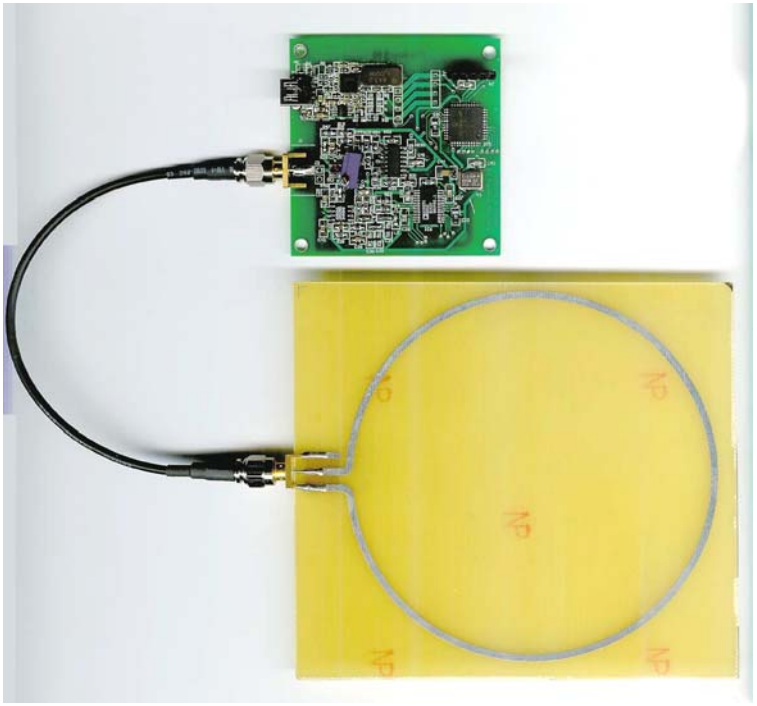
LC-10 Chipless TagReader

v 2.0 August 2006



The LC-10 is a portable instrument that connects to the USB port of any computer. The LC-10 operates in the frequency range of 1-50 MHz, and is designed to detect and track up to 64 separate resonance peaks. This instrument can be used to find the resonance of a single tag or can be used to monitor a set of resonance peaks or chipless RFID tags. The LC-10 has many built-in functions and commands which allow the LC-10 to be used in a wide variety of testing, instrumentation, and inventory applications in addition to simply reading chipless RFID labels.

The LC-10 comes packaged in a potting compound with a 2-pin antenna connector exposed. For the antenna, a simple 1 or 2-turn wire loop can be used. The unique proprietary design of the TagSense LC-10 reader enables the use of an untuned antenna, which also enables a wide frequency range and ease of use.

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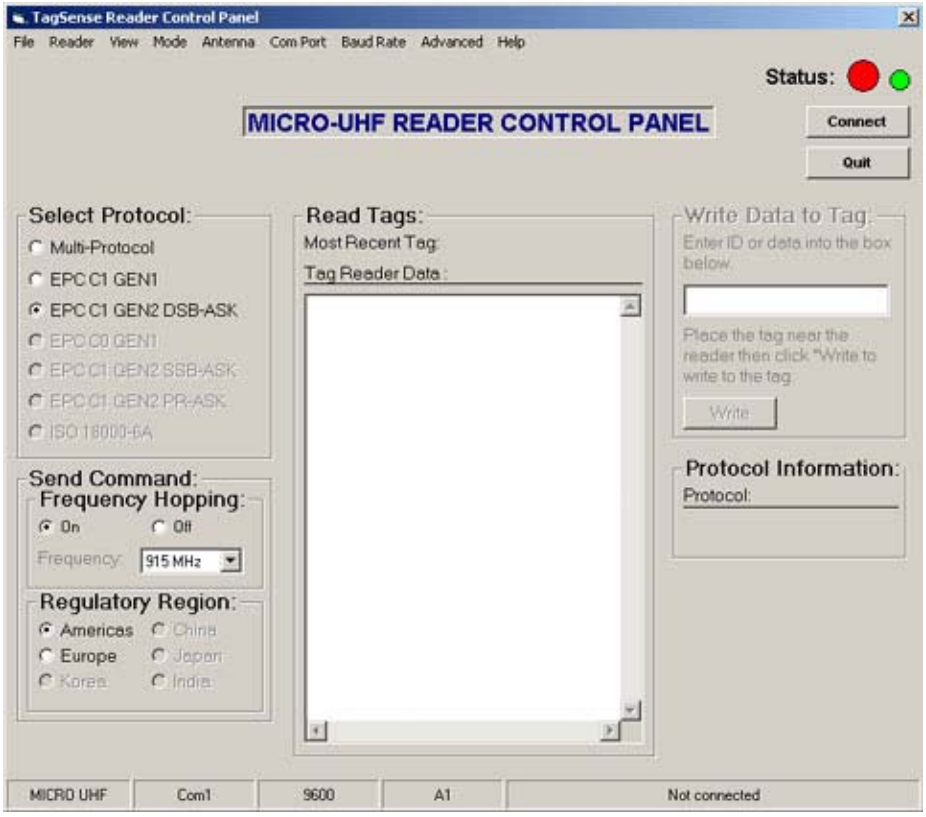
INTERFACING WITH THE LC-10

