ZT-50
PROGRAMMABLE ACTIVE RFID TAG WITH REAL-TIME CLOCK

v 1.0

DOCUMENT VERSION HISTORY

432 Columbia St, #B13B
Cambridge, MA 02141
Phone: +1 (617) 494-1001
Fax: +1 617 (494)-6006

http://www.tagsense.com
info@tagsense.com

Version	Date	By	Changes
0.1	12/11/06	RRF	Initial draft
0.2	1/1/07	RMR	Added command description and examples
0.3	10/25/07	RRF	Updated description to include new commands
0.4	01/09/08	RRF	Corrected pin designators

432 Columbia St, #B13B
Cambridge, MA 02141
Phone: +1 (617) 494-1001
Fax: +1 617 (494)-6006

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info@tagsense.com

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432 Columbia St, #B13B
Cambridge, MA 02141
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Fax: +1 617 (494)-6006

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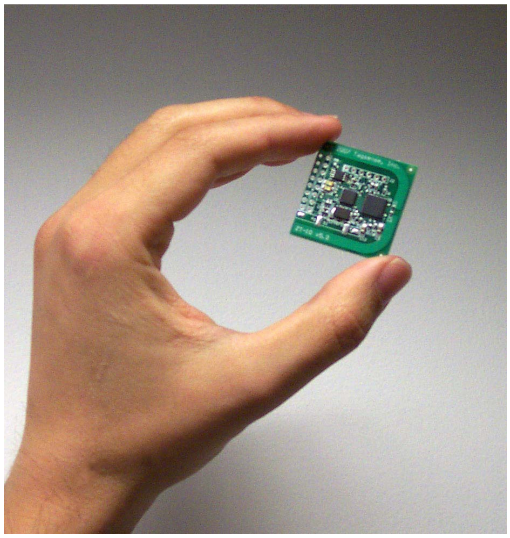
info@tagsense.com

ZT-50 ACTIVE INTRODUCTION



The ZT-50 is the most powerful small active tag on the market today. The internal settings of the tag (inputs, outputs, radio transmission data, and sleep functions) are completely programmable by the user and scheduled using a 24 –hour internal clock. Without the need for any additional hardware, TagSense has developed an integrated software-programmable Real-time clock that is accurate to better than 1 minute per day, which has not been possible previously with a low-cost data-logger tag.

The ZT-50 is a miniature programmable module that enables many new applications never before possible with a simple active RFID tag. TagSense is open to working with customers to create modified versions of the ZT-50 tailored to specific applications.

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Cambridge, MA 02141
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Fax: +1 617 (494)-6006

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Features of ZT-50:

- Integrated Real-Time Clock and data logger
- Bi-directional communication (tag<->reader)
- All settings are completely programmable via the wireless protocol
- Supports up to 8 scheduled programs
- Industry standard IEEE 802.15.4 (Zigbee-ready) air interface protocol
- Operating frequency range – from 2.400 to 2.483 GHz (DSS spread spectrum)
- 250 Kbps data rate with CSMA anti-collision protocol
- Does not interfere with Wi-Fi Networks (WLAN)
- Support for 128 bit AES-CCM security suite for high data security
- Real-time programmable tag transmission interval and power level
- Support for up to 6 external sensors (temperature, vibration, humidity, light, etc.) plus battery level
- Small size – 1.25 x 1.25 x 0.25 in
- Very low current consumption (<20 mA for communications <2 uA in sleep mode)
- Readers available in USB, PCMCIA and RS-232 versions
- Reading Range 30 to 200 meters, depending on reader antenna
- nearly omni-directional tag antenna integrated onto PC board

Applications:

- Data Logging Tags for tagging goods, shipments
- Recording events for medical, advertising, industrial applications
- Actuation (opening door locks, switching lights)
- Tagging of assets, vehicles, people, animals, and billboards

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BASIC SPECIFICATIONS

The ZT-50 is an active tag that communicates via the industry standard protocol IEEE 802.15.4.

This tag can be easily mounted on a variety of assets and used for tracking or monitoring of sensors.

The operating frequency of 2.45 GHz enabled this tag to have a small size antenna and long range (>70 meters).

