MCRF45X REFERENCE DESIGN

13.56 MHz Reader Reference Design for the MCRF450/451/452/455 Read/Write Devices and MCRF355/360 Read-Only Devices

1.0 INTRODUCTION

The anti-collision interrogator in the DV103005 Development Kit is for Microchip Technology Inc.'s 13.56 MHz RFID devices (MCRF35X/360 and MCRF45X). The interrogator is used in conjunction with rfLAB™ software version 3.2 or above. The user must select the device type in the rfLAB menu bar for either the MCRF35X/360 or MCRF45X device.

In the MCRF35X/360 mode, the interrogator transmits 13.56 MHz carrier signal continuously and receives tag's responses. This is often called "Tag Talks First" (TTF). The interrogator is working as the reader in the DV103003 kit that is for read-only devices (MCRF35X and MCRF360).

In the MCRF45X mode, the interrogator sends commands for reading or writing block data. Interrogator uses amplitude modulation for the commands. To initiate communications, the interrogator sends specially timed gap pulses: FRR (Fast Read Request) and FRB (Fast Read Bypass). These pulses consist of 5 gaps within 1.575 ms time span. Each gap pulse is 175 µs wide with 100% modulation depth. Gap means an absence of RF field. See Figures 4-3 thru 4-8 in the MCRF45X data sheet for details.

1-of-16 PPM (Pulse Position Modulation) is used for data and commands such as Read/Write command for block data, command to set/clear TF (Tag Talks First) and FR (Fast Read) bits, and command for end process. The 1-of-16 PPM signal consists of one gap pulse within 2.8 ms time span for a normal mode and 160 µs for a fast mode. The gap's position within 16 possible locations determines its representation for hex value. See Figure 4-9 in the MCRF45X data sheet (DS40232) for details.

The interrogator also sends a time reference pulse before the commands and data. This time reference signal consists of three gap pulses within 2.8 ms time span for a normal mode and 160 µs for a fast mode. See Figure 4-10 in the MCRF45X data sheet for details. Figure 1-1 shows the read/write pulse sequence between the interrogator and device.

The demo interrogator communicates with the device in conjunction with the rfLAB.

The rfLAB is a menu driven software package. Once the "MCRF450" - "Continuous" - "Run" menus are selected, the interrogator transmits FRR command continuously. Tags respond to the FRR command with a maximum of 160 bits of data, including its unique ID number (32 bits). To read or write a specific memory block, users must select the tag ID and block number.

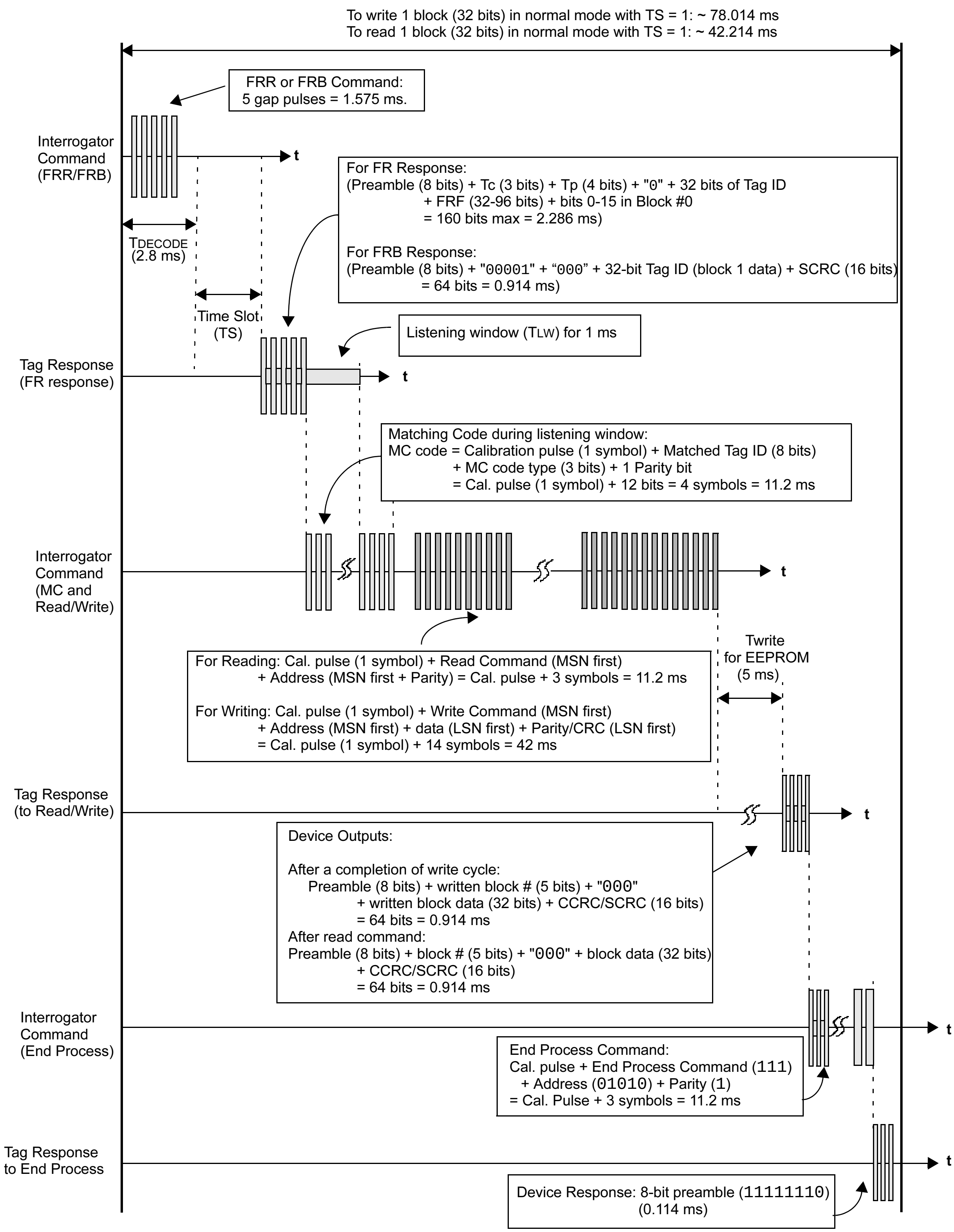
The demo interrogator, along with the rfLAB included in the DV103005 kit, is made as a reference material for various applications. The demo interrogator is designed for a general purpose utilizing all possible features shown in the data sheet. Both firmware and schematics can be modified for each individual application.

The interrogator uses two PICmicro® microcontrollers (MCUs) to communicate with a host computer, to send commands and data to the tag, and to receive and process the data from the tag.

The U17 includes the anti-collision algorithm shown in Figure 4-1 of the MCRF45X data sheet. It controls all functions of the interrogator except decoding the received Manchester data which is done by the U14.

The circuit is designed for medium read/write range applications (about 15" with 2" x 2" tag). The circuit can be optimized for lower cost or modified for long-range applications. Electronic copies of the PICmicro MCU source codes, schematics and Bill of Material (BOM) are available for download and contained on the CD provided in the DV103006 developer kit.

FIGURE 1-1: READ/WRITE PULSE SEQUENCE



2.0 INTERROGATOR CIRCUITS

The interrogator circuit consists of (1) transmitting, (2) receiving and (3) command control/data processing sections.