There are two ways to interface with the LC-10. The simplest way is to use the TagSense Reader Control Panel software, which comes with the LC-10 Evaluation Kit. To install this software, follow the instructions that come with the CD. Additionally, drivers for the USB Virtual Com Port must be installed (instructions for installing these can also be found on the CD). Linux drivers are also available, although TagSense does not provide any sample code.



Windows Interface

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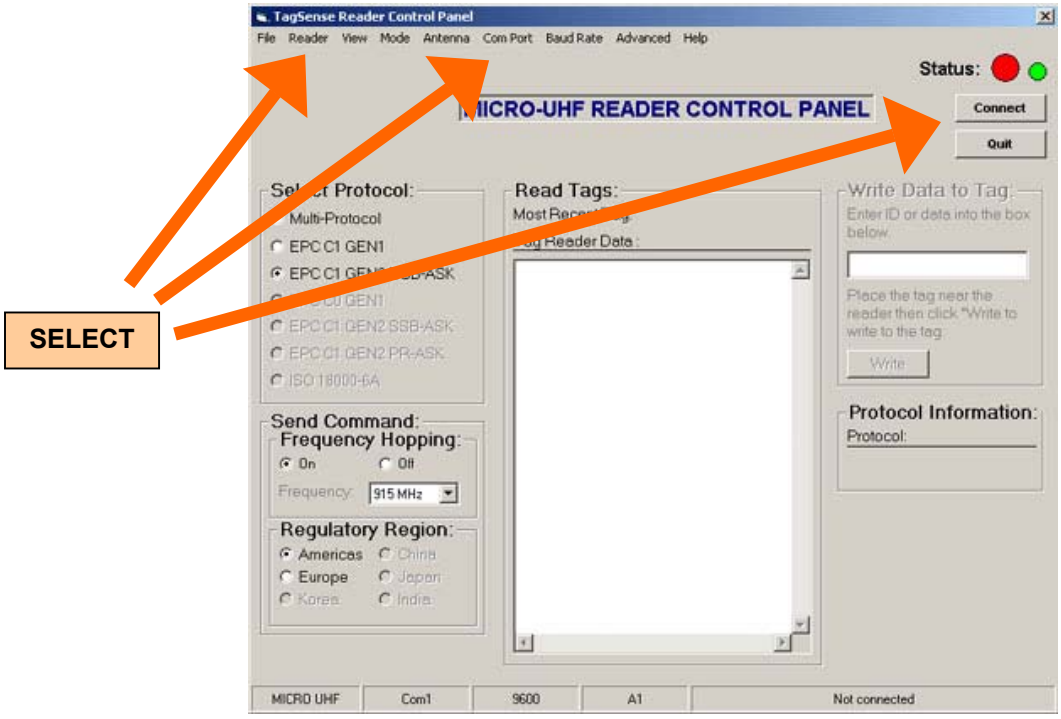
STARTING WINDOWS DEMO PROGRAM

After installing the USB drivers and the demo program, you can connect the reader to the computer using a USB cable. Please make sure that you have an antenna connected to the reader.

