TADD-2 Assembly and Operation Manual

RF to PPS Divider

Revised: 23 June 2023

Introduction

The TADD-2 is a frequency divider that accepts a 5 or 10 MHz input signal and generates pulse-per-second ("PPS") and other low rate digital outputs. Its primary purpose is to provide a low-jitter PPS output from a frequency standard; this PPS signal can be used for various timing measurements.

The TADD-2 is designed to be very versatile and offer flexibility in use. The six outputs are low impedance sources capable of driving coax lines with at least 3 volts into a 50 ohm load. The input and outputs use BNC connectors. Each output can be individually set to pulse rates of 10 KPPS, 1 KPPS, 100 PPS, 10 PPS or 1 PPS, all with 20% duty cycle, or to a 10% duty cycle PPS rate. The polarity of each output can also be set to normal (transition low-to-high) or inverted (transition high-to-low). There is a seventh true TTL output available via pads on the board.

The divider can be synchronized to an external signal (for example, to sync it to the PPS signal from a GPS receiver). Three LEDs indicate sync status as well as PPS activity.

The TADD-2 includes fused and reverse-polarity protected 5 and 10 volt regulators. The supply voltage can range from 12 to 24 volts. Current drain will depend on the output loads, but is typically in the range of 60 to 150 milliamps.

See the "Performance" section for further details.

Circuit Description

DC input drives voltage regulator IC1 that provides 5 volts to operate the digital portion of the circuit. It also drives IC3 which produces 10 volts to operate the input conditioning circuit. Fuse F1 is a 0.5A board-mouned picofuse and diode D1 is a transient suppresor.

BNC jack J1 accepts a 5 or 10 MHz input signal which is DC isolated by T1 and C6. Setting jumper JP7 establishes a 50 ohm RF termination and is recommended for most applications. The circuit following the transformer converts the input signal into a low-jitter square wave that can drive the PIC clock input. It is closely based on one published by Charles Wenzel.[1] with modifications suggested by Bruce Griffiths and Ulrich Bangert. The revised circuit works with inputs as low as -20dBm, although higher input levels provide more operating margin. It will tolerate input levels to at least +15 dBm.

The conditioned input signal is fed to IC4, a PIC16F630 controller that operates as a very low jitter divider providing multiple output frequencies: 1PPS with 100 ms pulse width, and 1 PPS, 10 PPS, 100 PPS, 1000 PPS and 10,000 PPS with 20% duty cycles. JP7 selects the input frequency of 5 MHz (default) or 10 MHz (jumper closed). If this is improperly set, the divider will run at either double or half speed.

The divider outputs go to headers JP8 – JP13 where jumpers select which rate is sent to each of the six output channels (channel 1 is set by JP8, channel 2 by JP9, etc.). Headers JP15 – JP20 set the output polarity -- "normal" is normally low output, going high on the leading edge of the pulse. "Inverted" is the opposite.

1 https://www.quanticwenzel.com/library/time-frequency-articles/waveform-conversion-part-i-sine-to-square/

John Miles, KE5FX, has noted that some crosstalk appears on an output channel if the other channel sharing the same 74AC04 output driver chip is set for a higher rate. For example, if channel 1 is set for 1 PPS and channel 2 for 1K PPS, there will be signs of the 1K pulse train on the PPS output. While this crosstalk is at a fairly low level, it can cause triggering problems with devices that have sensitive inputs. To avoid this, try to set each pair of channels (channels 1 and 2, 3 and 4, and 5 and 6) to the same rate.

The synchronization circuit works as follows. Momentarily shorting the two pins of the ARM connector (JP1) stops the PIC counter. Both the red ARM and green SYNC LEDs will illuminate. The rising edge of a TTL-level signal on SYNC input J1 will start the counter. The red LED will go out while the green LED stays illuminated. The pulse train on the output will now be synchronized to the SYNC pulse, within one or two clock cycles (*i.e.*, 100 or 200 nanoseconds at 10 MHz). The SYNC pulse polarity can be set via JP4. Once the counter is synchronized, the SYNC input may be removed.