2.1 RF Transmission Section

U6:A and 13.56 MHz crystal form a crystal oscillator and output a 13.56 MHz signal. The output signal is fed into pin 1 of U7. The input signal on pin 2 of U7 is coming from U17 (master microcontroller). The following is the output of U17 for pin 2 of U7.

- MCRF45X mode: Modulation signal for commands and block data for writing.
- Standby mode: Logic “HIGH”.
- MCRF35X/360 mode: Logic “HIGH”.

Therefore, U7 outputs (a) a modulated RF signal (for command or write data) or (b) continuous RF signals during the standby and MCRF35X/360 operation. The output signal of the U7 is fed into the gate of RF power amplifier U8 through U6:D, E and F. Splitting the output of U6:C using U6:D, E and F is helpful for preventing excessive heat on U6.

U4 is an adjustable voltage regulator and supplies the DC power supply voltage for U8. The U4 is controlled by U17 through U16 (DAC) and U3. The main idea of using the adjustable voltage regulator is to adjust the RF output signal level of U8. The power level is adjusted by the following procedure in the rfLAB menu:

“Configure” -> “Carrier Strength”

User can select the “Carrier Strength” from 0%-100% (from the above menu). Default is set to 100%. The interrogator outputs the maximum power level at this setting.

rfLAB sends the Carrier Strength information to U17 which adjusts U4’s output voltage through U16 and U3.

This corresponds to about 12.37 V_{DC} at pin 2 of U4 for the 15 V_{DC} input voltage.

The purpose of adjusting the carrier signal level is to reduce a possible near-field problem which may result in an irregular clock rate of the RFID device. This is due to an excessive input voltage to the device when the tag is placed too close to the reader antenna. In this case, the output power level from the interrogator should be decreased. However, for a longer read range, it is often necessary to output a higher power level so that it can detect tags in the far range.

Adjusting the carrier signal level is an optional choice. Therefore, the circuit components (U16, U3 and U4) associated with this feature can be easily removed. In this case, +15 V_{DC} or 9 V_{DC} should be directly applied to L9 for U8.

The RF output voltage from U8 is fed into the antenna circuit formed by C1, C2, C3, C4, C5 and antenna coil L.

The demo unit has three different sizes of antenna. Each one has one turn inductor along the edge of the PCB board. The metal trace is embedded inside the PCB.

Figure 2-1 shows the antenna circuit. The impedance of LC circuit is given by:

EQUATION 2-1:

$$Z(\omega) = \frac{\frac{1}{C_4}\left(j\omega L + \frac{1}{j\omega C_S}\right)}{-\omega^2 L + \left(\frac{1}{C_S} + \frac{1}{C_4}\right)}$$

where

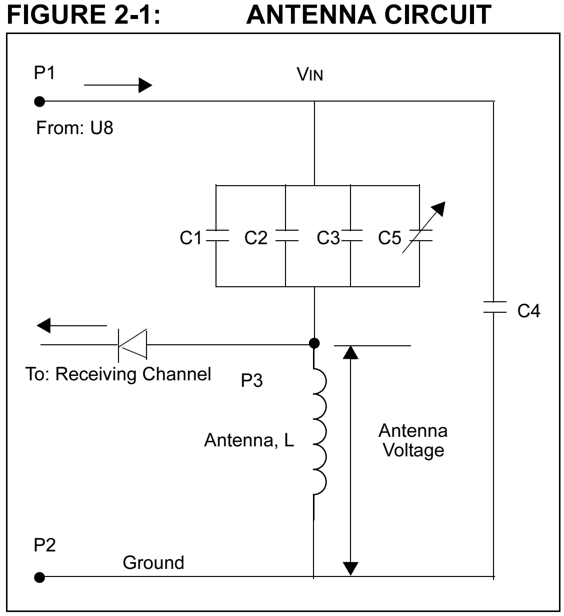
$C_S = C_1 + C_2 + C_3 + C_5$

$\omega = 2 \pi f$

f = output carrier frequency

The resonant frequency of the antenna circuit in the interrogator is given by solving the impedance equation in Equation 2-1. In Equation 2-1, the impedance $Z(\omega)$ has poles and zeroes. The poles are found at the condition when the denumerator goes to zero and the zeroes are found when the numerator goes to zero. The poles result in a maximum impedance, since the denumerate goes to zero. Therefore, the frequencies at the poles are the parallel resonant frequencies. The zeroes result in a minimum impedance since the number goes to zero. Thus, the frequencies at the zeroes are series resonant frequencies.

FIGURE 2-1: ANTENNA CIRCUIT



The resonant frequencies by solving the poles and zeroes are:

EQUATION 2-2:

$$f_{series} = \frac{1}{2\pi\sqrt{LC_S}} = \frac{1}{2\pi\sqrt{L(C_1 + C_2 + C_3 + C_5)}}$$

and

EQUATION 2-3:

$$f_{parallel} = \frac{1}{2\pi\sqrt{L\left(C_S\left(1 + \frac{C_S}{C_4}\right)\right)}}$$

where

$C_S = C_1 + C_2 + C_3 + C_5$

Equation 2-3 is used for the antenna circuit of the interrogator in the DEV103005 kit.

The antenna voltage across the L is given:

EQUATION 2-4:

$$V_{Ant} = \frac{jX_L}{r + j(X_L - X_{C_S})} V_{in}$$

where

r = Ohmic resistance of L and C

$X_L = 2 \pi f L$ (Ω)

$X_{C_S} = (2 \pi f C_S)^{-1}$ (Ω)

V_{IN} = AC voltage at points between P1 and P2.

The antenna voltage measured between P3 and P2 contributes the radiating RF field from the antenna. The voltage is about 60 V_{PP}-80 V_{PP}. C5 can be adjusted to get the maximum voltage across the antenna. The current that flows along antenna L generates magnetic fields.

Each interrogator unit may have a slightly different output parasitic capacitor. As a result, there will be a chance of tuning variation when the antenna is attached to the unit. This results in shorter read range. In this case, C5 in the circuit should be adjusted properly.

2.2 Receiving Section

The receiving section receives 70 kHz Manchester data from tag in the field. D1, C4 and R3 collectively form an envelope detector.

L1 and C3 forms a 70 kHz band-pass filter. D4 and D2 are used to limit signal amplitude level which prevents U1:A from going into a saturation condition. L3, C33 and C47 form a 13.56 MHz notch filter and bypass the induced carrier signal into ground. FB1 is an RF choker that gives high attenuation to high frequency signal. U1:A is a gain amplifier that gives about 26 dB voltage gain. U1: B is a unit gain second-order high-pass filter. U1:C is a gain amplifier with about 29 dB voltage gain. U1:D is a unit gain second-order low-pass filter. U1:B and D result in a band-pass filter for the 70 kHz Manchester data.

U11:A, B, T1 and T2 circuits are used to find a midpoint of the input data voltage. The resulting average voltage, $(V_{P}^{+} + V_{P}^{-})/2$, is used as a reference voltage for the voltage comparator U2. The output of U2 is fed into the PICmicro microcontroller U17 for data decoding.

2.3 Command Control and Data Decoding Section

The interrogator uses two PICmicro MCUs (PIC16F876-20/SP) for the command controls, data decoding and communication with a host computer.

The U17 includes PIC® code routines to follow the device's read/write anti-collision algorithm as shown in Figure 4-1 in the data sheet. The U14 performs bit timing calculation for the received Manchester code.