The IEEE 802.15.4 protocol is the most advanced tagging protocol used today and includes bidirectional communication between the tag and other tags or between the tag and the reader. This enables faster and more efficient communications when multiple tags are present (anti-collision) and also extends battery life.

Each tag contains 2 indicator LEDs (red/green) on the top side.

SPECIFICATIONS

- **Frequency: 2.400 - 2.483 GHz**
- **250 Kbps data rate (max)**
- **Operating Voltage: 2.2 - 3 V**
- **Current consumption:**
  - **<2uA when idle**
  - **< 20 mA when communicating**
- **Operating Temperature: -10C – 80C**

(lower temperatures are possible with reduced timing precision)

- **Shock and vibration Resistant**
- **Clock accuracy: +/- 1 minute per day**

ZT-50 SPECIFICATIONS

- **Battery: CR2032**
- **Battery Capacity: 220 mAh**
- **Battery life:**
  - **Depends on sensor choice and transmit power**
  - **Tag by itself (no sensors) will run for 12 months when using transmit interval of 1 minute**
- **Transmission distance at full power: 50-200 meters**
- **Size: 1.25 x 1.25 x 0.25 in.**

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UNIQUE FEATURES OF ZT-50

The ZT-50 contains an integrated real-time clock (RTC) and a powerful set of commands and programs that enables this tag to be used in many new applications and support many new features and unique capabilities that are not possible with other active RFID tags on the market in the same price class:

Data-Logging: The ZT-50, like the ZT-10, can read up to 8 simultaneous sensors including the battery level and digital sensor. The ZT-50 also has the ability to store the sensor information and record the exact time (year, month, day, minute, second) that this sensor reading was taken.

Event Monitor: The ZT-50 can also be used to monitor and record events, such as recording activity in front of an advertising sign, promotional display, patient hospital bed, or recording sensor events or alarms in a factory.

Programmable Time events and Modes: You can program the ZT-50 to perform different actions at different times of the day. For example, you can program the ZT-50 to take sensor readings every minute from 2pm to 4pm, then take data every half hour from 5pm to 8pm, then go to sleep from 10pm to 6am, then turn OFF the lights at 7am, etc. The ZT-50 support up to 8 different scheduled programs that can be run simultaneously.

Fully programmable settings: For each programmed state, all the major settings of the tag can be programmed remotely by the TagSense reader. These settings include: sensor data recording, which sensors to turn on, which output pins to turn on, which data fields are transmitted to reader, how often to transmit, transmission power level, battery level reporting, and sleep settings. All of these settings can be programmed and scheduled to change at different times.

Sensor Trigger: The ZT-50 can also be programmed to perform certain events when triggered by an external sensor, such as a vibration shock or a temperature deviating above a certain threshold.

Actuation: The ZT-50 has 2 outputs that can also be used to control an external switch, such as to activate a door lock or turn on a light or turn on a motor.

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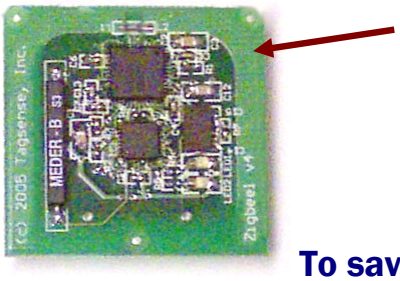
Tag Frequency: 2.4 GHz vs 433 MHz

Although most active RFID tags operate at 433 MHz (for historical reasons), TagSense has chosen the frequency of 2.4 GHz for its active RFID tags. 2.4 GHz has many advantages over 433 MHz:

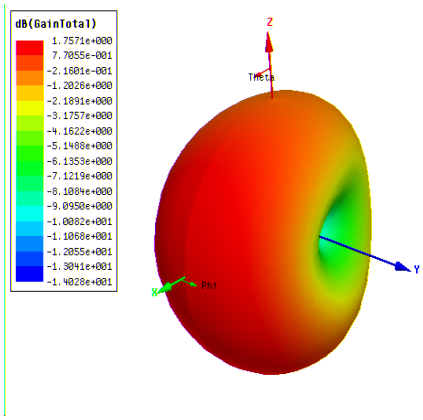
- 8X smaller antennas than 433 MHz
- many choices for reader antennas are commercially available
- Better indoor signal propagation and propagation through narrow openings because the wavelength is smaller
- 2.4 GHz radio chips have more advanced protocols and better radio performance (IEEE 802.15.4)

Integrated Antenna



PCB integrated antenna

To save size and cost, the ZT-50 contains an integrated antenna. The antenna is specifically designed for the ZT-50 and can be read in almost every orientation. In an indoor environment, where there are reflections off the walls, the tag performance will be improved further by such reflections.



