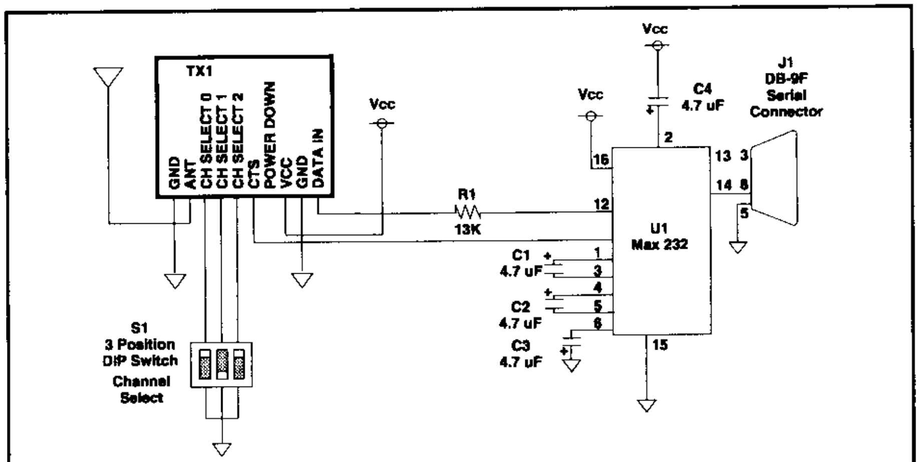


Figure 18: Typical Application: RS-232 Interface

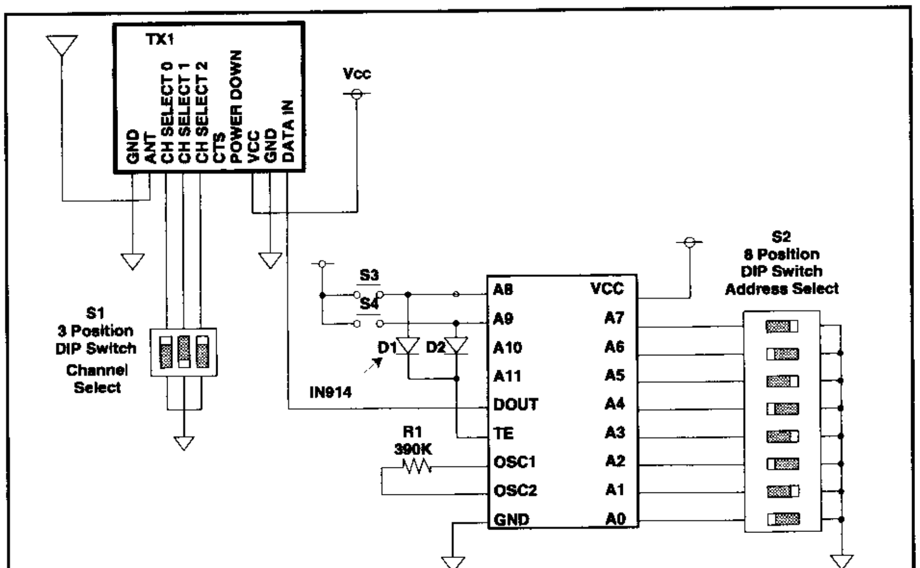


Figure 19: Typical Application: Remote-Control Transmitter

INPUTTING ANALOG SIGNALS

HP series modules are capable of transmitting a wide range of analog signals with minimal distortion. The Typical Performance Graphs on p. 3 of this manual illustrate the modulation linearity for a variety of simple waveforms. The module is equally adept at transmitting complex waveforms such as voice. Analog signals ranging from 50 Hz to 25 KHz may be applied to the data input pin. The voltage swing on the data input pin should be between ground and 3 volts. This voltage directly modulates the VCXO in order to obtain an FM output.

The illustration below shows the simplicity of transmitting audio with the HP series. In applications where the highest audio quality is required an external compandor such as a Phillips SA576 may be employed to increase dynamic range and reduce noise.

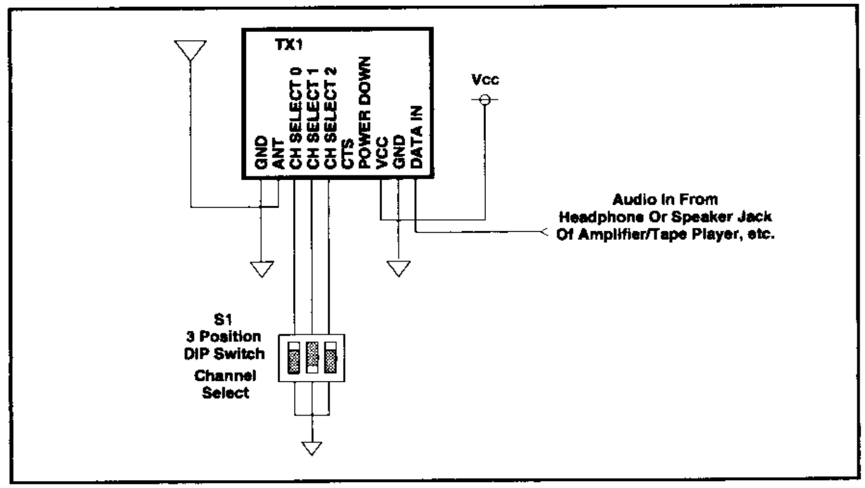


Figure 20: Typical Application:Voice Transmitter

PROXIMITY OPERATION

Multiple transmitters may be active on separate channels so long as an adjacent channel's signal does not enter the receiver at a level exceeding the rejection capability of the receiver. 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. For additional information about operating the HP modules in a multi-channel environment you may wish to reference application note #0128: "Considerations For a Multi-Channel RF Environment".

