Technical Description of the Red Tulip Home Monitor Electronics

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This paper is intended for those with a background in electronics. Both the design strategy and circuit details are given.

Smart Home Focus

The monitoring system is focused on the home which includes the house and yard. It is not concerned with mobile operations. The aim is to be as unobtrusive and light-weight as possible and does not include medical monitoring. It is confined to sensors and not control devices such as light switches (which are in any case already available on the market). While intended initially for the elderly, the system is suitable for any smart home, especially if optional sensors such as flood/water sensors are included. The system consists of wireless sensors deployed around the home and a gateway to the Internet where data processing is done. A typical home layout is shown in Fig. 1.

Fig. 1 Smart Home with Sensors and Gateway

Wireless Sensor Considerations

Wireless sensors are required for smart homes/buildings for flexibility and ease of installation. Receptacle (120v AC) mounted sensors are acceptable in some instances, and used for the gateway, but in most cases battery operation with a long life (> 1 year) is better. Low cost is important because multiple sensors usually are needed for a complete system and cost is often a concern for homeowners. A special consideration for sensors is that the bandwidth requirement is low since sensor data is only a few bytes and needs to be sent infrequently. The most suitable wireless technologies for building monitoring are:

- WiFi (best low power)
- Bluetooth LE
- Mesh network (Zigbee, 6LoWPAN, others)
- SubGHz proprietary (433 MHz)

We recognize that cellular solutions (4G, NB-IoT) also have potential but at present require too much power or are too high in cost for home use. Of those listed we have chosen the 433 MHz technology because of the combination of longer range, low power and low cost, although there are many almost equally good choices. The basic transceiver chip is the Texas Instruments CC 1310 which has a high sensitivity and other advanced features. We use mostly modules with internal antennas, rather than the basic chip, because FCC approval is easier and there are many available on the market. The outdoor range is 1 km (100 mw, 1200 baud). The indoor range is variable but is typically 100 meters (300 feet). We prefer 433 MHz over 2.4 GHz devices because the range is better indoors. For larger houses, two gateways may be used. A block diagram of the electronics is shown in Fig. 2.

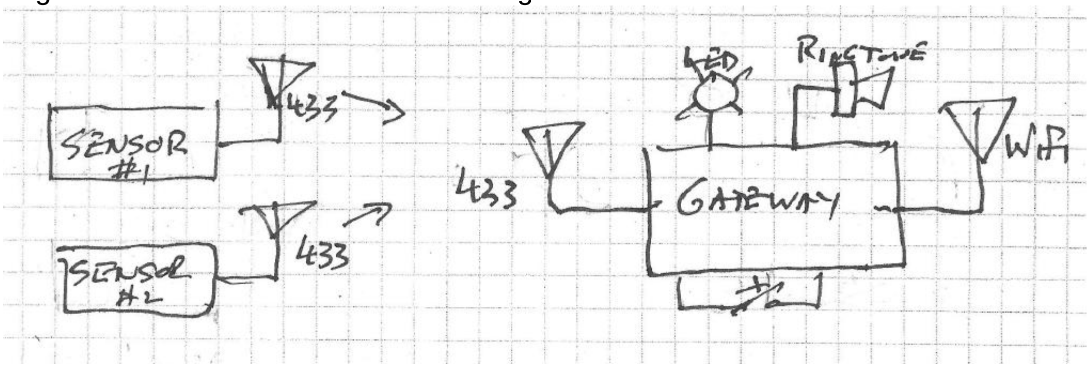

Fig. 2 Block Diagram of Wireless Sensor System

WiFi wireless (IEEE 802.11b/g/n, 2.4 GHz) is used to communicate with the Internet via a local router. We expect that many homes will already have WIFi but otherwise a router can be easily added. The range of WiFi is about 50 m.

All sensors are low power and battery operated, in most cases with a 3v coin cell. To achieve a long battery life (> 1 year), low power electronics is needed. For the sensors which are always on (e.g. E-field proximity, Fig. 3), very low current signal conditioners with a comparator output are used. All sensors include a low power microcontroller which is normally in sleep mode but wakes upon an event or by a watchdog timer. For sensors which are turned on occasionally (e.g. flood sensor), the duty cycle is low to minimize average current. Upon wakeup the microcontroller provides some data averaging, enables the transceiver, transfers the data block to the transceiver via the UART port, transmits the block of data (to the gateway), and finally the receiver is turned on briefly for a acknowledgement. If the sensor continues to be active, only occasional message updates are made and the microcontroller returns to sleep mode as soon as possible. The data block, which includes the sensor ID, is kept short to conserve power.

