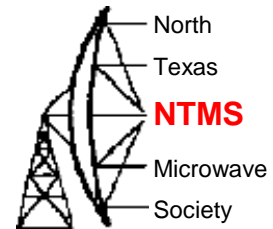
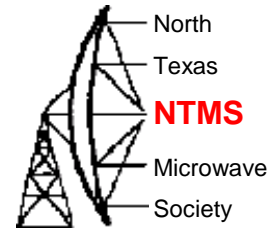


Wavelab 23 GHz ODU  
module and PA0MHE  
add on board  
Dec. 10, 2022

# Wavelab module



# Wavelab module



- According to Wavelab ODU brochure, frequency range is 21.2-23.6GHz but original PCB LO can't reach 21.2GHz. TR spacing is 1008 MHz

## 23X1008XP

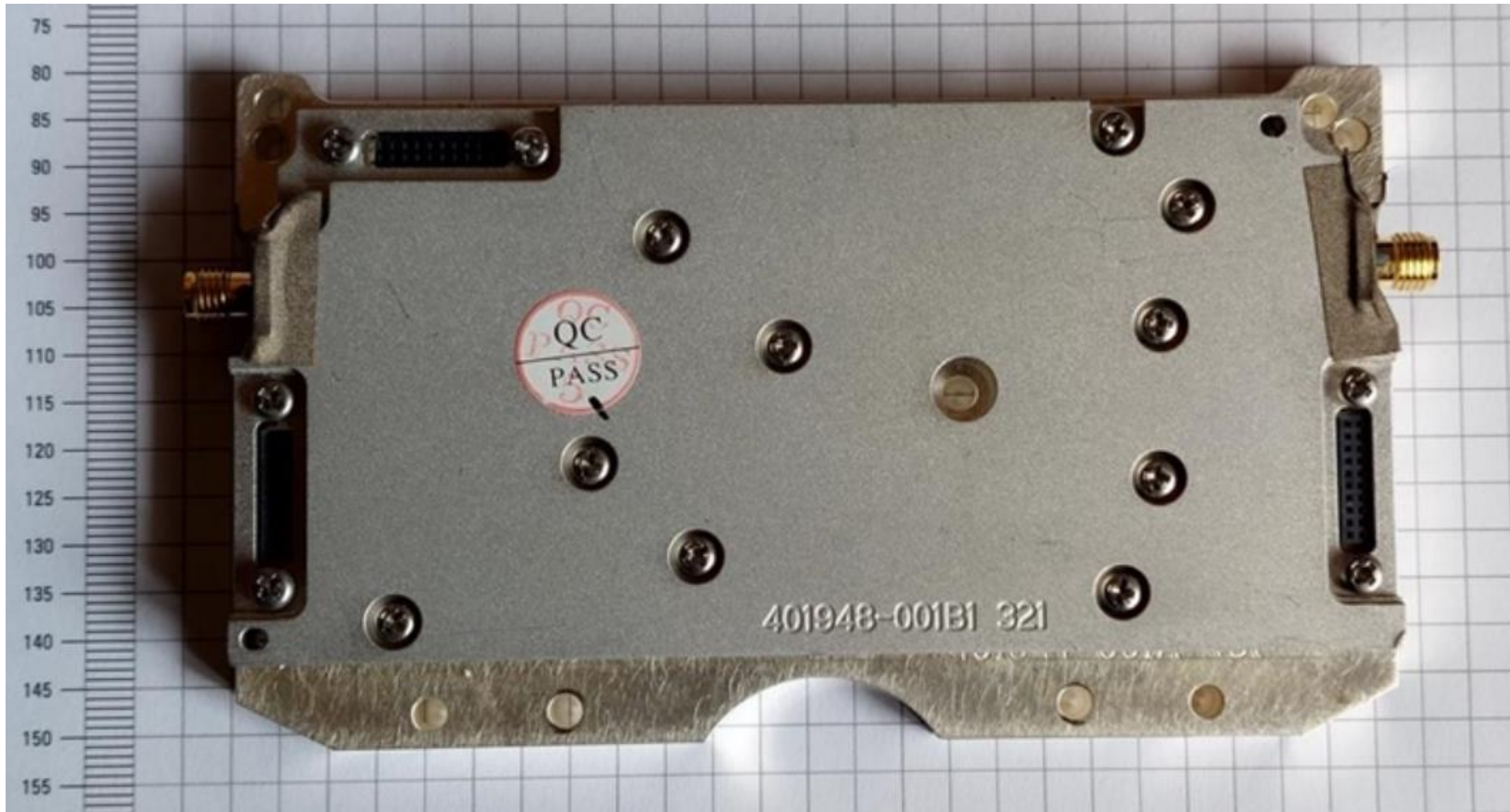
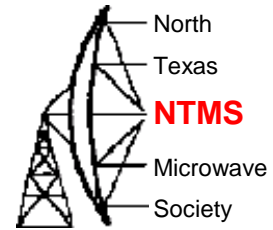
TR space 1008MHz (IF Tx 2364MHz-IF Rx 1356MHz); RX=LO+IF Rx; TX=LO+IF Tx; TX= RX+1008MHz  
 Motherboard ADF4153 PLL; VCO CRO1728T-LF; LO Range 1670-1770MHz

Frequency Band*	RX	TX	LO	LO/12 (input)
23.600GHz	22.592GHz	23.600GHz	21.236GHz	1769.66MHz