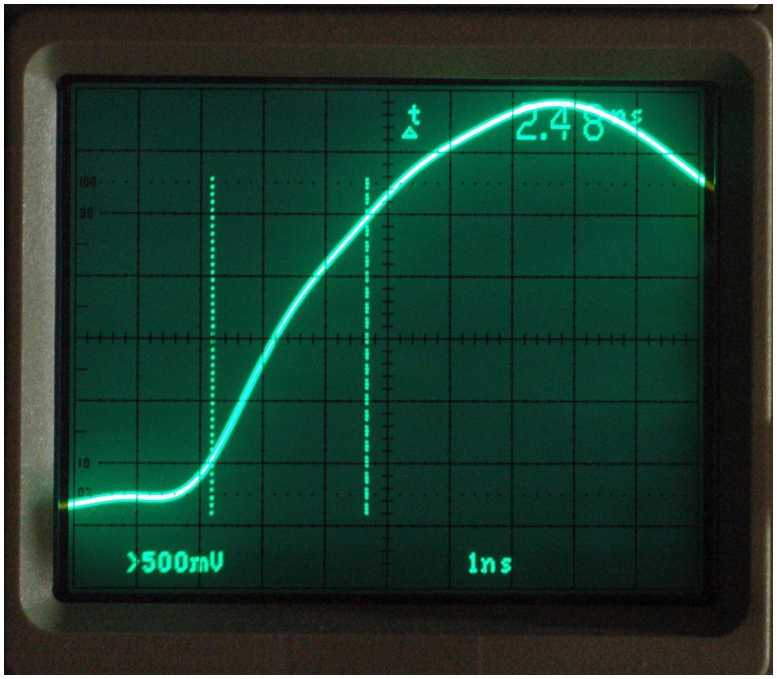
Typical Performance

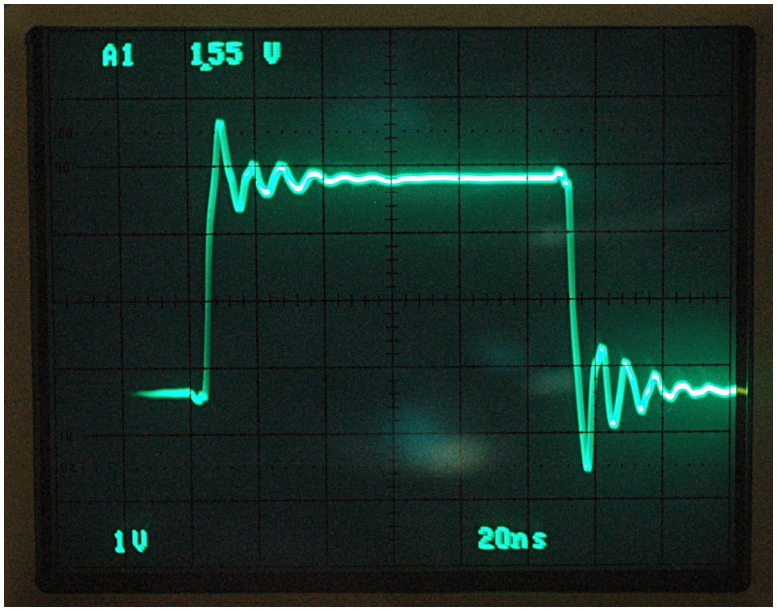
Current Drain

Approximately 65ma @ 13.8 volts, no input signal and no load. Current drain will vary significantly depending on the duty cycle of the input signal (and output signal, if inverted), and the output load. Maximum drain with all six outputs driving 50 ohms is under 250ma.

Output Waveform

(driving 50 ohm load)





Preparation

The TADD-2 kit includes the printed circuit board, one or two tubes containing ICs and sockets, a bag with eight BNC connectors, and several manila envelopes containing small components (the exact arrangement may vary depending on the mood of the guy stuffing the envelopes; please check all of them before assuming parts are missing!). Check to make sure your kit includes all these bits, and check the contents of the envelopes against the parts inventory below.