The U17 does the following tasks:

a) Communicate with a host computer
b) Encode and transmit:
   FRR and FRB Commands
   Calculate/Send MC1 and MC2
   Read/Write/End Commands
   Calibration Pulse
   Data and CRC
c) Decode receiving data
d) Calculate CRC for transmitting data and receiving data. CRC look-up table is used for the calculation.
e) Give a received data stream to U14 for decoding of the Manchester data.

The flow charts of the PICmicro microcontroller routines for U14 and U17 are shown in AN760 (DS00760). The source codes are available for download and contained on the CD provided in the DV103006 develop kit.

Figure 2-2 shows the functional block diagram of the interrogator.

FIGURE 2-2: FUNCTIONAL BLOCK DIAGRAM OF DEMO INTERROGATOR

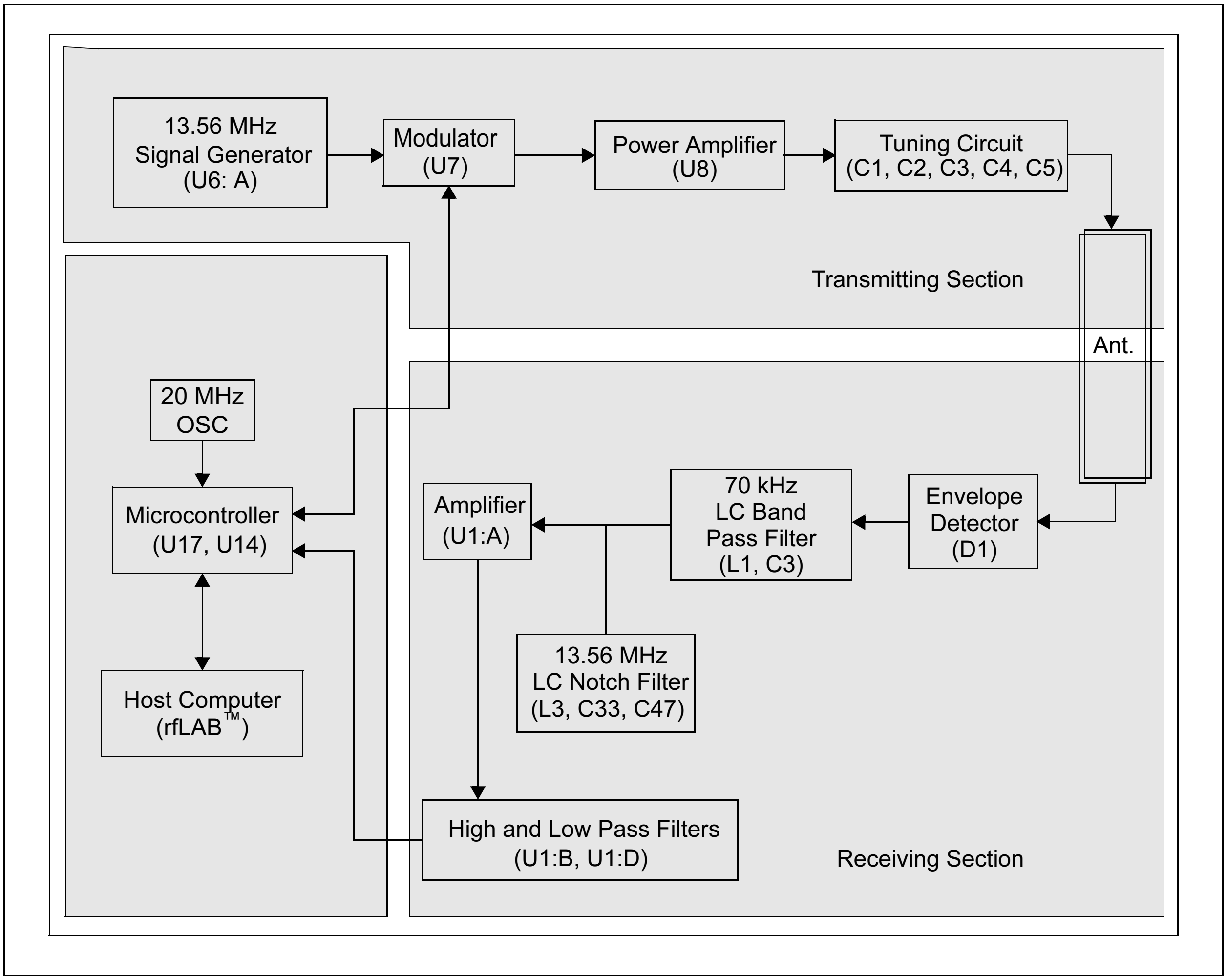


FIGURE 2-3: DATA SIGNAL WAVEFORMS FROM TAG

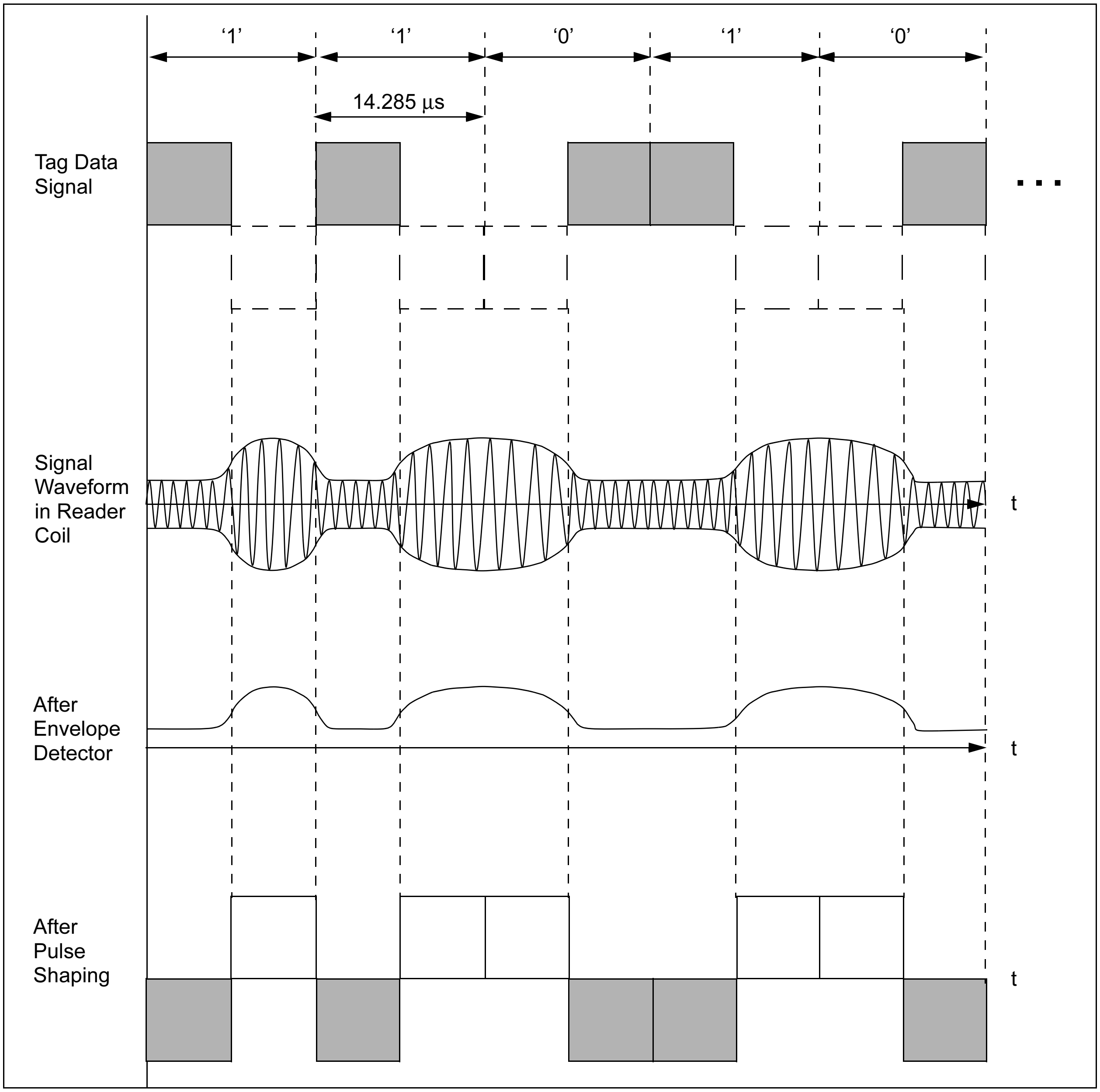
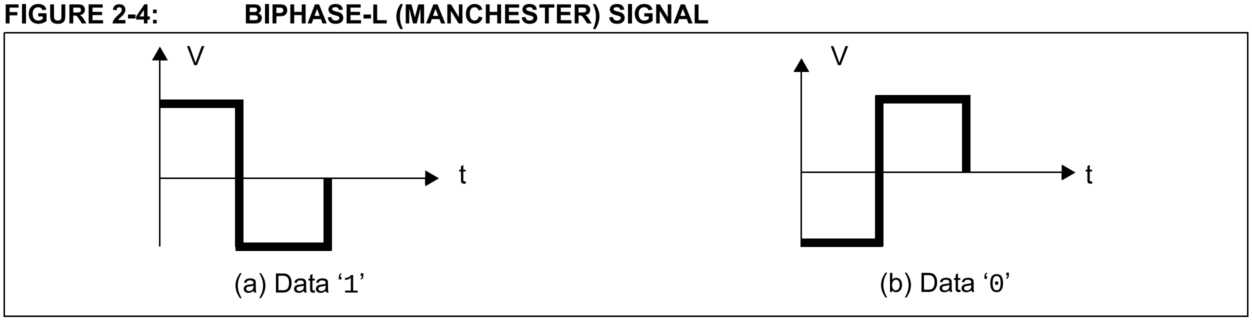
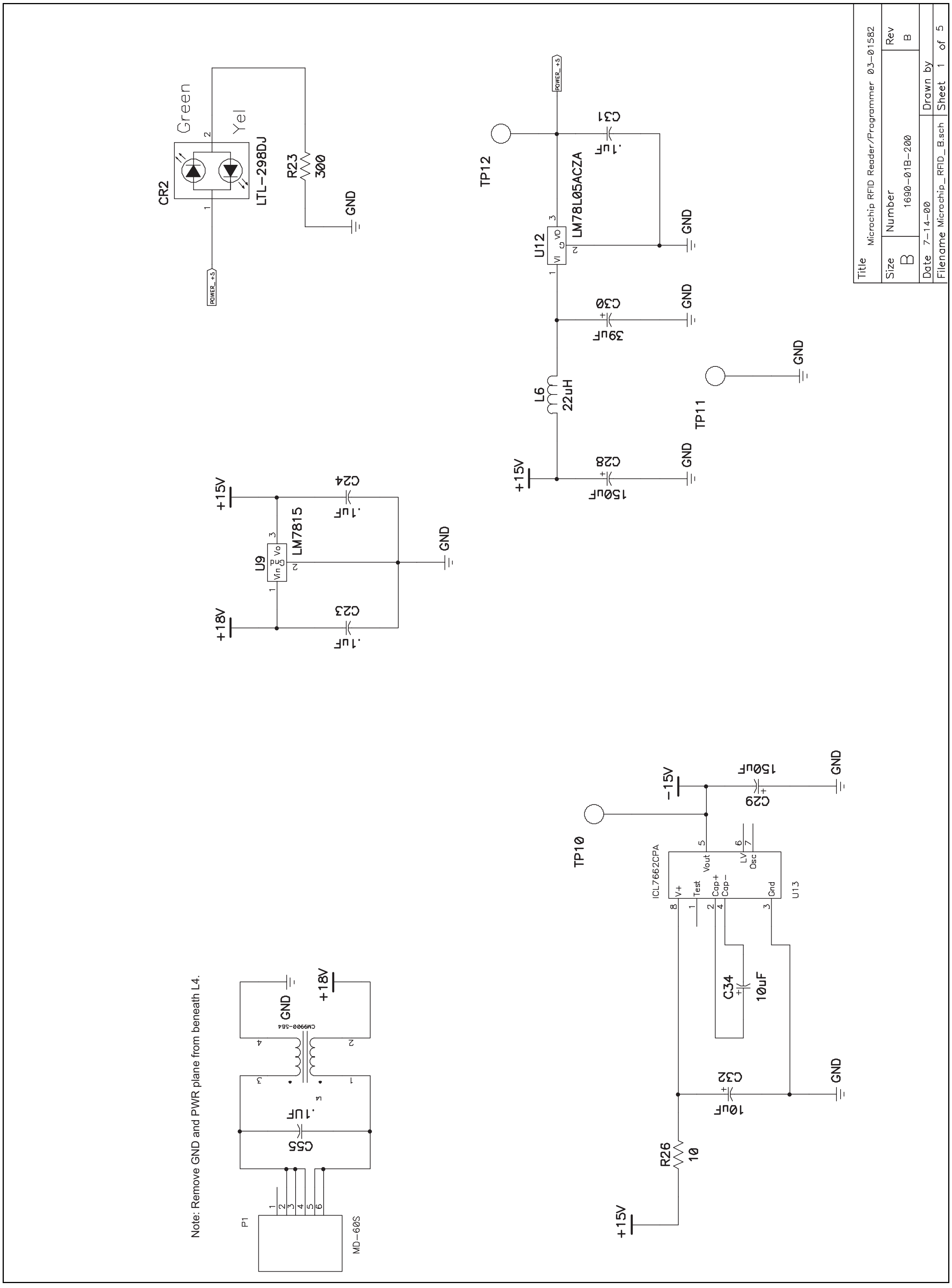