- The plan to put the module on USA terrestrial 24192 MHz

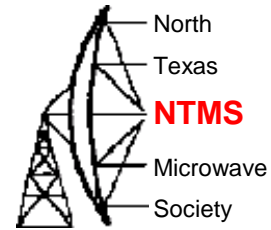
Synthesizer 1 ADF 1	1819 MHz	x 12 mult	21828 MHz	
Synthesizer 2 ADF 2	2220 MHz		2220 MHz	
			24048 MHz	
			144 MHz	IF
			24192 MHz	Final

# External view of module



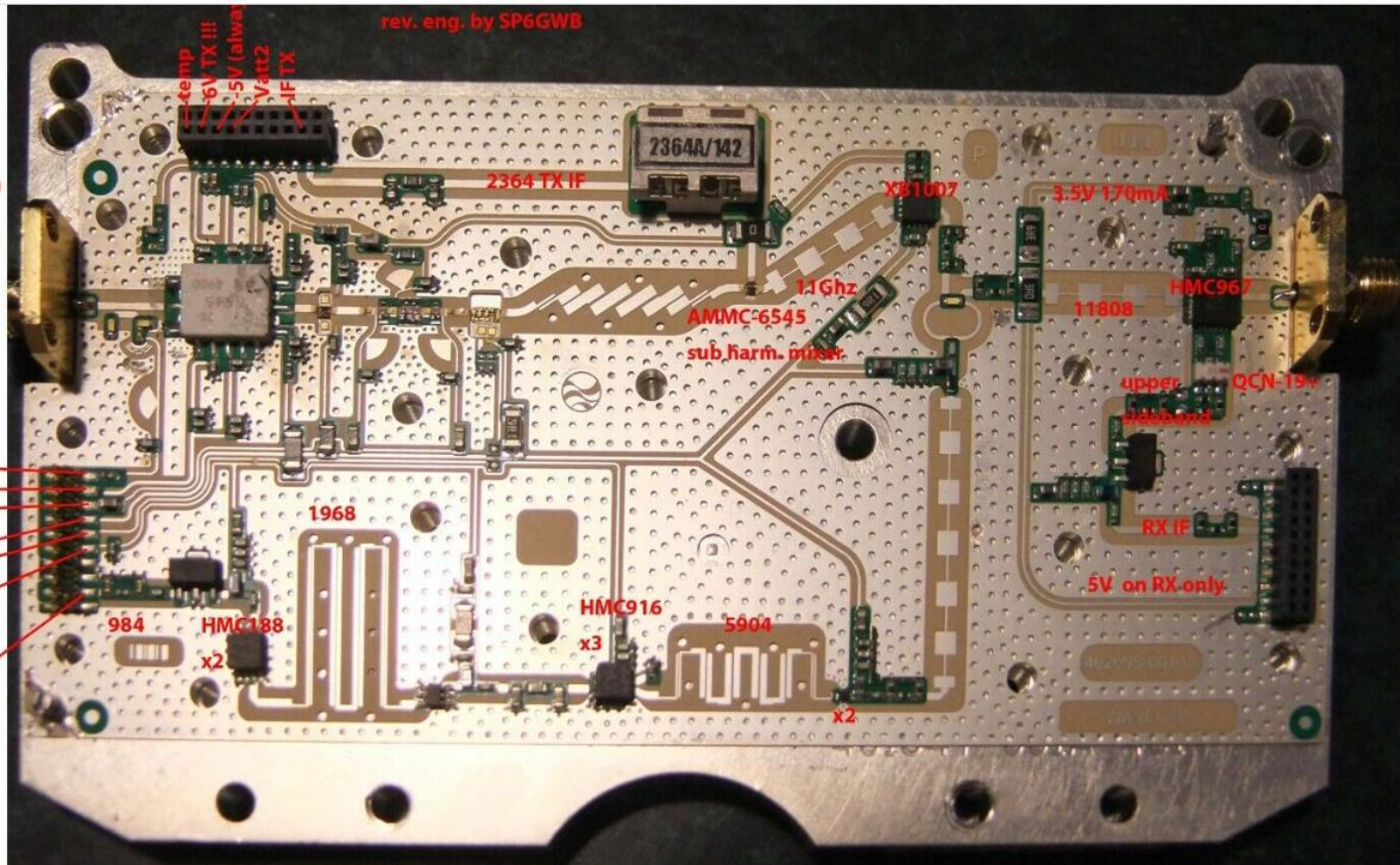


# Inside the module

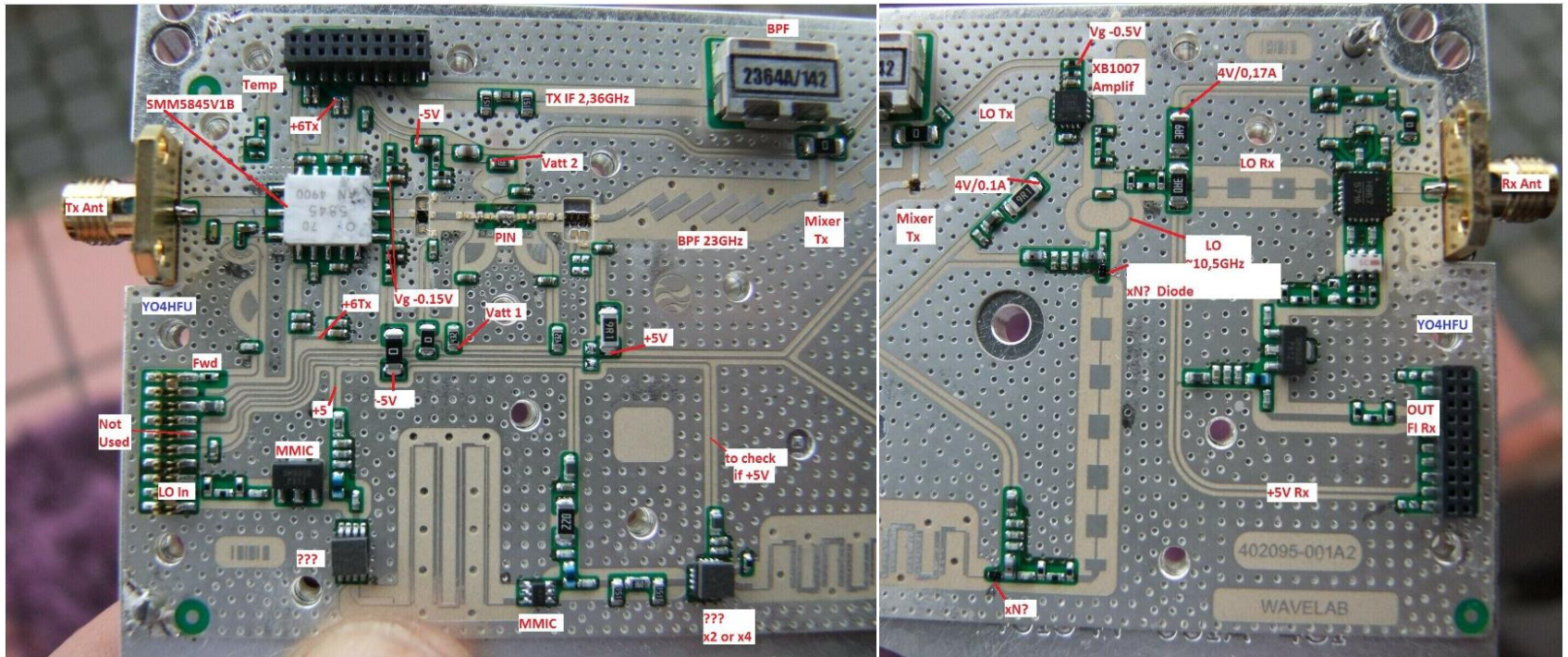
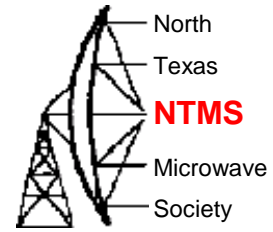


1. **NEGATIVE -5V voltage MUST be always present (also on RX)**
2. **6V and -5V on both connectors must be connected externally**
3. **TRY NOT TO OPEN it is hard to assemble**

- tx mon
- +6V TX !!! 1.4A
- Vatt1
- +5V TX&RX 400mA
- 5V (always)
- 5V TX&RX 275mA
- LO IN 5dbm min.