Refer to the layout diagram for clarification of parts placement. All references to up, down, left, and right assume that you are looking at the PCB with the "TADD-2" text and copyright notice along the right-hand side of the board. All components are mounted on the top of the PC board.

If you plan to mount the TADD-2 using the four corner holes, now is a good time to use the PC board as a template for marking the mounting holes in your enclosure.

Check your soldering iron to be sure the tip is in good condition. The tip should be the small conical tip type and must be clean. If you can't remember when you last replaced the tip, now would be a good time to do so.

All parts should be mounted as nearly flush to the board surface as practical without stressing the lead.

The installation sequence below is arranged logically by component type. You may find it easier to install the parts from lowest profile (e.g., resistors) to highest (e.g., electrolytic capacitors). In any case, don't install the ICs until the end.

Parts Inventory

OK?	QTY	NAME	VALUE	PART ID
	4	Capacitor, tantalum 12V	1.0uF	C1, C3, C17, C28
	8	Capacitor, mono	0.001uF	C2, C12, C16, C18, C19, C20, C21, C22
	2	Capacitor, tantalum 25V	0.33uF	C4, C8
	9	Capacitor, mono	0.1uF	C5, C10, C14, C15, C23, C24, C25, C26, C27
	4	Capacitor, mono	0.01uF	C6, C7, C9, C11
	1	Capacitor, electrolytic, 25V	10uF	C13
	1	Diode	SA15A TVS	D1
	1	PICOFUSE	0.5A	F1
	1	VOLTAGE REGULATOR	7805	IC1
	1	Schmitt Trigger	74AC14N	IC2
	1	VOLTAGE REGULATOR	78L10Z	IC3
	1	PIC	PIC16F8DIL	IC4
	5	Hex Inverter	74AC04N	IC5, IC6, IC7, IC8, IC9
	7	Socket, 14 pin DIL		
	8	BNC RA with washer and nut	AMP227161	J1, J2, J3, J4, J5, J6, J7, J8
	2	Polarized Power Connector	Molex	JP1, JP2
	2	Polarized Shell	Molex	
	4	Pin	Molex	
	7	3 Pin Header		JP4, JP15, JP16, JP17, JP18, JP19, JP20
	2	2 Pin Header		JP7, JP14
	6	12 pin (6x2) Header		JP8, JP9, JP10, JP11, JP12, JP13
	15	2 Pin Shorting Jumper		
	1	LED, Red		LED2
	2	LED, Green		LED1, LED3
	2	PNP Transistor	2N3906	Q1, Q2
	1	RESISTOR, American symbol	10K	R1
	1	RESISTOR, American symbol	120	R2
	1	RESISTOR, American symbol	51	R3
	7	RESISTOR, American symbol	100k	R4, R20, R21, R22, R23, R24, R25
	2	RESISTOR, American symbol	3.3k	R5, R11
	1	RESISTOR, American symbol	220	R6
	2	RESISTOR, American symbol	6.8k	R7, R10
	1	RESISTOR, American symbol	270	R8
	1	RESISTOR, American symbol	1	R9
	6	RESISTOR, American symbol	680K	R12, R13, R14, R15, R16, R17
	2	RESISTOR, American symbol	150	R18, R19
	6	SIL RESISTOR	47	RN1, RN2, RN3, RN4, RN5, RN6
	1	T1-1 Transformer	MCL	T1

Assembly Notes

Diodes
Diodes are polarity sensitive devices. The cathode end of the diode is banded and corresponds to the banded silk-screen legend on the PC board. If you have never worked with these devices, take a look at the photograph showing the banded ends.

Capacitors
Electrolytic and tantalum capacitors are polarized. The positive lead goes in the hole on the board marked with a "+". **NOTE: The orientation of the positive (+) leads are not all the same.** Be careful! The negative or the positive lead may be marked.

Headers and Molex Connectors
The plastic body of the male headers and Molex connectors should rest flush with the top surface of the PC board. Note that the short end of the pins go into the PC board, the long ends stick up.