Antenna Gain Pattern

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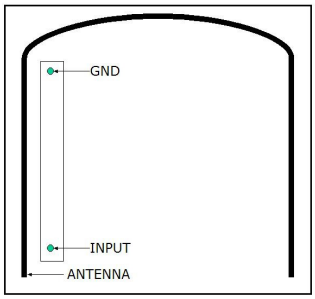
WAKE-UP TRIGGER



The ZT-50 tag contains solder contacts and pins that can be used to connect an external sensor for the purpose of triggering a specific behavior or simply waking up the tag. Sensor which can be used as external triggers include: contact switch, magnetic reed switch, photocell, vibration sensor. For example, the ZT-50 can be programmed to transmit an alert when the contact is broken. This digital input can be used for making security contact switches for secure locks, prisoner bracelets, or tamper detection sensors. The solder pads are shown in the illustration.

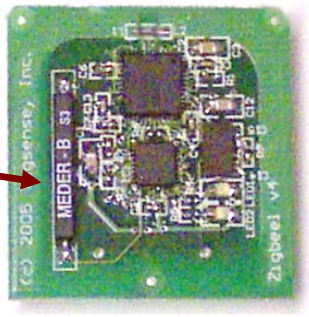
Magnetic Reed Switch:

The contact switch input on the ZT-50 can also be used with an optional magnetic reed switch. A magnetic reed switch is commonly used to wake up the tag by placing a permanent magnet near the sensor. Using this method, the tags will be set to deep sleep mode to conserve battery power during storage or shipping, and can then be woken up by bringing the tag near a magnet.

A photograph of the ZT-50 with a mounted magnetic reed switch is shown below. The reed switch sensor in not included with the ZT-50, but can be requested as an extra option.

TOP SIDE

Magnetic Reed Switch



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Cambridge, MA 02141
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ZT-50 HARDWARE INTERFACE

The ZT-50 contains 2 rows of header vias which provide a very versatile interface for a variety of sensors, input and outputs. Up to 7 analog inputs and 8 digital inputs are possible. A photograph of the connector and the description of the interface is given below.

FRONT SIDE

A3/D3	8	16	A7 (analog only)
IA2/D2	7	15	A5/D5/LED1
A1/D1	6	14	A4/D4/LED2
A0/D0	5	13	GND
VCC (3.3V)	4	12	VCC (3.3V)
GND	3	11	GND
RX (from host)	2	10	D6/INT0
TX (to host)	1	9	D7/INT1)

FRONT SIDE

A = analog input
D = digital input/output
INT = Interrupt input

Important Note:
For the ZT-50, pin 10 and pin 14 are used by the external EEPROM chip and are NOT accessible to the user

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HOST INTERFACE

The ZT-50 also contains certain special function pins. These are used to connect the ZT-50 to an external circuit board. For further information, see the datasheet for the ZT-Link.

PIN #	LABEL	DESCRIPTION
1	TX	TTL RS232 output to external circuit board
2	RX	TTL RS232 input from external circuit board
3, 11	GND	Electrical Ground
4, 12	Vcc (3 V)	This is the battery power.
5	INT1, INT2	These are Interrupt pins that can be used to trigger or wake up the tag. These are used for custom applications.