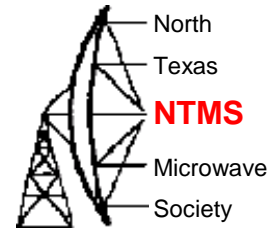


# Inside the module

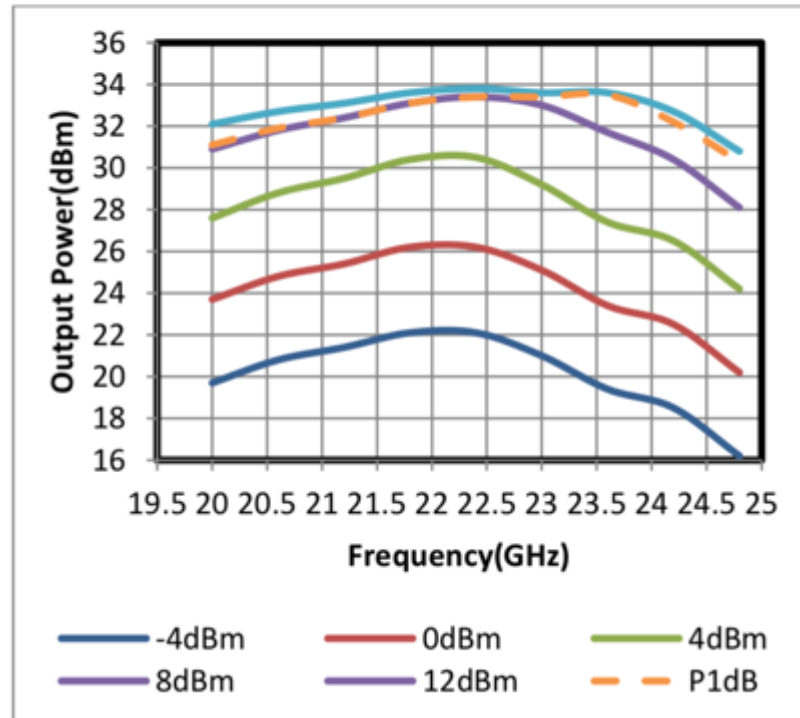




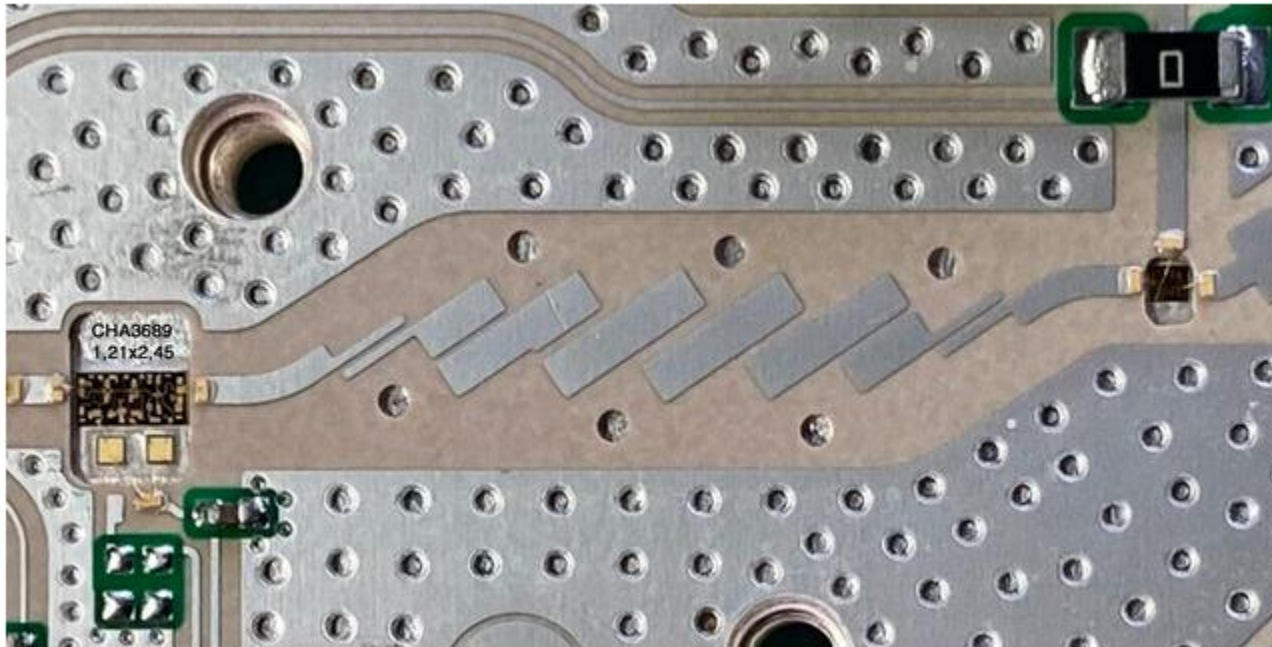
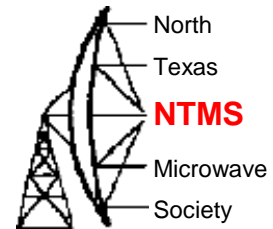