WARNING! Do not hold these parts with your fingers while soldering. The pins get very hot. Place one of the shunts on the header to insulate your finger from the pins, hold the header in place and tack solder one pin. Check for proper alignment. If alignment is off, you can reheat the pin to adjust. Once alignment is complete, resolder the pins to ensure a good connection.

Connectors and Extra Holes
The two Molex polarized connectors are installed in JP1 (ARM) and JP2 (DC IN) so that the two pins face the edge of the board, with the plastic latch piece facing into the board.

Header JP5 is not normally installed on the board. It provides an extra PPS signal (positive going, 10% duty cycle) using a spare 74AC14 inverter gate. This signal may be used to drive TTL or CMOS loads.

Headers JP3 and JP6 are not normally installed on the board. They are in parallel with the DC power input and can be used to daisy-chain boards requiring the same voltage.

LED Brightness
The 220 ohm resistor driving LED 1, and the 150 ohm resistors driving LEDs 2 and 3, may be adjusted to change the LED brightness if desired. The resistors on LEDs 2 and 3 are smaller in value than expected because the of the limited current that the PIC chip can source.

Transformer Polarity
The dot on transformer T1 is on the same end as pin 1, and the transformer should be mounted so the dot is aligned with the notch in the silkscreen. However, this transformer is actually symmetrical, so no harm is done if it is mounted backwards.

Initial Test -- 1

Preliminaries

Errors take two forms, the kind that damage components and the kind that don't. Neither is desirable, but the type that damages components will require you to find a replacement part. Before connecting the board for the first time, check the following:

Ok	Procedure
	Polarity of the electrolytic capacitor. The negative lead is usually identified with a white stripe and a big minus sign on it. The positive lead is identified on the PC board.
	Polarity of the tantalum capacitors. The positive lead is usually identified with a red line and plus signs.
	Polarity of diode D1. The band on the diode should align with the extra stripe on the PC board silkscreen.
	The orientation of the integrated circuits with pin 1 correctly oriented to the dot, notch or bevel outline on the PC board.

Be Alert! Observe anything unusual such as components heating up, smoke or smell. If anything unusual appears, immediately turn off the power. Find and correct all problems before continuing.

Ok	Procedure
	Place the ground lead of your meter on the anode (opposite the banded end) of D1. This is ground reference for all measurements.
	With the meter set to read ohms, check pins 1 and 3 of IC1. These may show a low resistance initially because of charging effects, but after a few seconds the resistance at pin 1 should be greater than 10kohms, and at pin 3 greater than 500 ohms. If either shows a very low resistance, check your work for short circuits.

Integrated Circuit Installation -- 1

Integrated circuits are polarity sensitive devices. The small notch in the body is on the end with pins 1 and 8. Make sure the notch on the component matches the one on the silkscreen!

Ok	Procedure
	Install a 7805 voltage regulator IC at IC1. The regulator can be mounted either flat on the board, or standing vertically, depending on the space available in your configuration. The heat sink tab should face the bottom or the back of the board.
	Install a 78L10 voltage regulator at IC3.

Initial Test -- 2

Ok	Procedure
	Place the ground lead of your voltmeter on the anode (opposite the banded end) of D1. This is ground reference for all measurements.
	Apply 13.8V power to JP2.
	Measure the voltage on the 5V bus by connecting the other lead of the meter to the cathode of D1. This should be 5 volts, ±0.25V. If not, fix the problem before proceeding.
	Measure the voltage on the 10V bus by touching the other lead of the meter to the left lead of R2 (when looking at the board from the RF Input connector side). This should be 10 volts, ±0.25V. If not, fix the problem before proceeding.
	If you have an ammeter, measure the current draw on the 12 volt input. It should be less than 15 ma. If it is significantly more, there is likely a short circuit.
	Remove power from the circuit.

Integrated Circuit Installation -- 2

Install IC 2 and IC 4 through IC 9. Integrated circuits are polarity sensitive devices. The small notch in the body is on the end with pin 1. Make sure the notch on the component matches the one on the silkscreen!