When combined with certain high-gain antennas the HP 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) to each other. If the user's application requires operation within this range, the user should operate the modules without antennas, use less efficient antennas with lower gain, or place an attenuation pad on the transmitter.

ANTENNA CONSIDERATIONS

The range of the RF link is widely variable and depends upon the type of antenna employed and the operating environment. 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 premade antenna from Linx. Our low-cost antenna line is designed to ensure maximum performance and Part 15 compliance.

It is usually best to utilize a basic quarter wave whip for your initial concept evaluation, which can easily be made from a piece of wire as shown on the next page. Once the prototype product is operating satisfactorily, a production antenna should be selected to meet the cost, size and cosmetic requirements of the product. It is important to recognize that the antenna plays a significant role in determining the performance and legality of your end product. In order to gain a better understanding of the considerations involved in the design and selection of antennas please review Linx applications note #00500 "Antennas: Design, Application, Performance".

The following notes should help in achieving optimum 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 ≥ the overall surface area of the 1/4-wave radiating element.

5. Remove the antenna as far as possible from potential interference sources. 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 transmitter 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.

COMMON ANTENNA STYLES

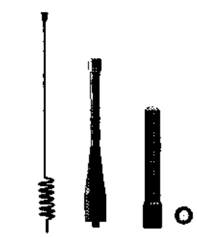
From a coat hanger to a tuned Yagi, there are literally hundreds of antenna styles and variations that can be employed. Following is a brief discussion of the three styles most commonly utilized in compact RF designs. The selection chart broadly categorizes key areas of antenna performance. In reviewing 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 antenna information can be found in Linx application notes #00500, #00100, #00126 and #00140.

HP Antenna Selection Chart

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

●=FAIR ●●=GOOD ●●●=EXCELLENT

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". The wavelength of the frequency to be received or transmitted determines an antenna's length. Since a full-wave antenna is quite long, a partial wavelength antenna such as a 1/2- or 1/4-wave is generally used. For testing, or even production, a whip can be easily made from a piece of solid conductor wire cut to the appropriate length. Length for a half-wave is easily determined using the following formula. The resultant length may be divided in half for a quarter-wave.

$$L = \frac{468}{F_{MHz}}$$

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

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, is it 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.

LEGAL CONSIDERATIONS

> *NOTE: HP Series 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 approvals necessary 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 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

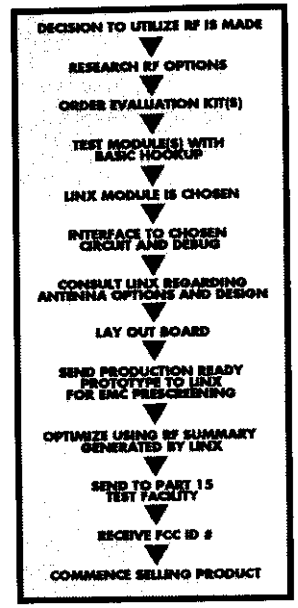
International approvals are slightly more complex, although many modules are designed to allow all international standards to be met. If you are considering the export of your product abroad, you should contact Linx Technologies to determine the specific suitability of the module to your application.

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 Series, the design and approval process will be greatly simplified. It is 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
00128	Considerations for multi-channel RF environments
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

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http://www.linxtechnologies.com

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HIGH PERFORMANCE
RF MODULE
TXM-900-HP

HP SERIES TRANSMITTER MODULE DESIGN GUIDE

DESCRIPTION:

The HP series transmitter module is designed for the cost-effective, high-performance wireless transfer of analog or digital data, in the popular 902-928MHz band. The transmitter offers eight selectable channels and, when paired with an HP series receiver, is capable of transmitting analog and digital information over distances in excess of 1/4 mile. To assure robust performance under all field conditions the transmitter employs an advanced microprocessor-controlled synthesized architecture. Like all Linx modules, the HP series requires no tuning and in most cases no external components *(except an antenna)*, making integration straightforward even for engineers lacking previous RF experience.

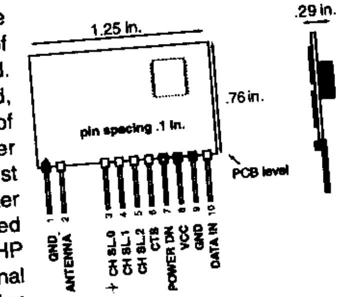

Figure 1: Physical Dimensions

FEATURES:

- 8 Binary Selectable Transmission Frequencies
- High Output Power (+5dBm typical into a 50 ohm load)
- Cost-Effective
- Precision Synthesized Frequency Reference
- Direct Serial Interface
- High Data Rate (50Kbps max.)
- Can Be Used To Transmit Analog (Including Audio) or Digital Data
- Wide Supply Range (2.7-16V DC)
- Clear-To-Send Output Eliminates The Need For Preamble Time
- No Production Tuning
- No External RF Components Required (Except Antenna)
- Manufacturing-Friendly SIP-Style Packaging

TX 19.15
Rx 28.16

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	Evaluation Kit 900 MHz
TXM-900-HP-**	Transmitter 900 MHz
RXM-900-HP-**	Receiver 900 MHz

** Insert TB for Tube Packaging