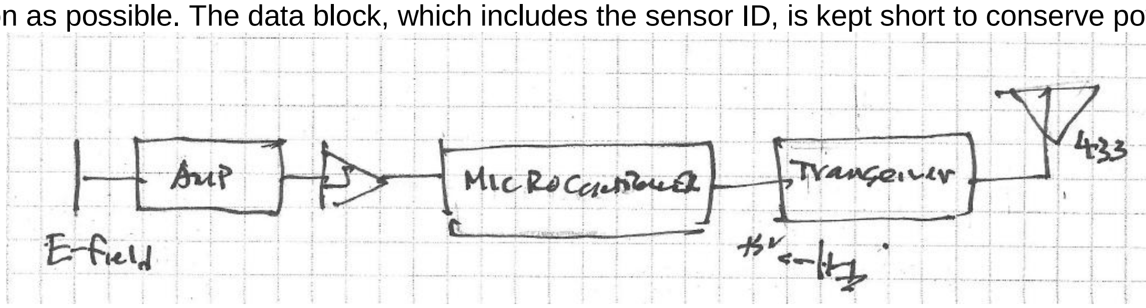

Fig. 3 Block Diagram of E-field Sensor as Example

<u>Sensor Types</u>

Basic Red Tulip home sensors

- Call/fall armband.
  Call activated by taping armband 2 times. Call cleared by tapping 3 times. Armband also detects fall of wearer. Based on 3-axis accelerometer.

- Motion NA
  This E-field sensor is a room occupancy sensor based on a proprietary Esensors design.
  It also has a room temperature and light sensor.

- Vibration NA
  This sensor is attached to doors which may be opened or objects which might be moved. Based on piezofilm sensor (accelerometer).

- Displacement NA
  These movement sensors are attached to objects such as a pill box or window to detect whether open, closed or moved. It is an alternative to the vibration sensor. Based on capacitance or magnetic reed.

  (NA means No Alert)

Damage Prevention Sensors

Selected sensors implemented initially

- Loud Sounds
  Detects smoke and similar alarms. Based on piezoelectric vibration sensor.

- Appliance Use
  The electrical current is monitored to determine use. Clip-on monitor for 2-wire cord. Based on existing non-wireless Esensors inductive sensor with 10 sec sampling period.

- Hot stove
  Detects overheated stove. Based on air temperature, IR surface temperature and MOS gas VOC sensor.

- Water/flood
  Detects water on floor (bathroom, kitchen, basement). Based on water conductivity.

- Displacement
  Detects object movement (e.g. window opening). May be used for intrusion alarms. Similar to Displacement NA sensors but produce an immediate alert.

- Vibration
  This sensor is attached to doors which may be opened or windows. Similar to Vibration NA sensors but produce an immediate alert.

Additional Status Sensors (NA)

- Sleep Monitor
  Monitors sleep movement, including respiration. Based on resistive force strips

- Chair Occupancy
  Detects a person sitting in a chair. Based on capacitance.

- Acoustic water pipe leak detector
  Detects sound of water escaping but does not generate immediate alert. Based on piezoelectric vibrations sensor.

Gateway

A block diagram of the gateway, which plugs into a wall receptacle is shown in Fig. 4. Data from the sensors (e.g. motion) is received by the 433 MHz wireless and retransmitted via WiFI to the Internet. Local alerts (LED and ringtone) are activated. Later signal processing (alert processing) may be added to the microcontroller.

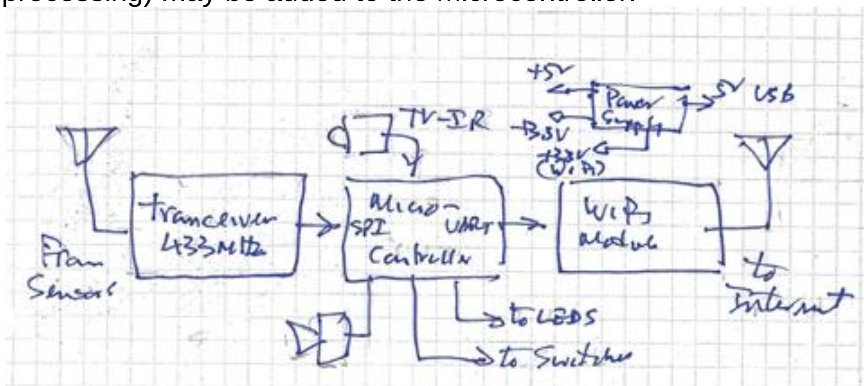

Fig. 4 Block Diagram of Gateway

Panel Controls

The following should be accessed from the front panel.

- Red LED for alert (large)
- White LED (small) as a nightlight
- Speaker
- Reset/clear push button (large)
- Reset push button (inside, along with test LED)

Future options

- Rechargeable battery (3v)
- Flash memory with ID (e.g. 11AA02)
- Real time clock (maybe)
- Sound recorder in place of transistor (maybe)
- Touch (capacitance) switch replacement for reset button
- TV remote (IR) receiver (allows more control options)

Major components

- 433 MHz transceiver module: Ebyte:
  http://www.digirf.com/XWFU/2016/299c3ed166617b18.pdf And
  Development Kit for CC1310: https://www.digikey.com/products/en?mpart=LAUNCHXL-CC1310&v=296
- Microcontroller: ATMEGA328-AUR
  https://www.microchip.com/wwwproducts/en/ATmega328
- WiFi unit: ESP8266EX-12E
  https://cdn-shop.adafruit.com/product-files/2471/0A-ESP8266__Datasheet__EN_v4.3.pdf