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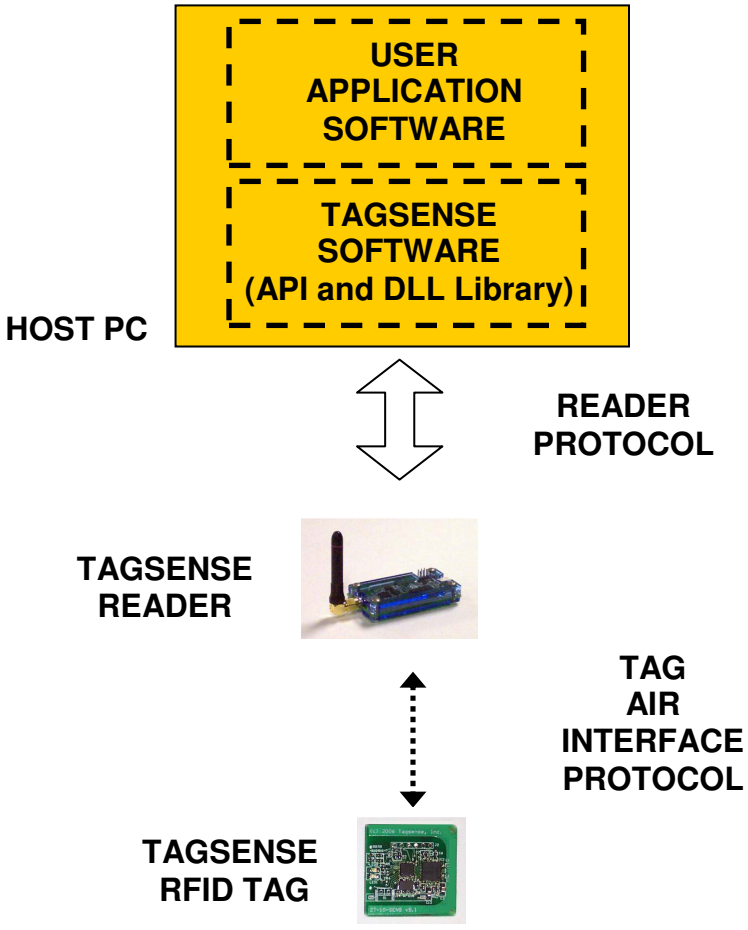
SOFTWARE ARCHITECTURE

To use any of the TagSense Active RFID tags, you can purchase any of the TagSense active RFID readers and software. TagSense provides a software API which allows users to easily integrate the TagSense active RFID tags into any software application.

The Software Architecture is illustrated in the following diagram.



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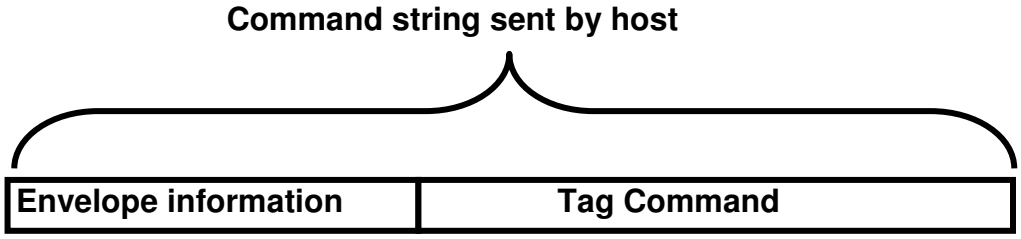
TAG PROGRAMMING AND PROTOCOL

For those users who are interested to know more information about the operation and technical implementation of the ZT-50 Tag, the following information brief is provided. Detailed protocol specs are available to TagSense clients, OEM resellers, and Licensees.

The TagSense *physical-layer* air interface protocol used between an active tag and the reader conforms to the standard IEEE 802.15.4. TagSense has also preserved to a large extent the Media Access Control (*MAC layer*) in the IEEE 802.15.4 protocol.

A given command string sent from the host to the reader is comprised of two parts: the tag command packet and the reader envelope information.



The *envelope information* contains instructions for the reader that specify: 1) how a given command is to be delivered to the tag, 2) the operation of the reader command queue, and 3) special functions such as synchronizing the time with the tag or setting the real-time clock on the reader itself.

The second part of the command string is the *tag command*. Since the TagSense RFID platform is designed to support a variety of tag devices and different versions of the protocol, the reader does not parse the tag command but rather transmits the command string verbatim to the tag. Thus, it is possible to use the same reader to communicate with different version of the tag protocol. This document describes Version 3 (v3.x) of the TagSense Active RFID protocol. Previous versions of the tag protocol are described in a separate documents.

