# Reply® DL Keypad Model CRS10000

## Operational Description (Part 15)

## Introduction

*General Characteristics:*

| | |
|---|---|
| Enclosure: | Each keypad is housed in an A.B.S. plastic molded enclosure. Overall size is approximately 6.7" L x 3" W x 1.4" H. Weight is approximately 8 oz. |
| User Interface: | Membrane keyboard with tactile feedback for response entry. Ten digit keys (1-10, A-E, Yes/No) and Enter, Clear, Talk, and Login keys allow intuitive entry of responses. A seven segment LED display provides immediate feedback of the user response and keypad status. A green LED provides talk status and a red LED provides wait status for the wireless microphone. |
| Supply: | Battery powered using readily available 9 Volt alkaline battery. Low battery detection and indication through rapidly flashing the LED provides feedback to user and to base unit. Keypads shutdown automatically between responses to extend battery life. |
| Technology: | Entirely solid state using a CMOS microcontroller. Receive and transmit are fully synthesized and crystal referenced. The receiver incorporates dual conversion superheterodyne FM design for superior sensitivity, stability, and selectivity. The transmitter is frequency locked to the reference and is FM modulated. The wireless microphone section is also synthesized and frequency locked to the crystal reference. |

## General System Description

The Reply® DL Keypad monitors user input from the membrane switch panel, displays the key value pressed on the LED display, and transmits the key value to the base unit.

The keypad is powered by a 9 volt alkaline battery. The operating voltage is regulated to 5 volts DC. To conserve battery current the keypad is shut down automatically when not being used. A hardware reset circuit (RC discharge) guarantees the keypad will be shut down even in the rare event that the microprocessor malfunctions. The five volt regulator provides a logic signal to alert the microcontroller when battery voltage nears 6.5 volts and is in need of replacement. If an option is enabled, the keypad can send low battery status to the base unit.

A system clock frequency of 10.200 MHz is provided by an external crystal circuit on the microcontroller. The same crystal reference is used for both microcontroller and RF portions of the keypad.

Key press inputs are read through a 14 key switch matrix. The matrix is configured in four columns (microcontroller inputs) and four rows (microcontroller outputs). The matrix columns are pulled up to 9 volts via the reset circuit so when a key is pressed, the primary regulator and microcontroller are powered up. The microcontroller then reads the switch matrix by alternately grounding each row until it sees a 'low' at the column input. Keypad configurations such as keypad address and channel number are stored in on-board EEPROM.

## Receiver Theory of Operation

### *Introduction to Receiver Operation*

The Control Receiver (CRX) is located within the CRS 10000 handheld communicator. The receiver is activated when the user enters a digit from the integral keypad. The receiver diagram is included in the block diagram exhibit.

The receiver operates with Frequency Shift Keyed (FSK) binary data with +/- 5kHz nominal deviation.

### *Receiver Frequency Plan*

The receiver is a double conversion super-heterodyne system with a 1$^{st}$ IF of 10.655 MHz and a 2$^{nd}$ IF of 455 KHz. It uses a 10.2 MHz crystal oscillator for the 2$^{nd}$ LO, processor clock, and as a reference signal for the synthesized 1$^{st}$ LO.

The eight channels and the respective 1$^{st}$ LO frequencies are listed below:

| Channel Number | Carrier Frequency | First LO Frequency |
|---|---|---|
| 1 | 216.0125 MHz | 205.3575 MHz |
| 2 | 219.0125 | 208.3575 |
| 3 | 217.0125 | 206.3575 |
| 4 | 218.0125 | 207.3575 |
| 5 | 216.5125 | 205.8575 |
| 6 | 217.5125 | 208.8575 |
| 7 | 219.5125 | 206.8575 |
| 8 | 218.5125 | 207.8575 |

The synthesizer uses an internal reference frequency of approximately 50 kHz.