The program supplied with the kit is able to interface to all the RFID readers made by TagSense. You should open the program (TagSense reader control panel), then go to the **Reader** menu and select "**LC-10**" . Then go to the **ComPort** menu and select the proper COM port for your USB port. If you are not sure, then you can use the **USB COM Port locator** utility, which is under the **Help** menu. You should then verify that the **BaudRate** setting is correct (38400), then you can click the **CONNECT** button. After you run the program for the first time, the software settings will be saved automatically so you should not need to reconfigure the control program unless you switch to another reader product.



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INTERFACING WITH THE LC-10

Communication Interface

USB Interface:

With the appropriate software driver, the LC-10 USB interface operates as a standard serial COM port. This allows the LC-10 to be easily integrated with any computer software which supports serial communications, such as JAVA, C++, Visual Basic, etc. The USB Virtual COM port drivers are included in the software CD which comes with the LC-10 evaluation kit. Other drivers can be downloaded from the following web site: http://www.ftdichip.com

RS-232 Interface:

For users wishing to connect the LC-10 to a hardware controller or external circuit board, the LC-10 also provides a 4-pin header. Two of the pins on this header are power (+5V DC) and ground. The other 2 pins are for TTL-level RS-232 communications (TX and RX).

COM port settings:

For both cases (USB or RS-232), the serial port settings for communicating with the LC-10 are: 38400 baud, 8 data bits, No parity, and 1 stop bit. Flow control is not supported and should be turned OFF.

Included free in the LC-10 evaluation kit is the TagSense PC software program which controls the LC-10 and displays the analog spectrum data graphically. This program is used to demonstrate the capabilities of the LC-10 and also to help customers to create their own PC software to control the LC-10.

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INTERFACING WITH THE LC-10

Operating Modes

The LC-10 and LC-100 readers are designed to support 2 basic modes of operation: *manual mode* and *inventory mode*.

Manual mode:

In *manual mode*, the user has full control over all the LC-10 reader settings. The user can specify the frequency sweep parameters such as the start frequency, stop frequency and frequency step. This operating mode enables full manual control of the tag reader functions. The LC-10 reader can automatically sweep a continuous range of frequencies or can be set to monitor a single frequency.

In manual mode, the data output format is the frequency value followed by the detected signal level.

A typical line of data appears as follows:

*340da6f2 7a<CR><LF>

The <CR> represents a carriage return (= CHR$(13)) and the <LF> represents a lne feed or tab character (= CHR$(10)).

Note that each line of data begins with an asterisk (= CHR$(42)).

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Inventory mode:

In *inventory mode,* the LC-10 reader will automatically scan a specific list of frequencies that correspond to a specific set of tags. This mode is used for applications where a specific set of tags is being tracked or monitored. In this mode, the user can train the LC-10 to track a specific set of tags that are stored in the onboard memory of the LC-10. The LC-10 can store up to 64 separate tags in its memory. Once the tags are stored in its tag memory table, the LC-10 will continuously track these tags by jumping discontinuously to specific frequencies specified in its Tag Memory Table. This table is essentially a list of tags and their corresponding resonant frequencies. Users are able to add or delete entries to this table using specified commands.

Since the resonant frequency of a tag will shift slightly depending on the coupling between the tag and the reader antenna, the inventory mode has a built-in peak tracking function that will track a set of tags and account for small shifts in their resonant frequencies. This feature is also useful when using the LC-10 with several different sets of tags with common frequencies, since all tags having the "same" resonant frequency will in actuality have slightly different resonant frequencies due to manufacturing slight variations in component values.