# SMM5845



**Output Power vs. Frequency**  
VDD=6V, IDD(DC)=1400mA



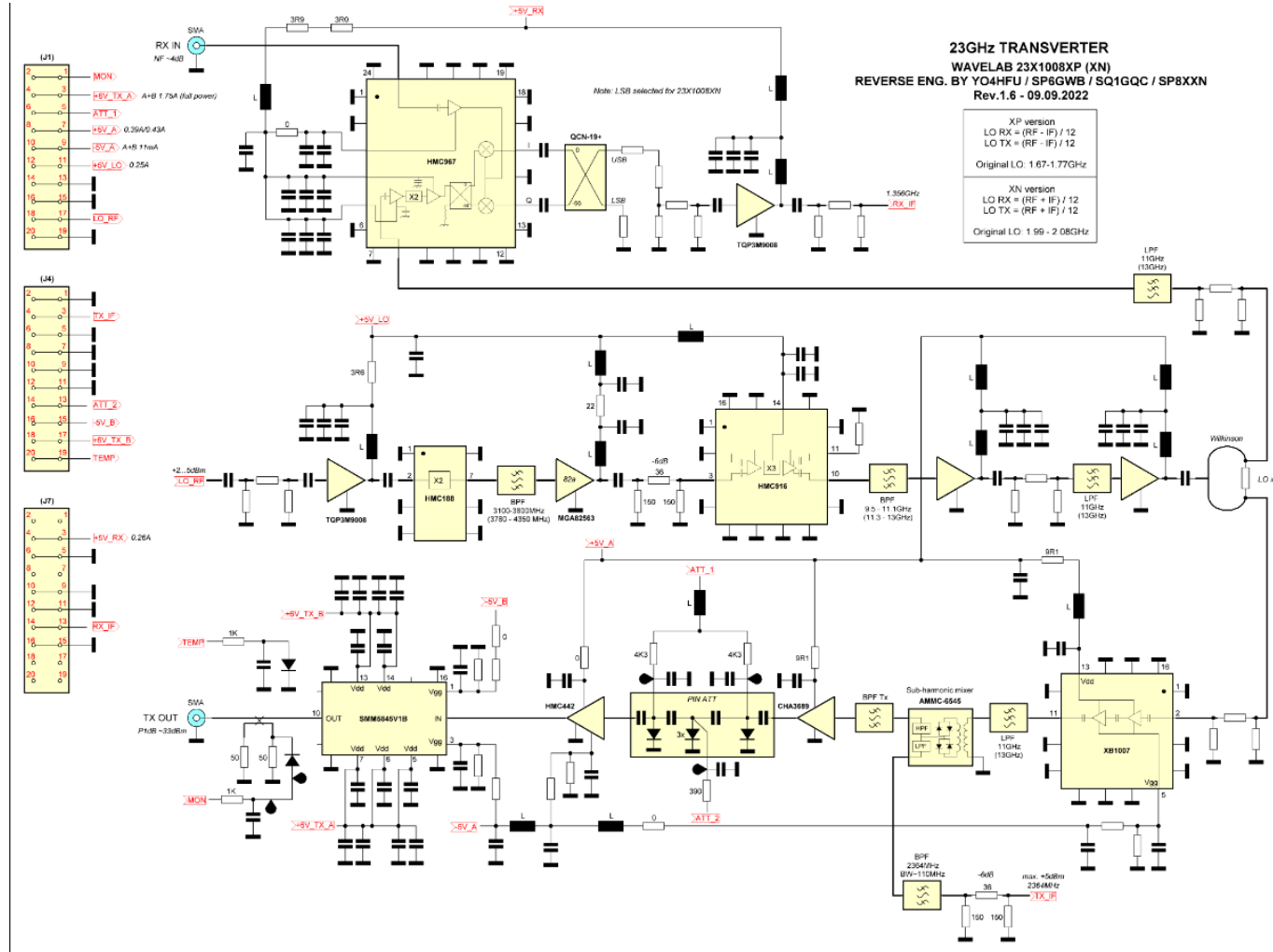
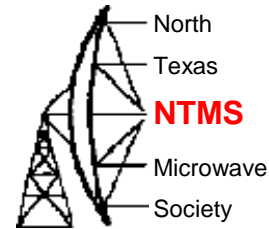
# Inside the module