Upon receiving a command packet from a reader, the tag will respond with an *acknowledgement packet*. (note this feature can be disabled if desired).

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GPIO (General Purpose I/O)

The ZT-x has 11 general purpose I/O pins. These pins can be configured to be digital inputs, digital outputs, analog inputs. Four of these pins have a special function: TTL level RS-232 RX, TTT-level RS-232 TX, and 2 external interrupts. Not every pin is capable of being set in every possible configuration, but with up to 7 analog inputs or up to 11 digital input/outputs (or some combination of the two), the ZT-x can be a powerful tool for either monitoring sensors, actuating external electrical devices, or interfacing to an external microcontroller.

Tag Parameter Reporting

In addition to being able to remotely set and configure the various state variables on the tag, it also possible to control which parameters are to be "displayed" or reported by the tag in each bacon data packet. This topic is known as reporting.

The most common application for reporting is to view the value of sensors that are connected to the tag analog or digital inputs.

All of the major parameters of the tag (such as the transit interval and RSSI) and the value of the analog or digital inputs to the tag can be reported in the tag beacon packet. By default, most of the paramter fields in the tag beacon packet are disabled (turned OFF) in order to save battery life and increase reading distance. However each of these fields can be enabled (turned ON) by means of enabling the reporting of the specific parameter that is needed.

If the user enables the reporting of a particular parameter, then this parameter will be permanently reported in every subsequent data packet until the reporting is disabled (turned OFF).

Tag Parameter Queries

In some cases, it is not necessary to enable reporting in every beacon packet, but rather the user simply wants to query a particular parameter to find out it current setting. This function is also supported y the TagSense version 3 protocol and is known as a parameter *query* or *reading*.

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Cambridge, MA 02141
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Fax: +1 617 (494)-6006

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In the case of a query, the query request is made via the command packet that is sent from the reader to the tag. This command will contain a request for the tag to reply with the parameter value.

Upon receiving the command, the tag will reply with the parameter value in the acknowledgement packet that it sends back to the reader. Note that for this to work properly, the user must make sure that the tag acknowledgement function is enabled.

Real Time Clock

The ZT-x contains a real time clock that has been implemented in firmware and is accurate to better than 15 minutes over a week. This performance is quite good, given the fact that the tag is put to sleep in between tag transmissions. An integrated calibration algorithm enables the ZT-x to maintain its clock accuracy despite changes in battery voltage or ambient temperature.

The time on the tag is represented by a 4-byte time integer which is equal to the number of seconds elapsed since January 1, 2000.

User Programmed Modes

One of the most powerful features of the ZT-x is the ability for the user to set up to 8 programmable states or *modes* of operation. A *mode* is defined by a set of internal state variables, which includes the configuration of the GPIO, the transmission interval, the sampling rate for data logging, etc.

The ability to create preset modes enables the tag to automatically and quickly switch from one behavior to another. For example, to conserve battery power, a user might want the tag to transmit only once an hour most of the time; but if an external sensor (such as a motion sensor) is triggered, then it is desirable for the tag to transmit more often. In this case, one mode can be set which transmit once per hour, and a second mode can be set which transmits once per second (for example). Similarly, it is possible to configure the tag to sample a sensor input at one rate, but then change to another sampling interval in another mode.

432 Columbia St, #B13B
Cambridge, MA 02141
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TAG PROGRAMMING AND PROTOCOL

There are several ways that a tag can be prompted to switch from one mode to another. The transition between modes is done through user-definable *triggers*. A trigger can be in the form of an analog input signal, a digital input signal, or an external sensor. These are described briefly below:

1) **Alarms**: An alarm is a time-based trigger. It is possible to set a time alarm such that a particular mode will be entered at a specific time. In addition to setting a specific start time to enter the mode, the user must also specify the duration for a particular mode. This is very analogous to programming a VCR for television. For example, the tag can be programmed to enter mode #4 at 12:45 pm and continue in this mode for 2 hours. At the expiration of this time, the tag will return to the previous mode or to the default mode (mode 0).