Note on Sweeping Vs Scanning:

It may be helpful to note here the difference between frequency *sweeping* and frequency *scanning*. "Sweeping" implies that the frequency value is varied "continuously" from one frequency to another. "Scanning" implies that the frequency value is varied discontinuously, jumping to discrete specific frequency channels.

Inventory mode works in an analogous manner to a consumer radio receiver: when set to scan, the radio will automatically cycle (scan) through a list of preset radio stations; but for each station, the radio will then do a local frequency sweep to find the maximum signal for that station (e.g. auto-tuning).

Additional information on setting up and using inventory mode is provided in a separate section of this document.

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Frequency units:

The output data format used by the LC-10 is a 32-bit scaled machine representation of the frequency in hexadecimal format.

To convert from the machine representation to actual frequency, the following formulas can be used:

Frequency in Hz = [(Frequency in machine representation) * 120,000,000]/(2^32)

Frequency in machine representation = [(Frequency in Hz) * (2^32)]/120,000,000

Entering Frequency units:

In manual mode, the start frequency, stop frequency, and step frequency can be entered in units of Hertz. For example, the start frequency can be set to 5 MHz by entering the following: “a5000000” followed by a carriage return (CHR$(13)).

For other frequency functions such as peak tracking and inventory mode, the frequency values are stored in the 32-bit machine representation. Therefore, when entering the frequency values for the tags in inventory mode, the user should use the machine representation of the frequency.

Peak Search Function (“Search for Resonance”):

In both manual mode and inventory mode, the LC-10 provides a peak search function which will cause the reader to scan the entire frequency span (from start frequency to stop frequency) and find the first peak. The command for this function is “Y”. Further information on this command is given in the other sections of this datasheet.

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INTERFACING WITH THE LC-10

Basic Operational Commands

COMMAND	ARGUMENT	DESCRIPTION
M		converts output data stream to machine readable non-ASC format. Using this binary data enables more compact and faster data communications with an external host device.
m		Converts output data to human readable format, which is ASC text characters. This is the default mode.
X		Pause the reader (scanning and data flow will stop)
x		Resume operation from paused state
E		Enables polling mode. In this mode, the reader will perform a single scan when the polling trigger command (“z”) is received. Upon completing the single scan, the reader will pause until the next polling command is received.
e		Disables polling mode. In this mode, the reader will continuously scan and stream data.
z		This is the polling command. This command will trigger the reader to do a one-time scan or sweep.

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BASIC COMMANDS

Additional operational commands:

COMMAND	ARGUMENT	DESCRIPTION
D	none	Enable continuous data streaming output
d	none	Output data only if the detected tag signal is greater than the threshold.
t	<int 8>	Set the detection threshhold
p	none	Automatically calculates and sets a threshold equal to the lowest value detected over the current frequency span
R	<int 32>	set 32-bit identifier for the reader. This is used when many readers are being networked together.
N	none	Reset DDS chip on the LC-10
s	<int 32>	display the value of all reader state variables

The ‘s’ command mentioned above is a very useful command that can be used both for debugging and also for allowing another software program to automatically query the state of the LC-10 tag reader.

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BASIC COMMANDS

Frequency control commands for MANUAL mode:

COMMAND	ARGUMENT	DESCRIPTION
a	<int 32>	Set the start frequency for sweeping
b	<int 32>	Set the stop frequency for sweeping
c	<int 32>	Set the frequency step size
f	<int 32>	Set the output frequency when in single-frequency mode
k	<int 8>	sets the delay (in units of 10 us) that the reader will wait before sampling the antenna signal. This delay is used to allow any transient signals to decay.
W	none	turn ON frequency sweeping
w	none	turn OFF frequency sweeping. This sets reader into single-frequency mode. The single frequency can be set by using the command f.

