Wag System

Theory of Operation

1 General Description

The Wag system is comprised of two components; the Wag Ring model WR1 and the Wag Base Unit model WAGRX1. The Wag Ring is worn on a finger of the hand and utilizes capacitive sensing to measure finger position. The Wag Ring sends the sensor data to the Wag Base Unit which converts the sensor data into MIDI and Expression Pedal signals to control music effects.

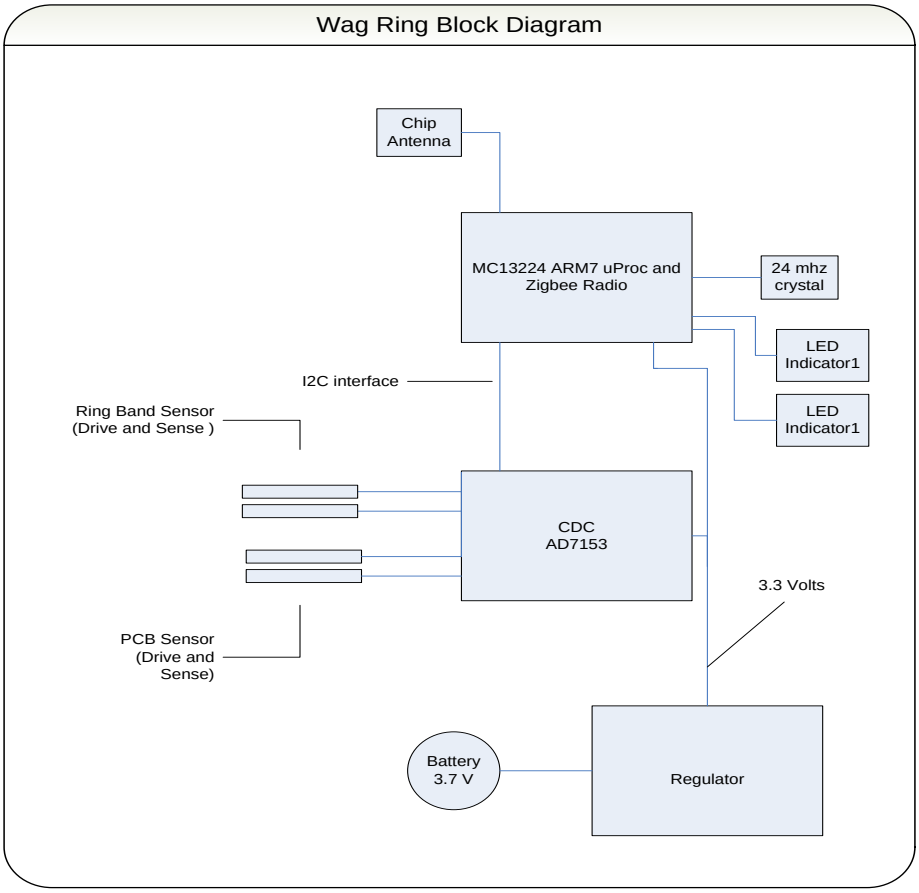
2 Wag Ring

2.1 General

The Wag Ring is comprised of the following named components:

PCB – a single printed circuit board assembly
Capacitive Sensors - 2 pair of capacitive sensor plates. One sensor pair is located in the ring band and the other pair are traces on the PCB
1 - 3.7 volt, 35 mAh Lithium Ion Button Cell Battery (LIR 2032)

A Block Diagram of the system is shown below.


Wag Ring Block Diagram
Chip Antenna
MC13224 ARM7 uProc and Zigbee Radio
24 mhz crystal
LED Indicator1
LED Indicator1
I2C interface
Ring Band Sensor (Drive and Sense)
CDC AD7153
3.3 Volts
PCB Sensor (Drive and Sense)
Battery 3.7 V
Regulator

2.2 PCB – Circuit Description

The PCB circuit contains the following primary components:

3.3 volt, 300 mA, CMOS low-dropout voltage regulator (Fairchild FAN 2503 LDO)
Platform-in-Package (PiP) - ARM7 Microprocessor and ZigBee Compliant Transceiver
24 mhz Crystal
12-bit sigma-delta (Σ-Δ) capacitance-to-digital converter (CDC)
2.45 GHZ Ceramic Chip Antenna
2 Led Indicators