2) **External Digital Trigger** (interrupt): A tag can be programmed to enter a specific mode when triggered by an external digital input (0 or 1, Active High or Active Low). Examples of this include a pushbutton, a contact switch, a motion sensor, or a magnetic reed switch.

3) **Analog Sensor Trigger:** It is also possible to program a tag to enter a specific mode through the use on an analog sensor. In this case, the user must define an *analog trigger threshold*, and an *analog trigger direction*. The particular mode will be activated when the analog sensor value (10-bit integer value) crosses the threshold. The trigger direction defines whether the mode is activated upon crossing the threshold from above or from below.

Special Cases:

There are a couple special modes that are also defined:

Select mode: This mode is used to put the tag in a special state for the purpose of transferring and erasing its data memory. The process of downloading data from a tag is described in detail in a separate section.

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Custom Program Sequence

For certain applications, there may be a need for the tag to perform a sequence of operations every time it wakes up. For such applications, TagSense has provided a means for the user to create a custom command sequence. This sequence is treated as one of the programmable modes and is activated by setting the appropriate bits in the Trigger Field of the command packet.

Real-Time Location (RTLS) Functions

For many manufacturing or asset tracking applications, it is necessary to provide some means for monitoring the physical location of a tag. Although an approximate location algorithm can be derived using the Received Signal Strength Indicator (RSSI) signal, the RSSI signal can be affected by environmental parameters and is not very reliable.

As an alternative to using the RSSI signal, TagSense has implemented some special functions and special commands that provide location information based on the loction of other tags in the network.

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APPLICATION EXAMPLE #1:
Smart Supermarket

Example scenario: **We are creating a "smart supermarket" and want to place an active RFID tag on shopping carts to enable value added features to the customers, such as location information, interactive coupons, etc. In order to save battery life, we want the tags to turn OFF automatically during the night time when the store is closed (10pm to 8am).**

Sample Solution:

We can program the tags as follows:

STATE #1:
From 8am to 10pm the tag is programmed to transmit every 10 seconds. No sensor information is recorded.

STATE #2:
From 10pm to 8am, the tag is programmed to sleep. All sensors and transmitter are turned OFF.

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PROGRAMMING FOR EXAMPLE #1:

To program the tag, the following state variables are used:

STATE #1:
Start time = 0800
Duration = 14 hours
All sensors = OFF
Sensor sampling interval = OFF
Transmit interval = 10 seconds

STATE #2:
Start time = 2200
Duration = 10 hours
All sensors = OFF
Sensor sampling interval = OFF
Transmit interval = OFF

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APPLICATION EXAMPLE #2:
Shipment of Perishable Goods

Example scenario: **We are shipping some perishable goods by air to an Army depot in a remote area. The containers will be dropped out of an airplane to the field of operation. We want to attach active RFID tags to the containers so that we can record the history of the shipment in addition to ID and location. We want to record barometric pressure (altitude), temperature and humidity every 30 minutes. During the time in the air, we do not want the tags to transmit any signals. But after the shipment arrives, we want the tags to transmit continuously every 5 minutes.**

Sample Solution:

We can program the tags as follows:

STATE #1:
Tag is set to record temperature, barometric pressure, and humidity data every 30 minutes. Tag is set to NOT transmit.

STATE #2:
State #2 is programmed to be triggered by the vibration sensor when the container is dropped from the airplane and lands on the ground. Sensor data continues to be recorded but the tag will also transmit every 5 minutes.

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Cambridge, MA 02141
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info@tagsense.com

PROGRAMMING FOR EXAMPLE #2:

To program the tag, the following state variables are used:

STATE #1:
Start time = not important
Duration = indefinite
Sensor 1 = ON
Sensor 2 = ON
Sensor 3 = ON
All other sensors = OFF
Sensor sampling interval = 30
Transmit interval = OFF

STATE #2:
Start time = triggered by Sensor 1 (vibration HIGH)
Duration = indefinite
Sensor 1 = ON
Sensor 2 = ON
Sensor 3 = ON
All other sensors = OFF
Sensor sampling interval = 30
Transmit interval = 5 minutes

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APPLICATION EXAMPLE #3:
Livestock Tagging and Monitoring

Example scenario: We want to tag and study some valuable livestock on a ranch. For study, we need to record the temperature history of each livestock. We know that feeding time is 8am-9am each day, and during this time we want to count the cattle and download data. We also know that the livestock are asleep from 8pm to 5am every day.