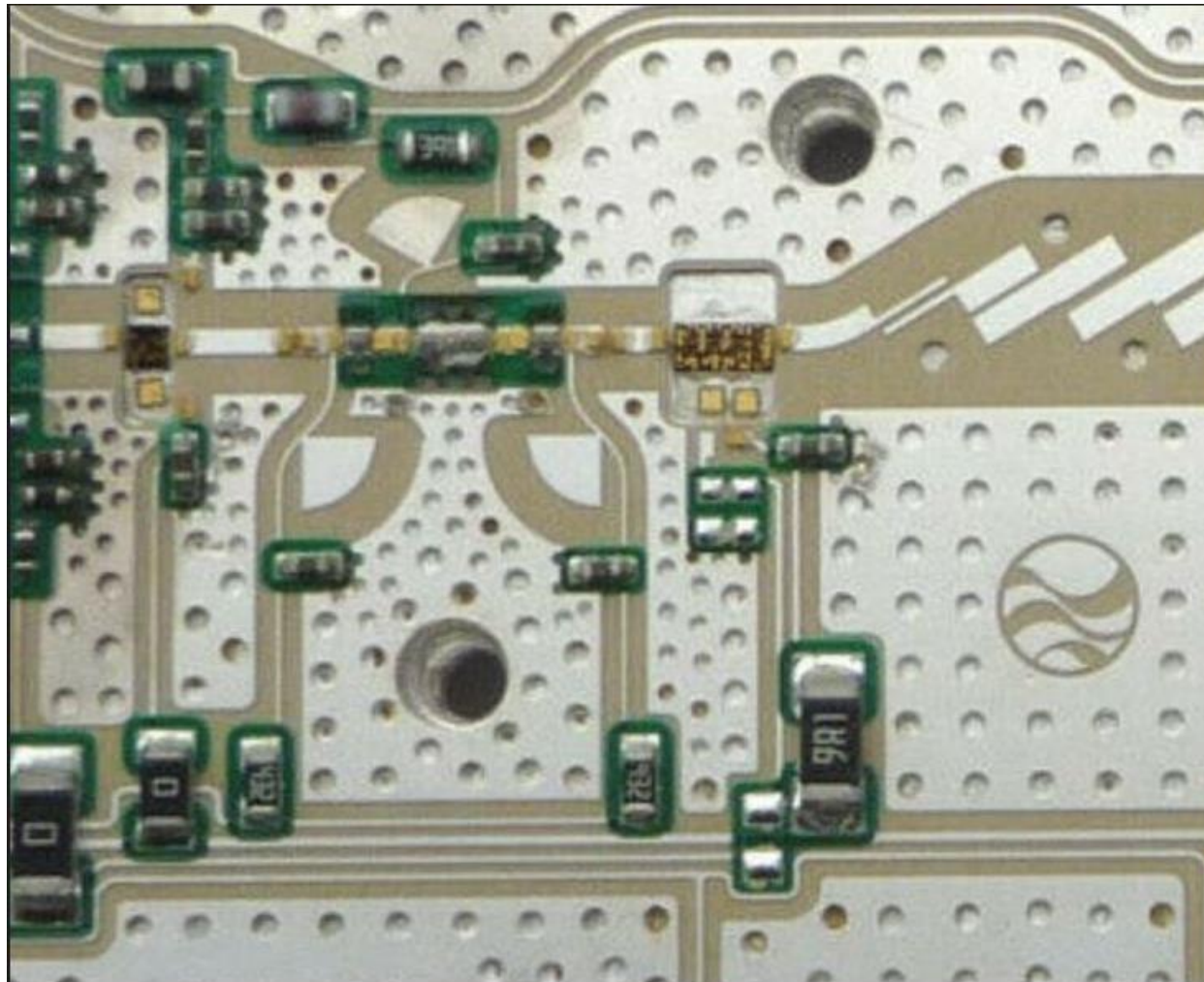
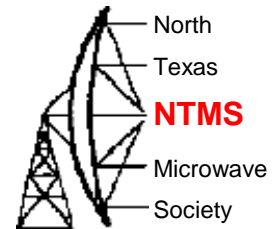
$12 \times 1700 + 2364 = 22764$		Ref
$12 \times 1633 + 2364 = 21960$	down 804	-3db
$12 \times 1774 + 2364 = 23652$	up 888	-3db
$12 \times 1807 + 2364 = 24048$	up 1284	-6db