2.2.1 Power and Power Regulation

The ARM7 Microprocessor operates over a supply voltage range of 2.0 – 3.6 volts. The CDC operates between 2.7 and 3.6 volts. Power is supplied by the 3.7 volt Lithium Ion battery. Charging voltage for the battery reaches 4.20 volts. The Power regulation is accomplished by a 3.3 volt CMOS low-dropout voltage (Fairchild FAN 2503) which features an ERR lead that goes low when the output voltage drops below 3.1 volts. This lead is connected to the reset lead of the ARM7 microprocessor to hold it in reset when the supply voltage drops below 3.1 volts. Peak current for the LDO is 300 mA. The significant contributors to current consumption are shown below.

Current Consumption
Platform-in-Package: 31 mA max (Radio On)
CDC – 100 uA max
2 Led Indicators 7 mA combined

Under software control, the Radio, the CDC, and the LEDs are never active at the same time. So, the maximum current draw is 31 mA.

2.2.2 Platform-in-Package

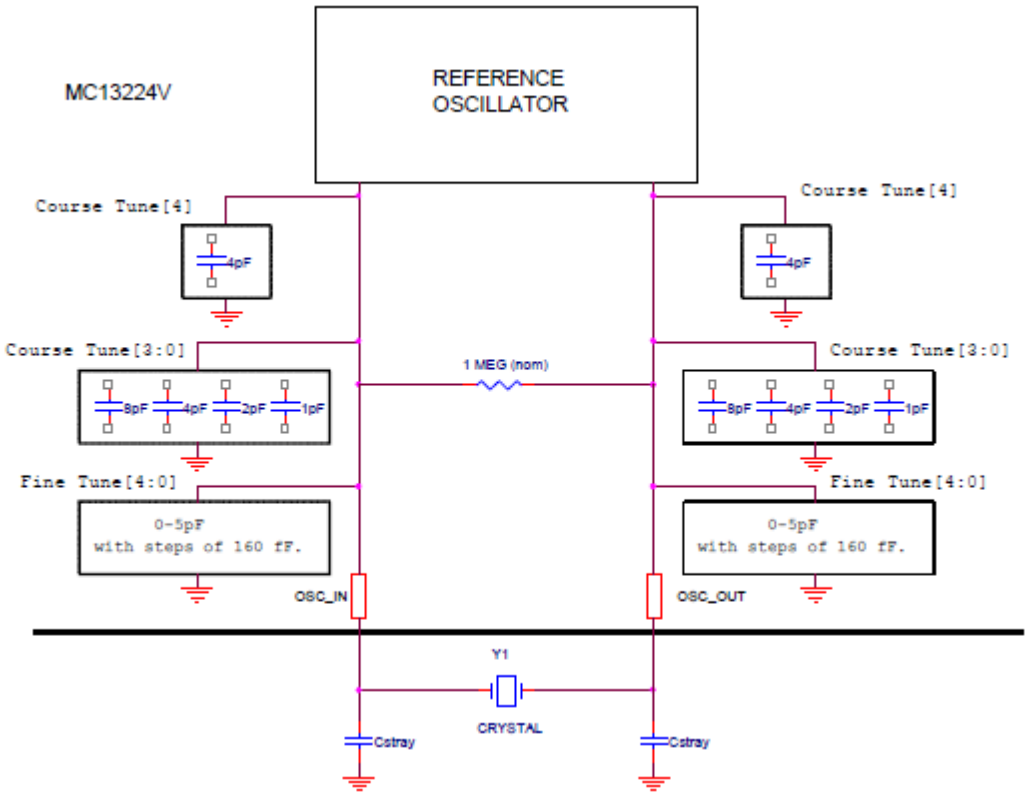
A single MC13224V IC acts as the main controller and radio for the system. The MC13224V is Freescale's third-generation ZigBee platform which incorporates a complete, low power, 2.4 GHz radio, 32-bit ARM7 core based MCU, hardware acceleration for both the IEEE 802.15.4 MAC and AES security, and a full set of MCU peripherals into a 99-pin LGA Platform-in-Package (PiP). The only external components required by the chip are a 24 mhz crystal and single-ended 50-Ω antenna. The radio antenna BALUN and crystal load capacitors are internal to the chip.