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INVENTORY MODE COMMANDS

COMMAND	ARGUMENT	DESCRIPTION
V	None	Turn ON inventory mode
v	None	Turn OFF inventory mode
i	None	Display list of inventory frequencies and corresponding tag numbers. If no tags have been entered into the reader memory, then the list of tags will be blank.
Y	None	This command instructs the LC-10 to perform a peak search. A resonance peak appears as a minima in the reflected power. The LC-10 does a single continuous frequency sweep from start frequency to stop frequency with step size c searching for a minima. If a peak is found, it returns a 32-bit value which corresponds to the resonant frequency. This value is stored in the reader's frequency buffer. This value can then be stored permanently in EEPROM memory using the G command described below. If no peak is found, it returns an 'underscore' character to indicate that no peak was found.
G	<int 8>	Writes the current value of the frequency buffer to the EEPROM memory location specified by the argument. For example, "G18" would assign the resonant frequency to memory location 18.
g	<int 8>	Delete tag entry #n. By deleting an entry form the inventory list, the tag reader will no longer scan for that tag frequency.

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INVENTORY MODE COMMANDS

Commands for INVENTORY mode (continued):

COMMAND	ARGUMENT	DESCRIPTION
q	<int 8>	when scanning (sweeping) is turned off in inventory mode, this sets the current tag frequency to tag n. Tag n thus becomes the currently selected tag.
h	<int 32>	This command enables the user to write directly to the frequency buffer. This command, used in conjunction with the G command, provides a way to manually enter a tag frequency into the LC-10 reader memory table. This command is provided as an alternative to the Y command which will automatically write to the frequency buffer once a resonant peak is found. This command takes a 32-bit frequency argument.
W	none	turn ON frequency scanning
w	none	turn OFF frequency scanning. The reader will continuously scan for just a single tag. The frequency slot to be scanned can be set by using the command q.
j	<int 32>	Sets the peak-search frequency step size.
J	<int 8>	Sets the peak-search frequency step divisor. This value must be between 0 and 7; the divisor itself is 2 raised to the power specified by the argument of this command.

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SOFTWARE RESET

Software RESET:

The reader can be reset via software control by sending the reader the command character “+” (ASC).

Default State: When the reader is RESET upon power up or when an explicit RESET command is received, the reader will enter the default state. In this state the following settings are pre-programmed at the factory:

PARAMETER	DEFAULT STATE
a	3400000
b	14000000
c	10000
f	8000000
K	10
k	20

By default, the reader will start up in the PAUSED state.

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SETTING UP THE TAG MEMORY TABLE

In *inventory mode*, the tag reader will search for specific tags. The inventory mode was designed so that a user does not need to know the specific frequency of each tag. A user can simply number a set of tags 1 though N, and the tag reader will automatically scan the correct frequency for each tag. For each new project, there is only a one-time set up required to train the tag reader so it will automatically recognize the user set of tags.

To make inventory mode possible, the list of user tags is stored in the tag reader permanent memory (EEPROM) and is called the *Tag Memory Table*. At present the LC-10 memory can store up to 64 different tags, which is upgradable. Each entry of the Tag Memory Table includes the tag number (1 to 64) and its associated resonant frequency. The Tag Memory Table is illustrated below.

Tag #	Tag Frequency
1	11ae1458
2	--
3	124e7145
4	1281d45f
5	12a5e22a
6	--
7	1305d73a
8	11533ce4
9	113e1d37
Etc…	Etc…

It is important to note a few key observations: 1) the tags in the table do not need to be ordered by frequency. 2) it is not necessary to populate all entries of the memory table 3) the frequency value is stored in machine frequency units.

Sending the command ‘i’ at any time will prompt the tag reader to display the entire Tag Memory Table. This is very useful.

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SETTING UP THE TAG MEMORY TABLE

By default, the tagreader memory is empty, but users can add tags to the Tag Memory Table through the use of a few simple commands. The user can either have the tag reader automatically detect the tag and add it to the Tag Memory Table, or the user can manually enter the tag frequency into the table.