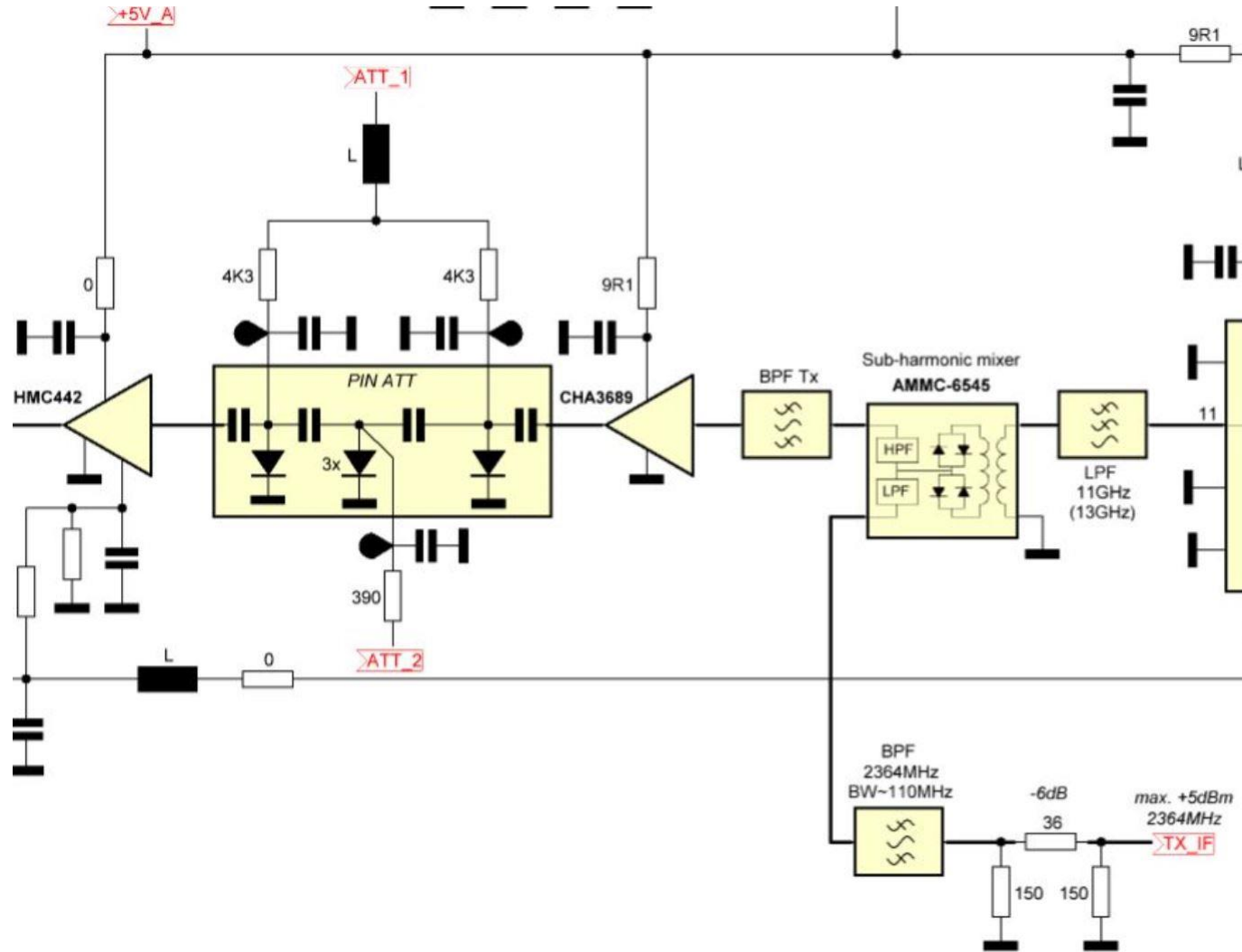
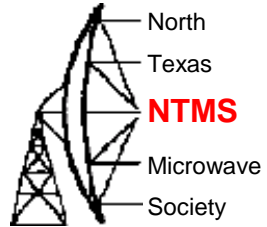
# Module schematic



# PIN attenuator

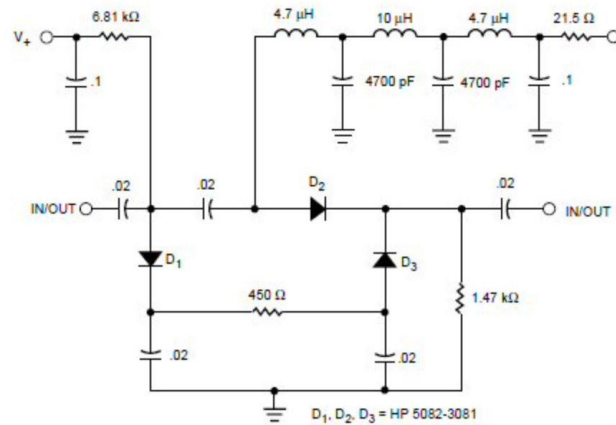
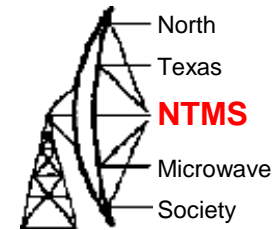