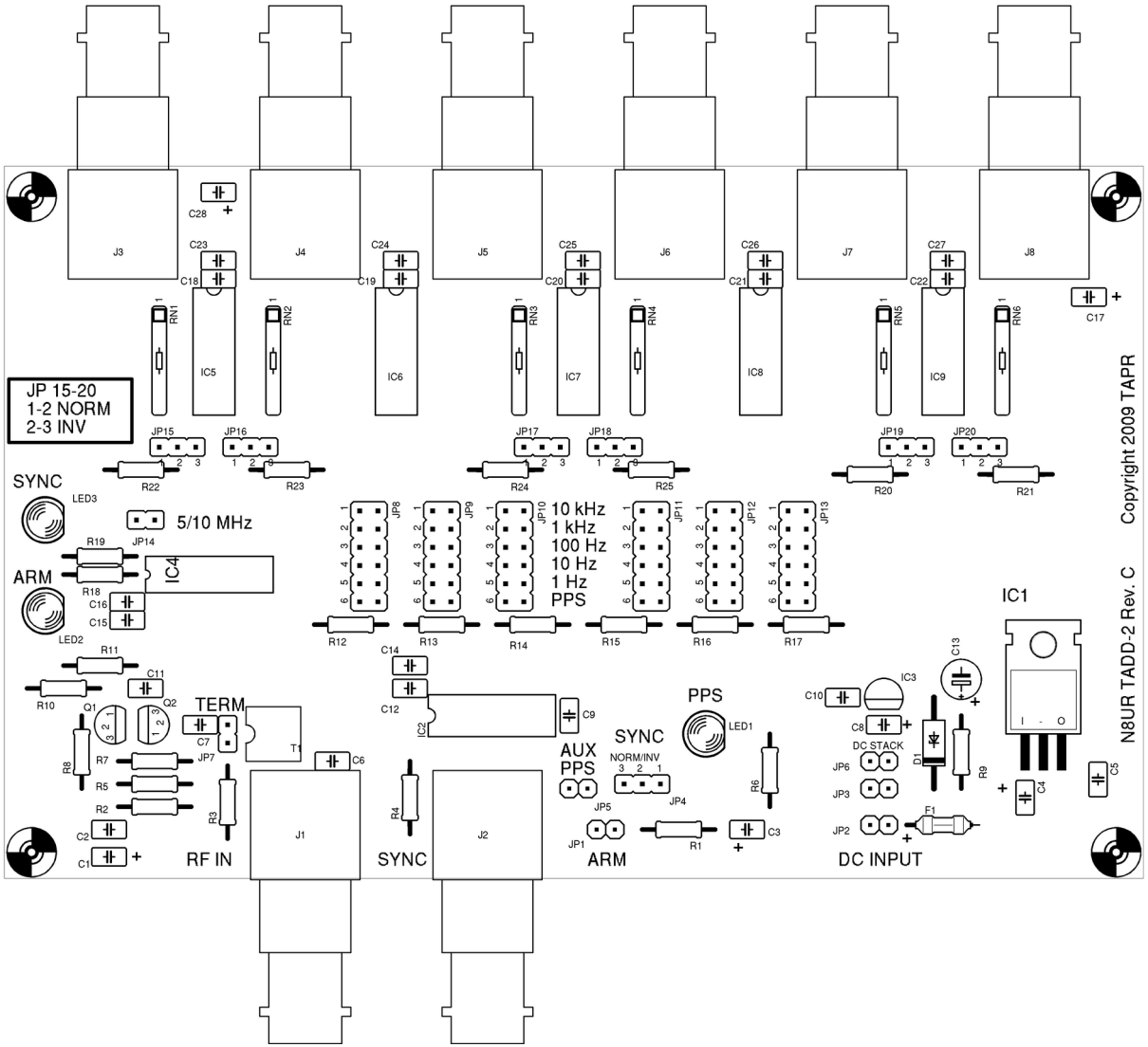
Initial Test -- 3

Ok	Procedure
	If you have an ammeter, connect it in series with the 12 volt power lead and make this test.
	Apply 13.8V power to JP2, preferably using a current-limited power supply set to limit at about 150ma.
	Measure the current draw. It should be about 35ma. If it is over 75ma, there is likely a short in the DC bus, or one or more high impedance IC inputs have been left floating.
	Remove power from the circuit.