Automatic Tag Detection , Adding and Deleting Entries:

To illustrate the process, if a user wants to assign slot 8 in memory to a new tag frequency, then the user would place a tag on the antenna and send the command "Y", and the reader would automatically detect the new tag, report its resonant frequency, *as well as store this frequency in an internal frequency variable*. Then typing "G8" followed by a carriage return would store the value of the internal frequency variable to memory slot #8. If tag #8 did not already exist in the memory table, this would create a new tag #8. If a tag #8 already existed in memory, this would essentially overwrite the entry for tag #8. This can be verified by typing "i" to view all the stored frequency entries. Note, the user can also delete slot entries; for example if the user wants to remove tag #5, the user would type "g5."

Manual Entry:

Instead of using the Y command, another way for the user to assign tag numbers is by using the 'h' command. Using the 'h' command, the user can directly enter a frequency value, which will get written to the internal frequency variable. Sending the command 'h' followed by the 32-bit frequency value will cause the reader to write this frequency value into its temporary frequency buffer. This frequency value can then be permanently stored into a tag memory slot in the reader's memory. For example, sending "G8" would cause the frequency to be stored in slot #8.

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SETTING UP THE TAG MEMORY TABLE

The user enters Inventory mode by sending the “V” character. For normal operation, the reader should be unpaused (by sending an “x” character), and scanning can turned on (“W”) or off (“w”). In Inventory mode, when sweeping is on, the reader will scan every memory slot with a stored frequency, and report whether the tag is present or not. Here is an example output if slot #6, #7, and #8 have a stored frequency values, but only tag #8 is present:

*06 _
*07 _
*08 11ae1458 0023

Note that the underscore character printed after the memory slot number indicates that no tag was found at that frequency.

When sweeping is off (using the ‘w’ command), the reader will continuously scan only a single tag slot. Assuming there are multiple tags in the reader’s tag list, the specific tag to be monitored can be specified using the “q” command. For example, if there are 20 different tag frequencies that are stored in the tag reader’s memory, but the user wishes to monitor only tag #5, then the user can send the command “q5”. Although the reader, in this case, is scanning only a single tag slot, the reader will automatically track this specific resonance peak by performing a local peak search around the frequency stored in bin #5. This should be contrasted to manual mode, where turning off sweeping will cause the reader to continuously scan a single frequency.

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ADVANCED COMMANDS

Additional Commands for Baseline Correction :

Since the baseline frequency response of the reader antenna is generally not flat or monotonic, the LC-10 reader contains an additional interpolation function in order to help detect the resonant peaks of the tags. The commands u and U and used to turn ON and turn OFF the baseline correction.

If baseline correction is turned ON, the LC-10 reader will sample several different frequency points in the neighborhood of the expected tag resonance peak. The reader will then interpolate between these points in order to calculate an effective baseline. The LC-10 then compares the received signal at the resonant frequency with the effective baseline. In this mode, since the reader output corresponds to deviations from this computed baseline, and the output data from the reader will be nearly zero when no tag is present.

The command j<int 32> assigns a frequency width to the currently selected tag. This is the frequency width that is used to do the interpolation.

COMMAND	ARGUMENT	DESCRIPTION
u	none	turn OFF averaging
U	none	turn ON averaging
J	<int 8>	Set averaging factor
k	<int 8>	Set the duration of excitation pulse. This value gets multiplied by 20 us. This is nominally set to 10.
K	<int 8>	Sets the time delay that the reader will wait after the excitation pulse before sampling the received signal. This value is multiplied by 10us.

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ADVANCED COMMANDS

Fine Tuning Search Parameters:

For advanced users, the LC-10 provides a few additional parameters that can be adjusted by the user to fine tune the speed and precision of the peak searching algorithm.

A typical resonant peak is shown in Figure 1 below. The parameter 'j' (lower-case j) is the peak search frequency step. The parameter 'J' (capital j) is the peak search frequency step divisor. These parameters are utilized in both the peak-tracking feature of the Inventory Mode, as well as in the "Search for Resonance" function. Figure 1 illustrates the peak-tracking feature of the Inventory Mode. For a given stored frequency $F_o(n)$, which is one of the n frequencies that are stored in the tagreader's memory table, the reader will sweep over a range extending from $F_o(n) - j$ to $F_o(n) + j$.