# Pin closeup





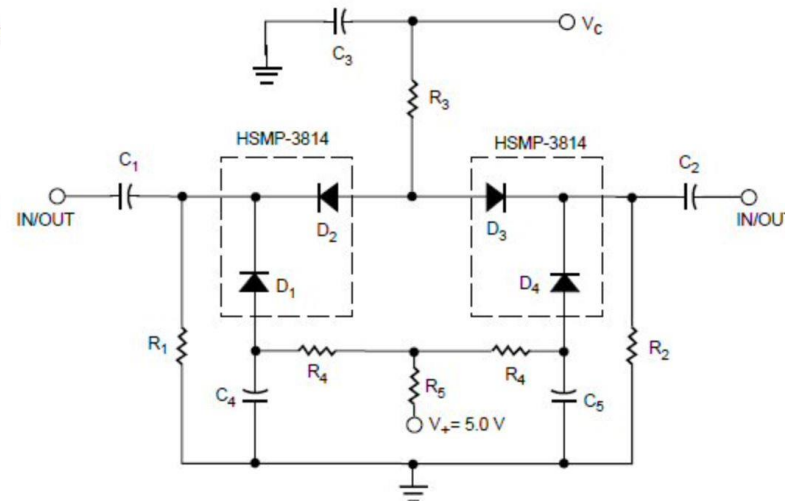
# PIN examples



Voltage-variable attenuator using PIN diodes prior to Waugh



Ulrich Rhode

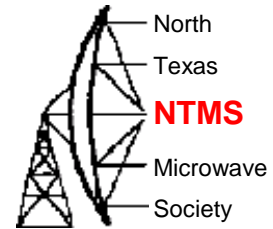


Waugh's attenuator



Ray Waugh

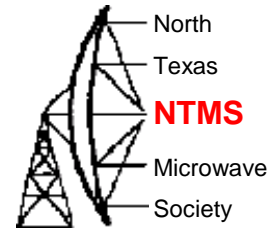
# NTMS Group order



Call	Name	Qty
KM5PO	Jim McMasters	2
KI5EMN	Paul Sarver	2
W5LUA	Al Ward	1
AA5AM	Scott Armstrong	1
WA5JAT	Jim Hudson	2
AB5SS	John Maca	1
AA9IL	Mike Kana	2
AF4JF	Herb Ullmann	2
K4CSO	Charles Osborne	2
N7JA	Jim Allyn	1
K6ML	Mike Lavelle	3
		19

Order placed with JLCPCB for 20 boards

# JLCPCB order



## Most Efficient, Economic, Innovative PCB Solutions

Founded in 2006, JLCPCB has been at the forefront of the PCB industry. With over 15-year continuous innovation and improvement based on customers' need, we have been growing fast, and becoming a leading global PCB manufacturer, who provides the rapid production of high-reliability and cost-effective PCBs and creates the best customer experience in the industry.