Board Check

This completes assembly of the TADD-2. At this point, components, their location, and proper orientation should be double-checked. Soldering must be carefully inspected, preferably with a lit magnifier. If there are any suspicious solder connections, reflow the solder and check the result. Do this until you are satisfied that the board is OK. Finally, if the input frequency is to be 5 MHz, leave jumper JP14 open; if it is to be 10 MHz, put a shorting header across JP14. Unless the input signal level is too low to allow it, installing a shorting jumper at JP7 will provide a 50 ohm termination at the input, which may reduce reflection effects.

Ok	Procedure
	Board checked and OK.


J3
J4
J5
J6
J7
J8
C28
C23
C24
C25
C26
C27
C18
C19
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C21
C22
C17
RN1
RN2
RN3
RN4
RN5
RN6
IC5
IC6
IC7
IC8
IC9
JP 15-20
1-2 NORM
2-3 INV
JP15
JP16
JP17
JP18
JP19
JP20
R22
R23
R24
R25
R20
R21
SYNC
LED3
5/10 MHz
JP14
R19
ARM
R18
IC4
C16
C15
LED2
JP8
JP9
JP10
JP11
JP12
JP13
10 kHz
1 kHz
100 Hz
10 Hz
1 Hz
PPS
R12
R13
R14
R15
R16
R17
IC1
C14
C13
R11
C11
IC3
C10
R10
Q1
Q2
TERM
C12
C9
C8
IC2
PPS
LED1
SYNC
NORM/INV
DC STACK
C7
T1
AUX
PPS
JP7
JP6
D1
R9
C6
R8
R7
R5
R2
JP3
JP4
JP5
R6
C5
C4
F1
JP2
R4
R3
C2
C1
RF IN
J1
J2
SYNC
JP1
ARM
R1
C3
DC INPUT
I - O
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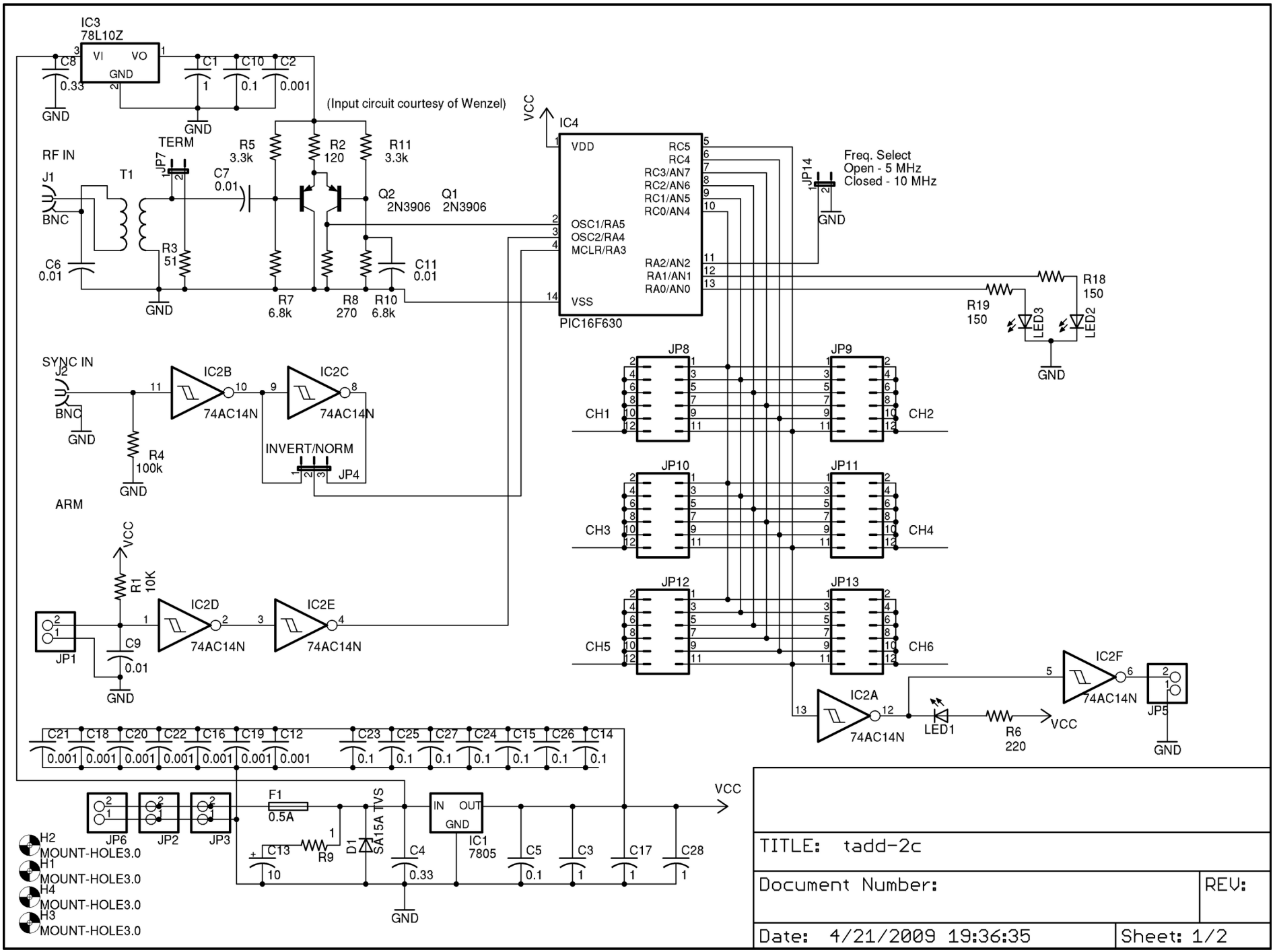
N8UR TADD-2 Rev. C