FIGURE 2-4: BIPHASE-L (MANCHESTER) SIGNAL

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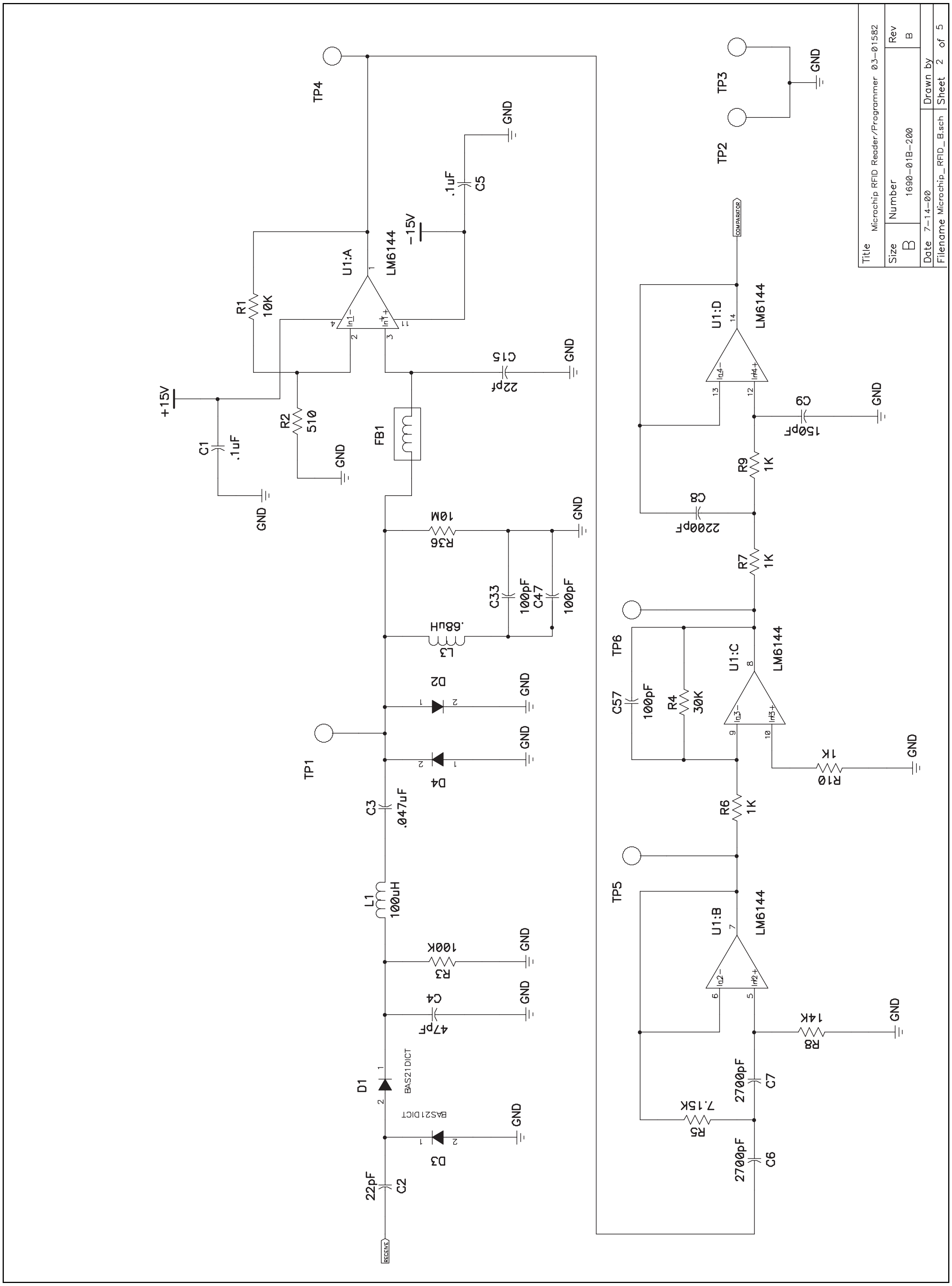
CR2
LTL-298DJ
Green
Yel
R23
300
GND
POWER_+5
U12
LM78L05ACZA
C31
.1uF
TP12
C30
39uF
L6
22uH
C28
150uF
+15V
TP11
U9
LM7815
C24
.1uF
C23
.1uF
+18V
TP10
-15V
C29
150uF
ICL7662CPA
U13
C34
10uF
C32
10uF
R26
10
Note: Remove GND and PWR plane from beneath L4.
P1
MD-60S
C55
.1uF
CM9900-584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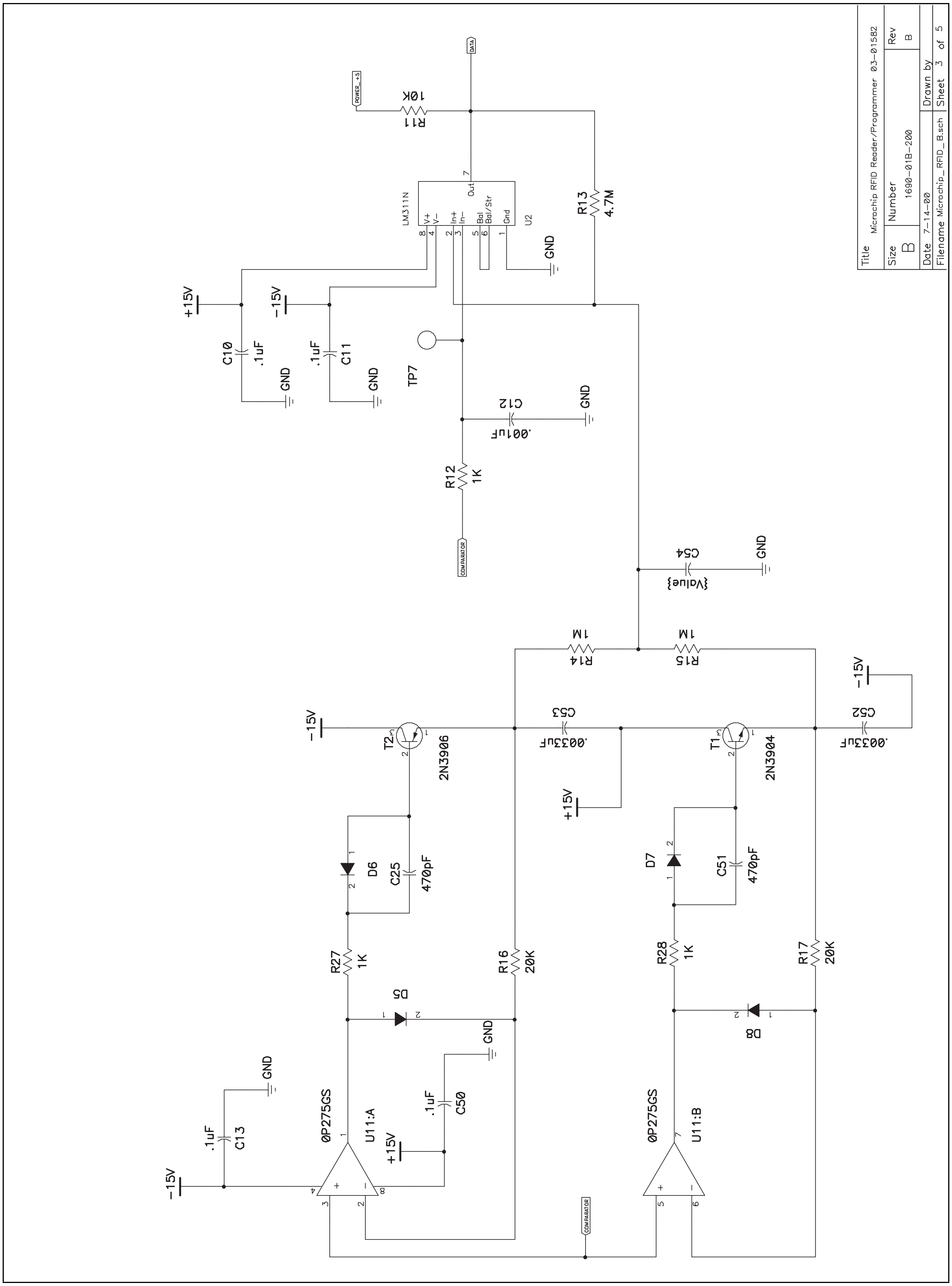
TP2
TP3
TP4
TP5
TP6
U1:A
U1:B
U1:C
U1:D
LM6144
+15V
-15V
GND
R1 10K
R2 510
R3 100K
R4 30K
R5 7.15K
R6 1K
R7 1K
R8 14K
R9 1K
R10 1K
R36 10M
C1 .1uF
C2 22pF
C3 .047uF
C4 47pF
C5 .1uF
C6 2700pF
C7 2700pF
C8 2200pF
C9 150pF
C15 22pf
C33 100pF
C47 100pF
C57 100pF
L1 100uH
L3 .68uH
FB1
D1
D2
D3
D4
BAS21DICT
RECEIVE
COMPARATOR