When the tagreader is scanning, it will start by looking at the frequency stored in slot #1, $F_o(1)$, and perform a local search around $F_o(1)$. The tag reader will then proceed to the next frequency which is stored in slot #2, and so on. The frequencies stored in the tagreaders memory table do not need to be in any specific order. The reader will discontinuously jump to the frequencies stored in the list in the tagreader's memory.

For a given memory slot, N, the tagreader will perform a local frequency sweep from $F_o(N) - j$ to $F_o(N) + j$.The step size used by the tag reader is given by j/J. By varying the step divisor 'J', the user can control the speed and precision of the local peak search; a smaller step divisor means more frequency points sampled and more precision, a larger step divisor means less frequency points sampled and less precision.

The value of the step 'j' should be chosen so that the anticipated variation in frequency falls within the range $F_o(n) - j$ to $F_o(n) + j$. For example, if tag N is expected to have a very small frequency variation, then the parameter j can be chosen to be small. However, if the tag N is expected to have a large frequency variation (such as for a chipless sensor tag), then the parameter j must be sufficiently large in order to ensure that the peak search will include all possible resonant frequency values of tag N.

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ADVANCED COMMANDS

If the Quality factor (= Q) is known for a given tag, then it is recommended that j/J should typically be less than or equal to F/(4*Q). For example, given a planar LC resonant tag with a typical Q factor of 60 and resonant frequency of 12 MHz, j/J should be set to approximately 60 KHz or less.

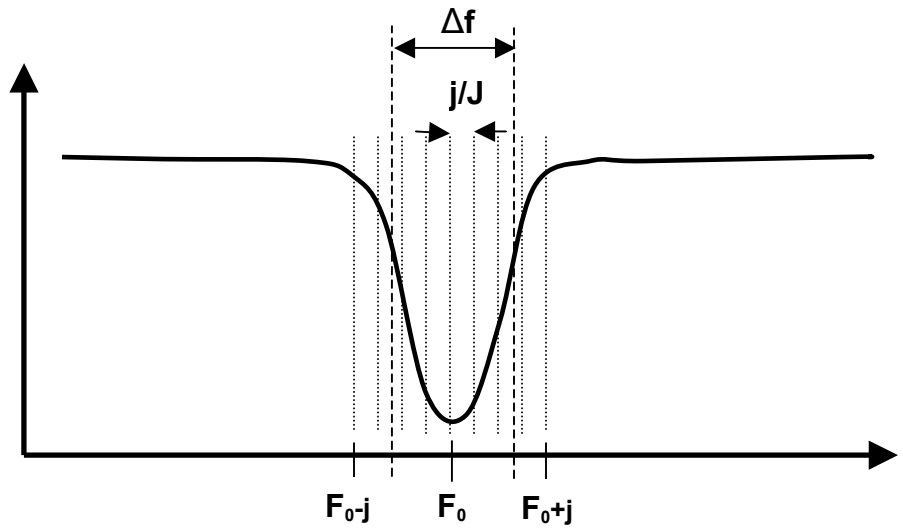

Figure 1. Illustration of a typical resonance peak and the relevant reader parameters for peak tracking in Inventory Mode.

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ADVANCED COMMANDS

In Figure 2, the Search for Resonance function is illustrated. This function is typically used to discover the resonant frequency of an unknown tag. Also, this function is intended to find a single resonance peak. If multiple peaks are being track simultaneously, then the inventory mode should be used. Beginning from the Start Frequency specified by the 'a' command, the reader does a scan, incrementing by the peak search frequency step 'j'. As soon as the reader detects a deviation in the detected signal, the reader automatically decreases the step size to j/J, where 'J' is the peak search frequency step divisor. By providing this variable step size for the peak search, the LC-10 thus provides a reasonable compromise between a search speed and search accuracy. When using this function, 'j' should be set to a value of 100 KHz or smaller when using an LC resonant tag; if it is too large, the resonance peak may be missed altogether; if the value of j is too small, the search will be slow.