The MC13224 general purpose I/O leads are used to drive 2 status LEDs. The MC13224 I2C interface is used to configure and take capacitive sensor readings from the CDC. A single logic level MOSFET is used to power down the CDC during microprocessor reset to save battery charge. Software running on the MC13224 takes capacitive sensor readings from the sensor in the ring band every 15 milliseconds (via the CDC) and sends the value to the Wag Base Unit. In addition, the software periodically takes readings from a second sensor (traces located on the PCB) which indicates that the user has touched the Lid of the ring to request the Wag Ring to

pause or resume sending of sensor readings. The MC13224 flashes the LEDs to indicate the status of Pause and Sleep. The process is sequential so that the sensor readings, flashing of LEDs and radio functions are not occurring at the same time. A secondary function is provided by the secondary sensor is for the user to request the ring to acknowledge a radio channel change request from the Wag Base Unit.

2.2.3 24 mhz crystal

The MC13224 requires only a single crystal for operation (optimized for 24 MHz) for full radio and MCU operation. The load capacitance to the crystal oscillator is supplied on-chip to eliminate the need for the otherwise required external capacitors. The reference oscillator model including external crystal in shown in the figure below. With a suitable crystal the device frequency tolerance can typically trimmed to be held to +/- 30 ppm over all conditions. The following diagram is from the manufacturer documentation for the MC13224 IC.



2.2.4 Capacitance-to-digital converter (CDC)

The CDC used is an Analog Devices AD7153 which contains a 12-bit sigma-delta (Σ-Δ) capacitance-to-digital converter. The CDC has two channels for sequentially reading two capacitive sensors. The operating voltage range is 2.7 – 3.6 volts. Current consumption is 100 uA. Configuration and readings are performed over an I2C interface. Excitation frequency for the CDC is 30.9 – 32.8 khz. Conversion time is set at 5 msec. The I2C max data rate for the chip is 400 khz. The ring software is using a data rate of 150 kbps.

2.2.5 Antenna

The antenna is a 50 ohm 2.45 GHz ceramic chip antenna part 2450AT43A100 from Johanson Technology. This antenna has a maximum input power rating of 3 Watts, a frequency range of 2400 – 2500 mhz, a Peak gain of 2.0 dBi typical, an Average Gain of .5 dBi typical, and a Return Loss of 9.5 dB minimum.

3 Wag Base Unit

The Wag Base Unit converts the sensor data into MIDI and Expression Pedal signals to control music effects. It also provides user interface for configuring the musical interface for the desired mode of control.

3.1 General

The Wag Base Unit is comprised of the following named components:

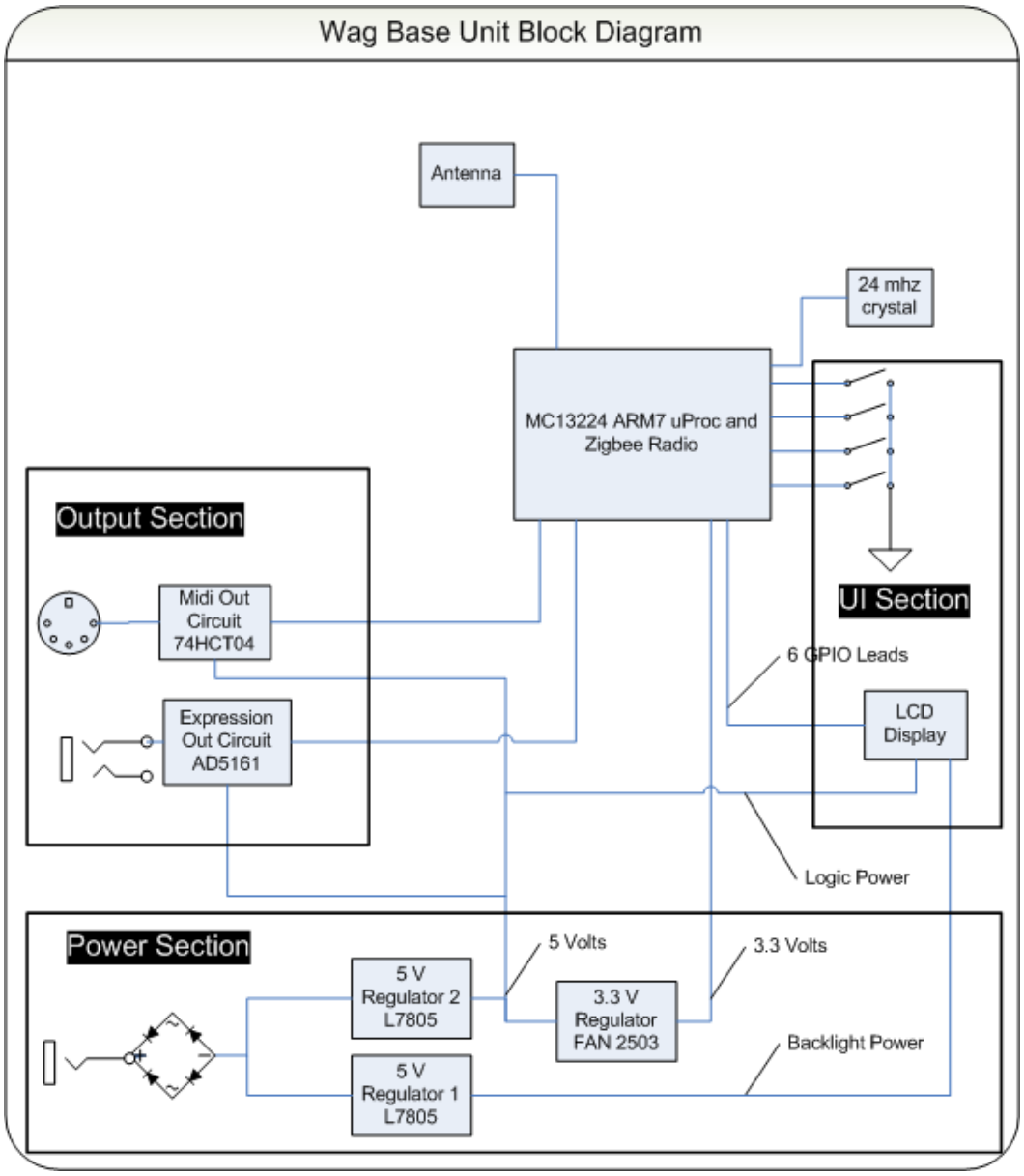
PCB – Printed Circuit Board Assembly
LCD – Display Assembly including connectors to PCB
Wall wart Power Supply

3.2 PCB – Circuit Description

The PCB circuit contains the following primary components:

Platform-in-Package (PiP) - ARM7 Microprocessor and ZigBee Compliant Transceiver
24 mhz Crystal
Antenna
UI Section – User Interface Switches and LCD Display
Output Section – MIDI Output and Expression Pedal Output (Digital Potentiometer)
Power Section – Bridge Rectifier and Regulators
External Power Supply – Wall Wart

A block diagram follows.



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The MC13224 general purpose I/O leads are used to drive an LCD Display and reads input switches (User Interface). The MC13224 UART interface is used to drive the MIDI Output. The MC13224 SPI interface is used to configure and control the Digital Potentiometer for the Expression Pedal output. Software running on the MC13224 scales and converts sensor data from the ring into the appropriate signals to drive MIDI and Expression Pedal outputs per user selected options submitted and stored by the User Interface. Requests for radio channel changes are initiated at the Wag Base Unit.