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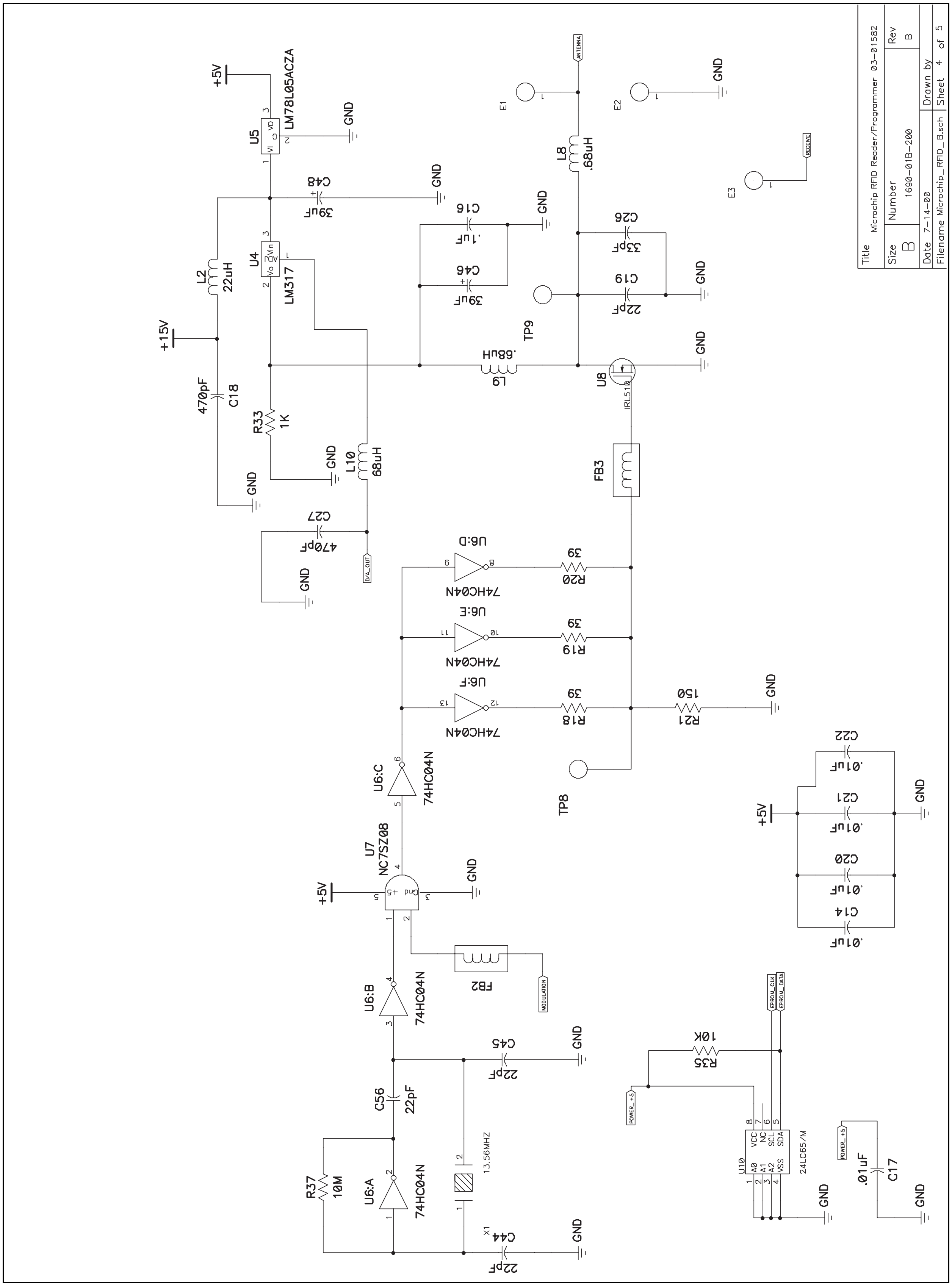
LM311N
U2
R13 4.7M
GND
+15V
-15V
C10 .1uF
C11 .1uF
TP7
C12 .001uF
R12 1K
COMPARATOR
C54 {Value}
R14 1M
R15 1M
C53 .0033uF
C52 .0033uF
T2 2N3906
T1 2N3904
D6
C25 470pF
D7
C51 470pF
R27 1K
R16 20K
R28 1K
R17 20K
D5
D8
C50 .1uF
C13 .1uF
OP275GS
U11:A
U11:B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C48
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+15V
L2
22uH
U4
LM317
C18
470pF
R33
1K
L10
68uH
C27
470pF
C16
.1uF
C46
39uF
L9
.68uH
TP9
ANTENNA
E1
E2
E3
RECEIVE
L8
.68uH
C26
33pF
C19
22pF
U8
IRL510
FB3
D/A_OUT
U6:D