IC3
78L10Z
VI
VO
GND
C8
0.33
C1
1
C10
0.1
C2
0.001
(Input circuit courtesy of Wenzel)
VCC
IC4
RF IN
J1
BNC
T1
TERM
JP7
R5
3.3k
R2
120
R11
3.3k
C7
0.01
Q2
2N3906
Q1
2N3906
R3
51
C6
0.01
C11
0.01
R7
6.8k
R8
270
R10
6.8k
VDD
OSC1/RA5
OSC2/RA4
MCLR/RA3
VSS
RC5
RC4
RC3/AN7
RC2/AN6
RC1/AN5
RC0/AN4
RA2/AN2
RA1/AN1
RA0/AN0
PIC16F630
JP14
Freq. Select
Open - 5 MHz
Closed - 10 MHz
R18
150
R19
150
LED3
LED2
SYNC IN
J2
BNC
IC2B
74AC14N
IC2C
74AC14N
R4
100k
INVERT/NORM
JP4
ARM
R1
10K
IC2D
74AC14N
IC2E
74AC14N
JP1
C9
0.01
JP8
JP9
CH1
CH2
JP10
JP11
CH3
CH4
JP12
JP13
CH5
CH6
IC2A
74AC14N
LED1
R6
220
IC2F
74AC14N
JP5
C21 C18 C20 C22 C16 C19 C12
0.001 0.001 0.001 0.001 0.001 0.001 0.001
C23 C25 C27 C24 C15 C26 C14
0.1 0.1 0.1 0.1 0.1 0.1 0.1
JP6
JP2
JP3
F1
0.5A
D1
SA15A TVS
C13
10
R9
C4
0.33
IC1
7805