3.4 24 mhz crystal

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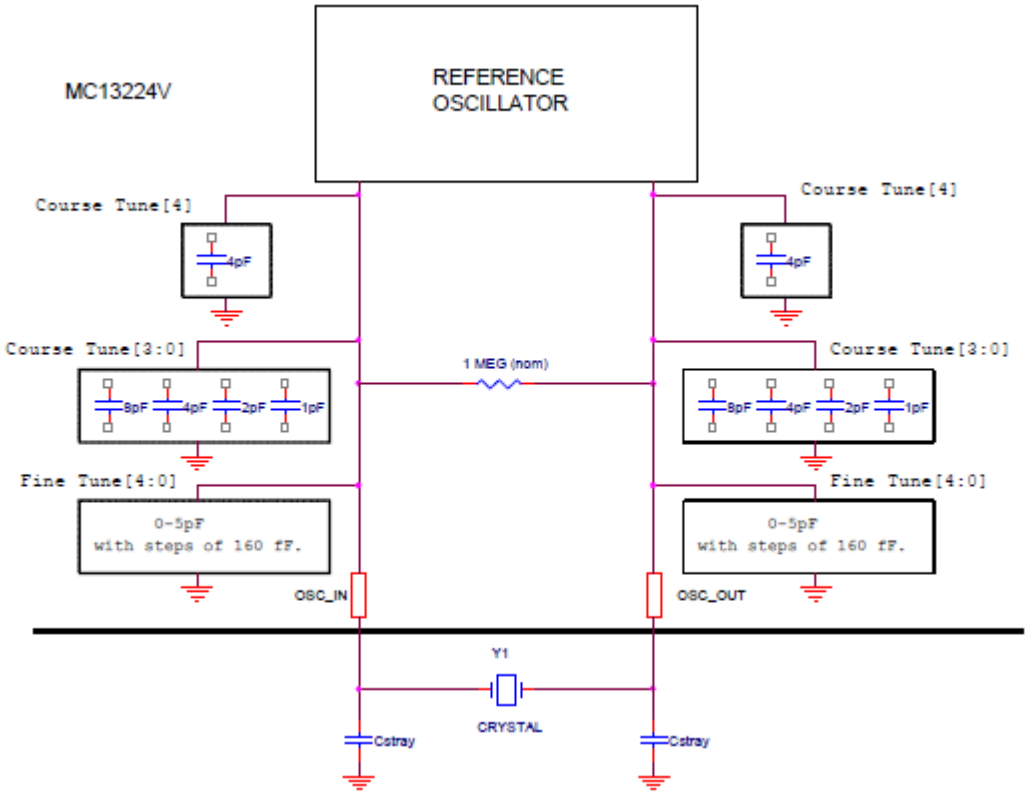

3.5 Antenna

The antenna is part ANT-2.4-CW-RCS from Antenna Factor configured with a Part 15 compliant RP-SMA connector. The antenna has the following features and specifications per the manufacturer. The Wag Base unit is enclosed in an extruded metal case measuring approximately 5 ½ x 5 ½ x 1 ½ inches.

Features
- Reduced height helical whip
- Right-angle mount
- Excellent performance
- Omni-directional pattern
- Fully weatherized
- SMA or Part 15 compliant RP-SMA connector
- Use with plastic* or metal enclosures

Specifications
- Center Freq. 2.45GHz
- Bandwidth 50MHz
- Wavelength 1/4-wave
- VSWR <1.9 typ. at center
- Impedance 50 ohms

Electrical specifications and plots measured on 4.00” x 4.00” reference ground plane

3.6 User Interface Section

This section is comprised of 4 front panel input switches and a single LCD display. MC13224 GPIO leads read the switch states and drive the logic in the LCD display.

3.7 Output Section

The output section is comprised of a MIDI output and Expression Pedal Output. The Midi output is driven by the MC13224 UART interface and utilizes a 74HCT04 IC (Hex Inverter) to set the proper logic level for Midi interfacing. The physical interface for Midi is a 5-pin din jack. Standard Midi baud rate of 31250 is utilized. The Expression Pedal Output is provided by a digital potentiometer (Analog Devices AD5161). The MC13224 configures and controls the AD5161 using it’s built in SPI interface running at 93.750 khz. The maximum data rate for the AD5161 is 400 khz. The software configured clock rate used for the AD5161 is 25 mhz. The physical interface for the expression pedal output is a ¼ inch phone jack.

3.8 Power Section

The power source for the Wag Base Unit is 9 Volt regulated DC 800 mA Class 2 Transformer manufactured by CUI Inc. (P/N DPR090080-P5P-SZ). The Wag Base Unit circuit contains two 5 volt regulators (L7805) and one 3.3 volt LDO (FAN 2502). The FAN 2502 features a BYP lead to which a bypass capacitor is connected for optimal noise performance. One of the L7805 regulators is dedicated to the backlight for the LCD display. The other L7805 powers the MIDI output logic, LCD logic and Display, and Expression Pedal output. The 3.3 volt LDO powers the MC13224 which has an operating range of 2.0 – 3.6 volts. Peak current for the FAN 2502 LDO is 300 mA. Peak current for the L7805s is 1 amp each.

The MC13224 current draw is 31 mA maximum (Radio On). The LCD display including backlight draws 106 mA. Total current draw for the Base Unit is 138 mA.