U6:E
U6:F
74HC04N
R20
R19
R18
39
R21
150
TP8
U6:C
U7
NC7SZ08
C22
C21
C20
C14
.01uF
FB2
MODULATION
U6:B
C45
22pF
C56
22pF
R37
10M
U6:A
X1
13.56MHZ
C44
22pF
R35
10K
EPROM_CLK
EPROM_DATA
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24LC65/M
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NC
SCL
SDA
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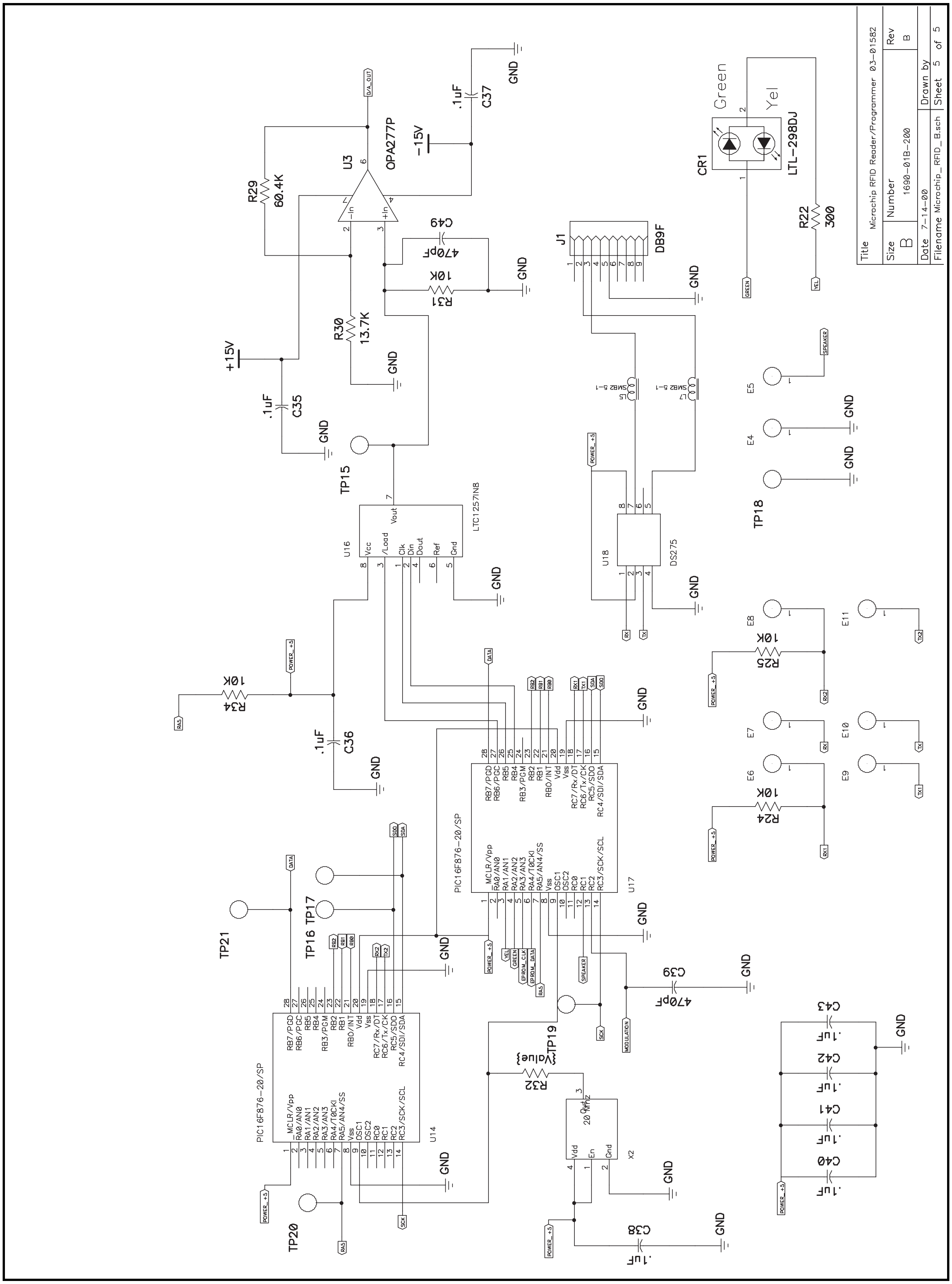
A1
A2
VSS
C17
.01uF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U14
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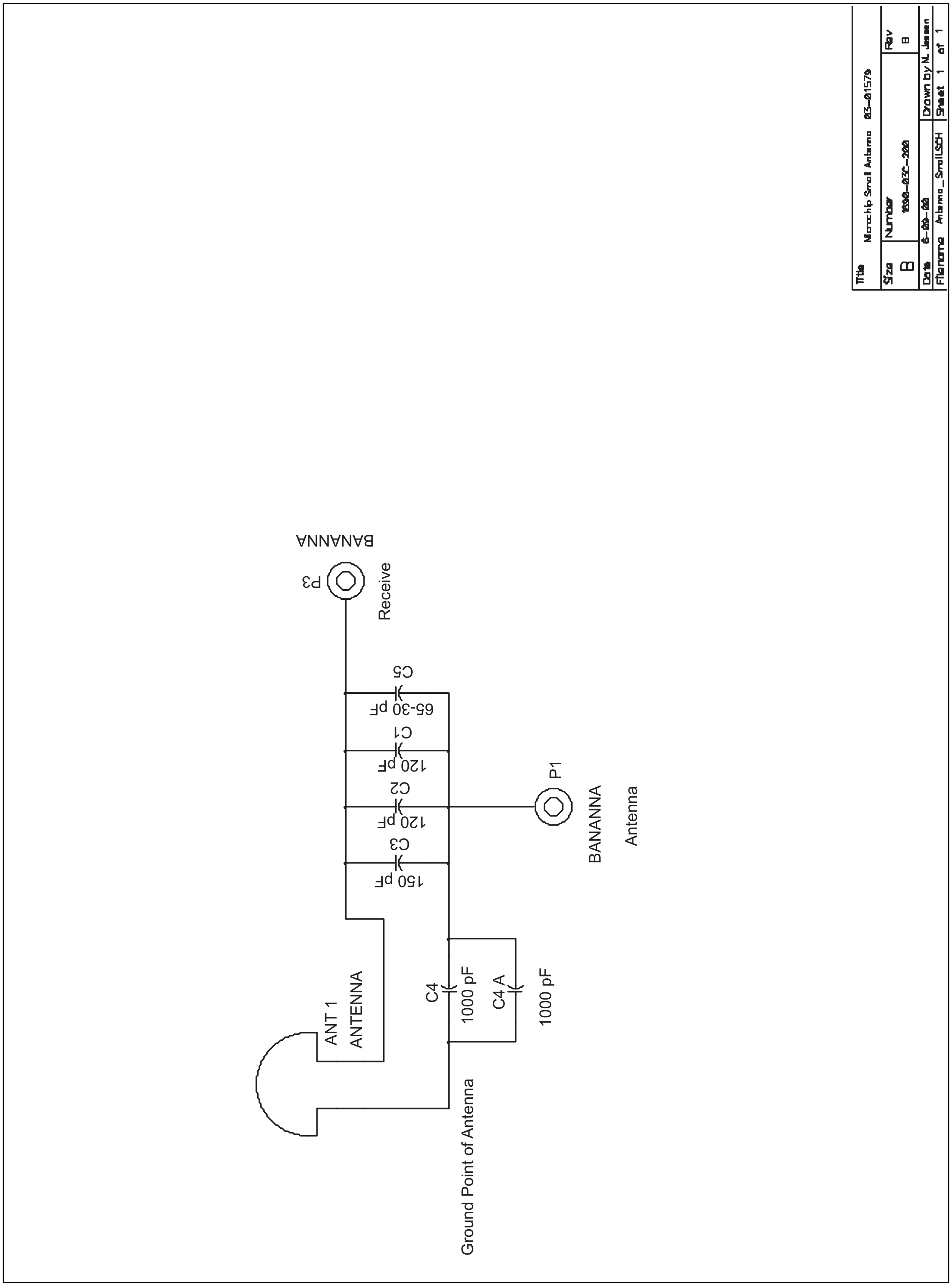
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C1