Sample Solution:

We can program the tags as follows:

STATE #1:
5am to 8am – Tag is set to wake up and record temperature data every 15 minutes. Tag is set not to transmit to save power.

STATE #2:
8am-9am – Tag is programmed to continue recording temperature every 15 minutes, but also transmit its ID every 30 seconds to it can be counted more easily.

STATE #3:
From 9am to 8pm – Tag is programmed to record temperature data every 15 minutes. In order to save power, the ZT-50 Tag is set NOT to transmit any information during this time period.

STATE #4:
From 8pm to 5am – During this time, the livestock are asleep, so the tag can be turned off and set to SLEEP to save battery power.

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PROGRAMMING FOR EXAMPLE #3:

To program the tag, the following state variables are used:

STATE #1:
Start time: 0500
Duration: 180 minutes
Sensor 1 sampling interval = 15
Transmit interval = OFF

STATE #2:

Start time: 0800
Duration: 60 minutes
Sensor 1 sampling interval = 15
Transmit interval = 30 seconds

STATE #3:

Start time: 0900
Duration: 11 hours
Sensor 1 sampling interval = 15
Transmit interval = OFF

STATE #4:

Start time: 0800
Duration: 9 hours
Sensor 1 sampling interval = OFF
Transmit interval = OFF
Sleep mode: ON

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APPLICATION EXAMPLE #4:
Data-collection and Automation

Example scenario: We want to collect data from a biological experiment that is flying on the Space Shuttle. The experiment involves recording sensor data (temperature and pH) at specific intervals (5 minutes) and also actuating a motor (to spin the experiment) every 2 hours and turning on a light every day from 8am to 4pm. An active RFID tag is used to eliminate wiring and minimize power, size, and weight. Data from the experiment can be downloaded any time, but the each experiment and corresponding tag must transmit its ID every 10 minutes to signal proper operation of the system.

Sample Solution:

We can program the tags as follows:

STATE #1:
From 4pm to 8am, the Tag is programmed to record temperature and pH every 5 minutes. All outputs are OFF. Tag is programmed to transmit every 10 minutes.

STATE #2:
Every 2 hours, for 30 seconds duration, the tag will turn on OUTPUT #1 which is used to control an external motor to spin the experiment. The 30 seconds is chosen because this is the exact amount of time that it takes to spin the biological sample 1 time. Tag is programmed to transmit every 10 minutes.

STATE #3:
Every 2 hours, the tag is programmed to turn on OUTPUT #2 which controls an external light source. This state is programmed to start at 8am (0800) and end at 4pm (1600). In this state the sensor data sampling must also continue, taking a sample every 5 minutes. Tag is programmed to transmit every 10 minutes.

PROGRAMMING FOR EXAMPLE #4:

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Cambridge, MA 02141
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Fax: +1 617 (494)-6006

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To program the tag, the following state variables are used:

STATE #1:
Start time: 0800
Duration: 180 minutes
Sensor 1 sampling interval = 5 minutes
Transmit interval = 10 minutes
Output #1 (external light control) = OFF
Output #2 (motor control) = OFF

STATE #2:

Start time: indefinite
Duration: 30 seconds
Sensor 1 sampling interval = None
Transmit interval = 10 minutes
Output #1 (external motor control) = ON
Output #2 (external light control) = OFF

STATE #3:

Start time: 0800
Duration: 8 hours
Sensor 1 sampling interval = 5 minutes
Transmit interval = 10 minutes
Output #1 (external motor control) = OFF
Output #2 (external light control) = ON

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This device complies with part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) This device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

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432 Columbia St, #B13B
Cambridge, MA 02141
Phone: +1 (617) 494-1001
Fax: +1 617 (494)-6006

http://www.tagsense.com
info@tagsense.com