### *Receiver Block Diagram*

The following explains the receiver block diagram exhibit:

> The 216 to 219 MHz signal is first received by the printed antenna followed by a two-pole band-pass filter, and low noise amplifier (U102a). Next, potential interference from the keypad transmitter is removed in the 345 to 370 MHz band reject filter (FL3), followed by additional gain in U102b. The output of U102b is impedance-matched to the 1$^{st}$ conversion mixer (M1) with a transformer (which is realized with L107, L109, and C117 – Figure 2). The output of M1 (10.655 MHz) is amplified by A1 and filtered by FL4. Next, the signal is converted to 455 KHz in M2, amplified by A2, and band-pass-filtered in FL5. The

sequence of A3, A4, and M3 form a traditional limiter/discriminator that provides a 2Vp-p detected signal. The detected signal is low-pass filtered and AC coupled in FL6 and sent to a threshold comparator as realized in U202 to form a conditioned signal out to send to the microcontroller.

# **Transmitter Theory of Operation**

## *Introduction to Transmitter Operation*

The Control Transmitter (CTX) is located within the CRS 1200 handheld keypad. The transmitter is activated within assigned 10mS slots with slots as determined in the fixed base station. After the user enters a digit in the keypad the keypad receiver is activated and subsequently receives time slot information, following which the CTX is turned on within the appropriate slot. The CTX is diagrammed in Figure 1, with schematic shown in Figure 2.

## *Transmitted Waveform Description*

The Control (CTX) transmitter is a Frequency Shift Keyed (FSK) binary data transmitter, which is activated by a keypress for a period of 10 mS. It has a minimum interval of 500 milliseconds between transmit intervals. As such, the legal peak power is increased by 20 dB since the CTX has a duty cycle of less than 10% in a 100mS interval.

The transmitted signal has a deviation of +/- 300 KHz nominal.

## *Transmitter Modulation and Synthesizer*

Referring to the transmitter block diagram exhibit Figure 1, the transmitter is phase-locked to a 10.2 MHz crystal oscillator (X1) that is factory-set to +/- 2.5 ppm. The Phase-Locked-Loop (PLL) has an internal reference in the range of 200kHz to 500kHz, selected to result in the best possible set-on accuracy of the CTX carrier frequency.

The synthesizer uses a ‘fastlock’ routine, which is described as follows:

> The phase detector charge pump is initially set to a high gain state (4mA/ radians) and the PLL open loop frequency response is optimized by opening SW5. Following the initial 700 uS settling transient, the charge pump gain is set to a low value (1mA/$\pi$ radians) and the open loop frequency response is optimized for lower gain by closing SW5. The switch , SW5, is actually a CMOS gate located within the control processor; it is toggled between a High-Z and active–low state.

The overall PLL activation sequence is as follows:

1. T=0, Begin transmission cycle with high loop gain for fast settling
   - a) Load PLL (U103B) divider registers and set the phase detector to a high gain, fast-settling state
   - b) Compensate the loop for high gain by opening SW5
   - c) Turn on VCO and PLL power (turn on Q103 and Q105, Figure 2),
   - d) Set RF switch (SW1-SW3) to high insertion loss state

*2.* T=400 uS, Transmitter Settled
   Set the RF switch (SW1-3) to a low insertion loss state

3. T=700uS, Reduce the loop gain for lower distortion during transmission
   a) Set the phase detector (U103B) to low gain
   b) Compensate  the loop for low  gain by closing SW5

4. T=1300uS, Loop settled completely
   a) Start modulation by toggling TX data

5. T=10mS, Transmit cycle complete
   a) Shut down power to transmitter and PLL (turn off Q013 and Q015)

## *RF Switch and Harmonic Filter*

The RF Switch (RFS) and Harmonic Filter (HF) are shown in Figure 1 as SW1-3 and FL1 respectively. The switch is actually comprised of  one series and two shunt  PIN diodes (D016,107, and111 in Figure 2). The series stage immediately follows the VCO (See Figure 1) with the shunt stages prior to and following the filter. This combination produces 40 to 50 dB of on/off isolation.

## *Transmit Antenna*

The transmit antenna is a printed strip-line antenna. It presents a relatively high impedance to the transmit circuitry, thereby optimizing the effectiveness of the RF switch.