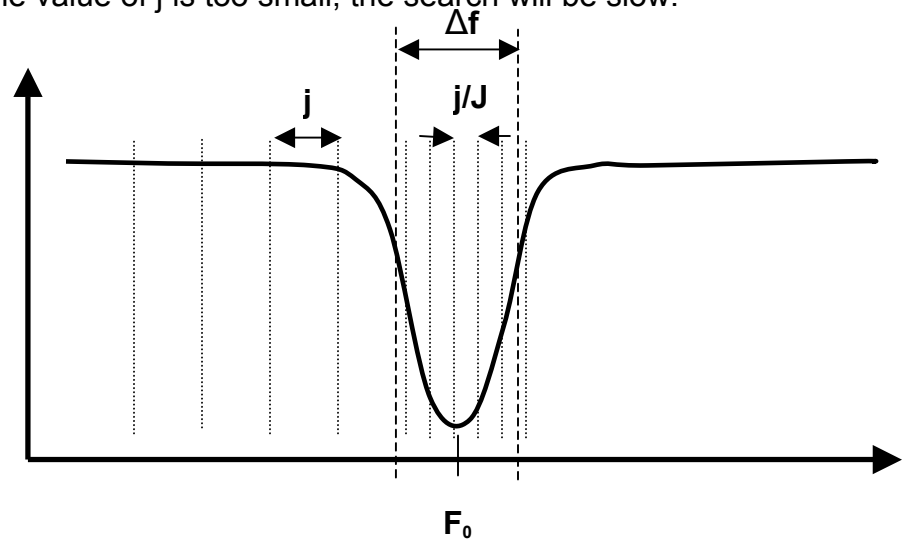

Figure 2. Illustration of a typical resonance peak and the relevant reader parameters for the Search for Resonance function.

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EXAMPLES

Examples using Manual mode:

When using Manual mode, each output line will have the following format:

**[FREQ]<SPC>[SIGNAL]<CR><LF>*

For example, the following are a few lines of data output from the LC-10 reader with data streaming on, pause off, running in Manual mode:

*32c5f8e0 78<CR><LF>
*333332e6 79<CR><LF>
*33a06cec 79<CR><LF>

The frequency [FREQ] is a 32 bit value given in machine units. The value [SIGNAL] is an 8 bit digitized value of signal strength.

Examples using Search for Resonant Frequency function:

The search function is useful when trying to identify the resonant frequency of an unknown tag. The output from sending a 'Y' command depends on whether a tag is present or not, and whether data streaming is turned on or off. With data streaming off, if a tag is present, the output will have the following format:

*[FREQ]<CR><LF>

where [FREQ] is the 32 bit resonant frequency given in machine units. Here is an example output for a tag with a resonant frequency of approximately 9.8 MHz:

*14deb82c<CR><LF>

If no tag is present, the output will be:
*_<CR><LF>

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EXAMPLES

It should be noted that the character after the asterisk is the “underscore” character. This character indicates that no resonant frequency was found.

If data streaming is turned on, the reader will also output a line of data for every frequency point sampled during the scan, much like the manual mode output, with the final line either being the resonant frequency if a tag is present, or an asterisk and underscore symbol if no tag is present.

Examples using Inventory mode:

When in Inventory Mode, the output will depend on whether the stored tag is present or not. If it is present, it will have the following format:

**[SLOT]<SPC>[FREQ]<SPC>[SIGNAL]<CR><LF>*

where [SLOT] is the memory slot number in hexadecimal, [FREQ] is the 32 bit frequency in machine units, and [SIGNAL] is the 16 bit signal strength.

A typical line of data looks like the following:

*08 11ae1458 0023

If the stored tag is not present, the output will be:

**[SLOT]<SPC>_<CR><LF>*

A typical line of data for this case looks like the following:

*08 _

keeping in mind that each line is terminated by a carriage return and line feed.

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