120 pF
C2
120 pF
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150 pF
P1
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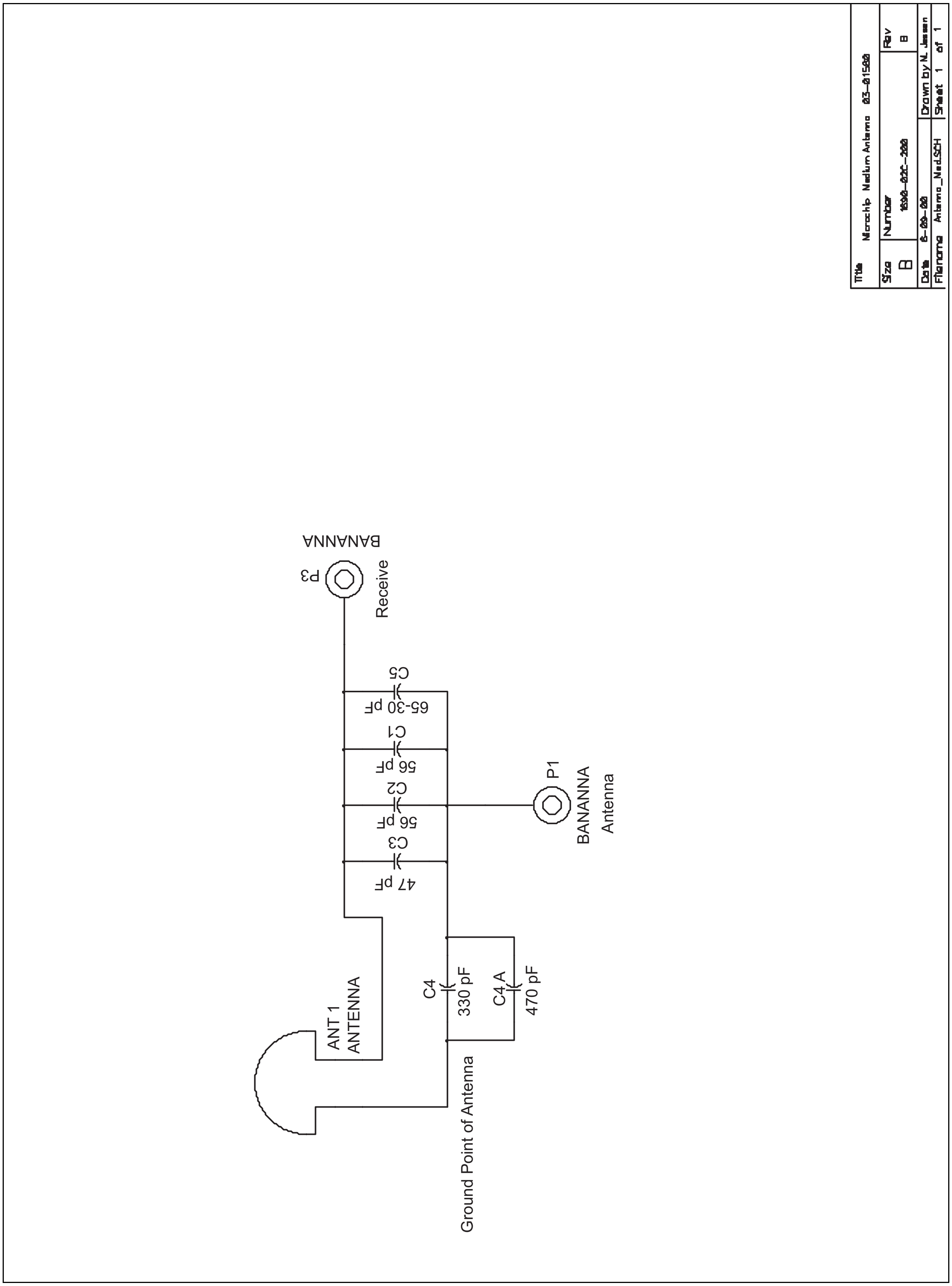
C4
1000 pF
C4 A
1000 pF
Ground Point of Antenna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Antenna
ANT 1
ANTENNA
C4
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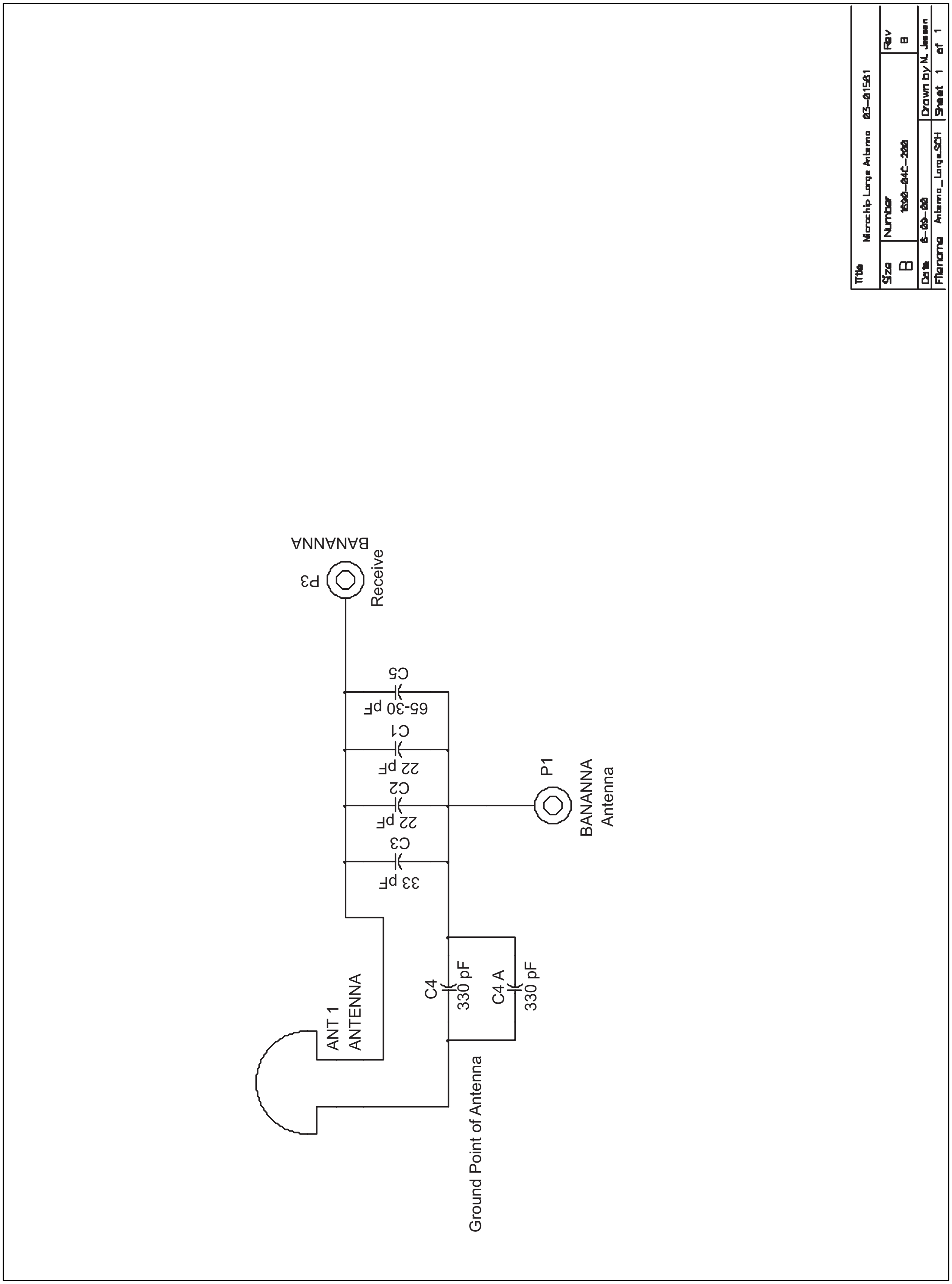
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C5
65-30 pF
C1
22 pF
C2
22 pF
C3
33 pF
P1
BANANNA
Antenna
ANT 1
ANTENNA
C4
330 pF
C4 A
330 pF
Ground Point of Antenna

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