IN
OUT
C5
0.1
C3
1
C17
1
C28
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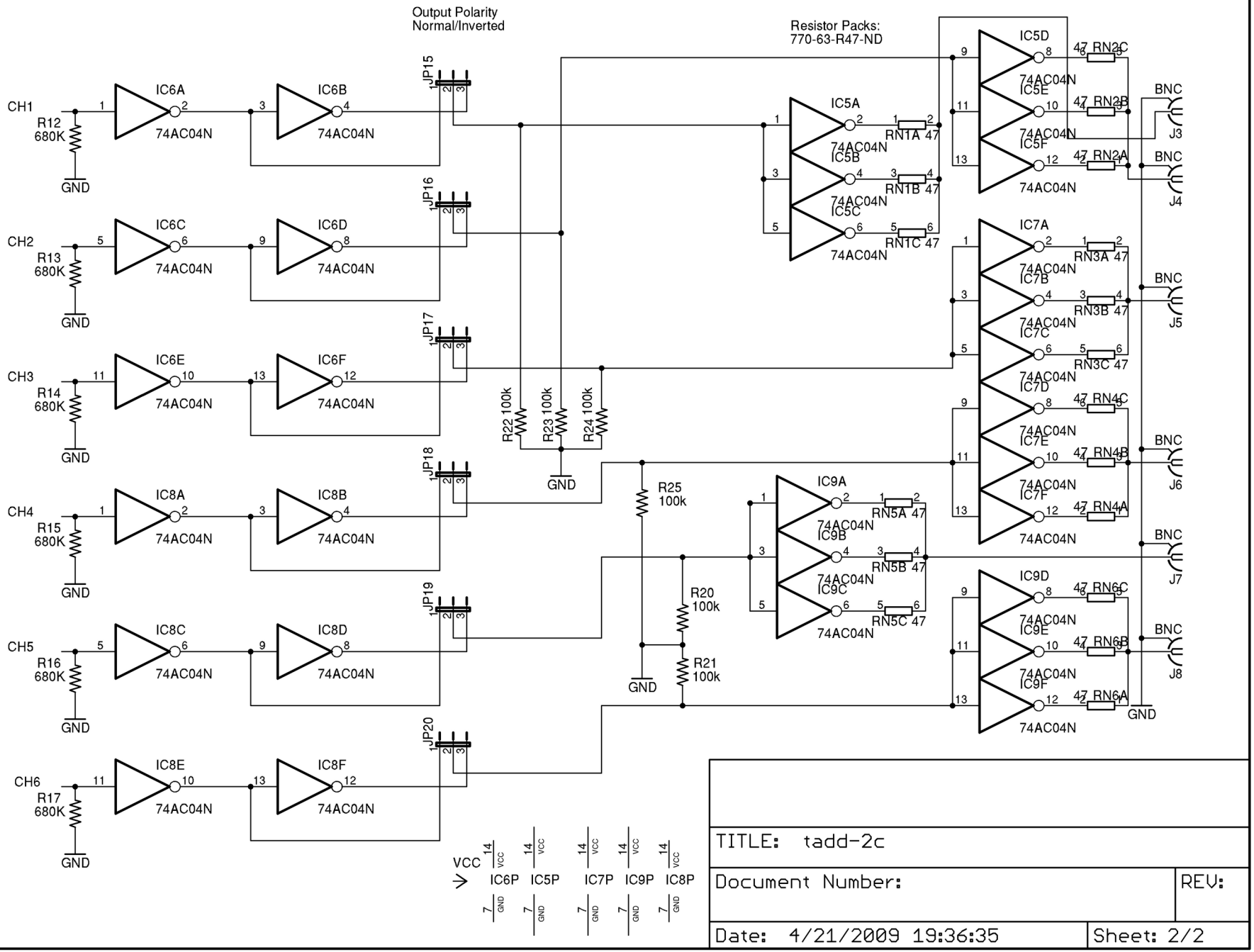
Output Polarity
Normal/Inverted
Resistor Packs:
770-63-R47-ND
CH1
CH2
CH3
CH4
CH5
CH6
R12 680K
R13 680K
R14 680K
R15 680K
R16 680K
R17 680K
GND
IC6A
IC6B
IC6C
IC6D
IC6E
IC6F
IC8A
IC8B
IC8C
IC8D
IC8E
IC8F
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JP17
JP18
JP19
JP20
R22 100k
R23 100k
R24 100k
R25 100k
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IC5D
IC5E
IC5F
IC7A
IC7B
IC7C
IC7D
IC7E
IC7F
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IC9B
IC9C
IC9D
IC9E
IC9F
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RN1B 47
RN1C 47
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RN4C 47
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