800,000<sup>+</sup>

Customers

20,000<sup>+</sup>

Orders Daily

450,000m<sup>2</sup>

Factory Area

620,000m<sup>2</sup>

Production Capacity/Month

6 Million<sup>+</sup>

PCBs Produced/Year

170<sup>+</sup>

Countries Covered

3000<sup>+</sup>

Employees

15

Years Founded

>99.97%

On-time delivery

<0.23%

Quality Complaint Rate

1 Day

PCB Prototype

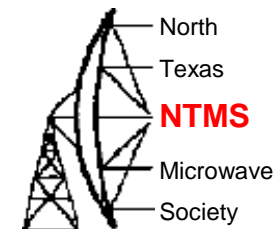
24/7

Online Service

\* As of January 2021

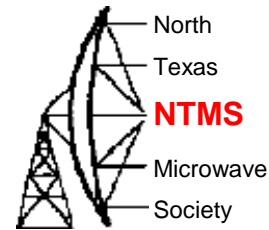


# JLCPCB order

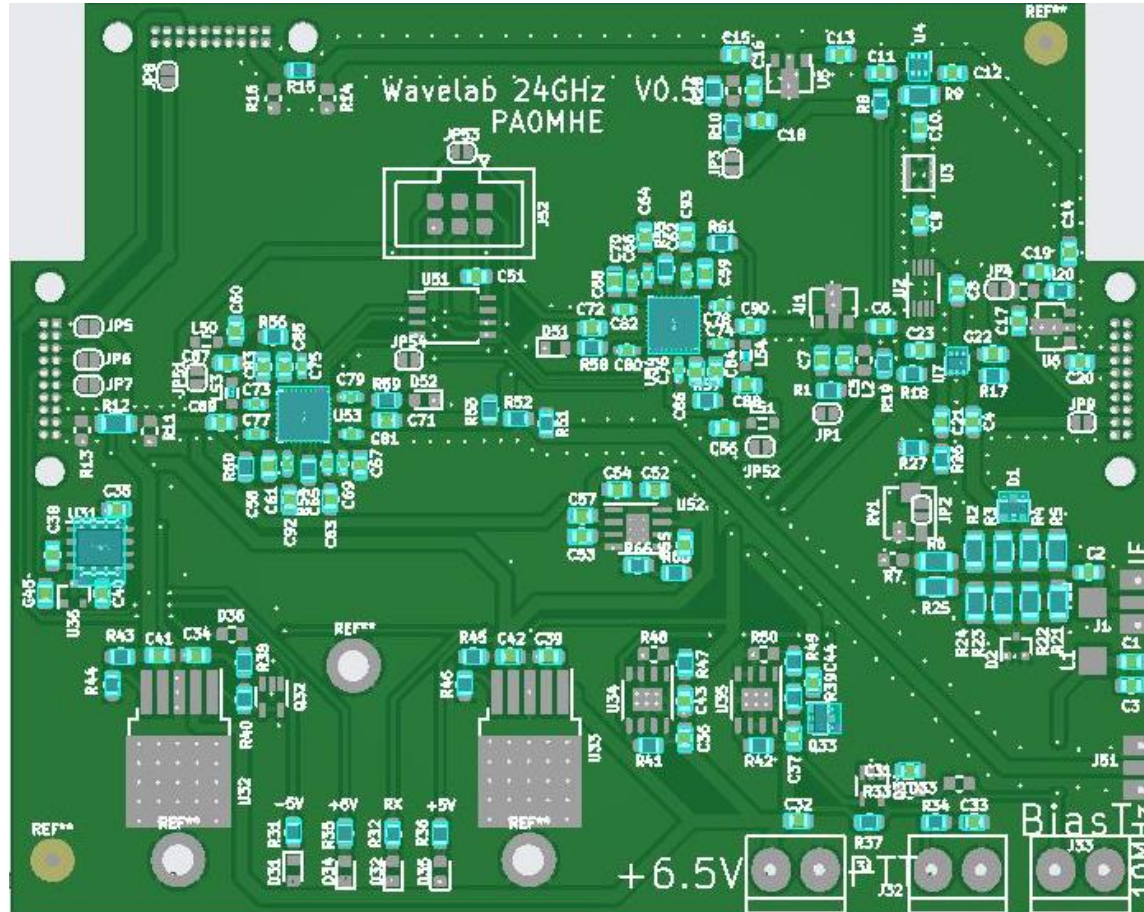


- Create an account on the website
- Upload the gerber, BOM, positions files
  - [Wavelab-24G-Addon-module/Kicad/V05 Kicad6/Wavelab24GHz\\_v05/production at main · PA0MHE/Wavelab-24G-Addon-module · GitHub](#)
- Review component placement and jlcpcb inventory shortages
  - Using search features you may find replacement parts
- Place the order

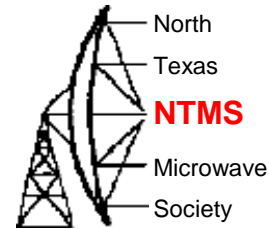
# JLCPCB order



Confirming parts placement via website image



# JLCPCB order



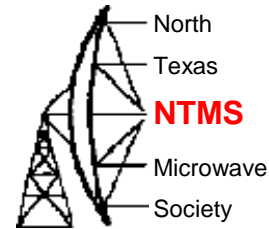
- Initial cost of PCBs was about a buck each.

The screenshot shows the JLCPCB website's 'Order History' page. The navigation bar includes 'Order History', 'File Manager', 'Parts Manager', 'Payments', 'Account Settings', and 'Messages'. Below the navigation is a search bar for 'Order #, Gerber file name...'. The main content area displays a table of orders with columns for 'Product Detail', 'Product File', 'Price', and 'Order Status'. Two orders are listed:






Product Detail	Product File	Price	Order Status
 PCB Prototype Order #: Y4-5139041A Build Time: 1-2 days 20 pcs \$20.80 <a href="#">Product Details</a>	gerber_Y4 Production Completed <a href="#">Quality Complaint</a>	Merchandise Total: \$755.89 Shipping Charge: \$26.87 Order Total: \$782.76	Shipped DHL Express Worldwide <a href="#">Shipment Tracking</a>
 Standard PCBA Order #: SMT0221113102520... Build Time: 2-3 days 20 pcs \$731.34 <a href="#">Product Details</a>	wavelab 24 GHz BOM.xlsx positions.csv <a href="#">DFM Analysis</a> Production Completed <a href="#">Quality Complaint</a>		



# JLCPCB order



- Shipment timeline. From payment to shipment < 6 days


 Submitted 2022-11-14 06:58	 Paid 2022-11-14 19:17	 Reviewed 2022-11-14 19:17	 In Production 2022-11-15 12:05	 Shipped 2022-11-20 13:13
--	---	--	--	--

**Shipped**

Tracking #: [1248274300](#)

DHL Express Worldwide

Photos of package:



2022/11/23 10:43:00 Shipment has departed from a DHL facility CINCINNATI HUB - USA,CINCINNATI HUB, OH - USA

2022/11/23 07:14:00 Clearance processing complete at CINCINNATI HUB - USA,CINCINNATI HUB, OH - USA

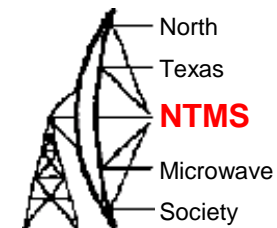
2022/11/23 06:31:00 Processed at CINCINNATI HUB - USA,CINCINNATI HUB, OH - USA

2022/11/23 05:21:00 Arrived at DHL Sort Facility CINCINNATI HUB - USA,CINCINNATI HUB, OH - USA

2022/11/22 21:40:00 Customs clearance status updated. Note - The Customs clearance process may start while the shipment is in transit to the destination.,CINCINNATI HUB, OH - USA

2022/11/22 14:15:00 Shipment has departed from a DHL facility HONG KONG - HONG KONG SAR, CHINA,HONG KONG - HONG KONG SAR, CHINA

# Add on board by PA0MHE



- Board provides:
  - +3.3v, +/- 5v, +6v power to add on board and module
  - LO / IF frequencies (programmable ATTINY for LO freqs)
  - Connections to pin attenuator
- Key components:
  - 2 x ADF4351 RF synthesizers and ATTINY
  - Mixer 1.5-4.5 GHz
  - 800 ma 3.3v regulator
  - 3 x DC-6 GHz 3.9 db NF, 21 db gain MMICs
- Support:
  - NTMS Group PCB order
  - Wavelab groupsio - [Wavelab24GHz@groups.io](mailto:Wavelab24GHz@groups.io) | [Home](#)

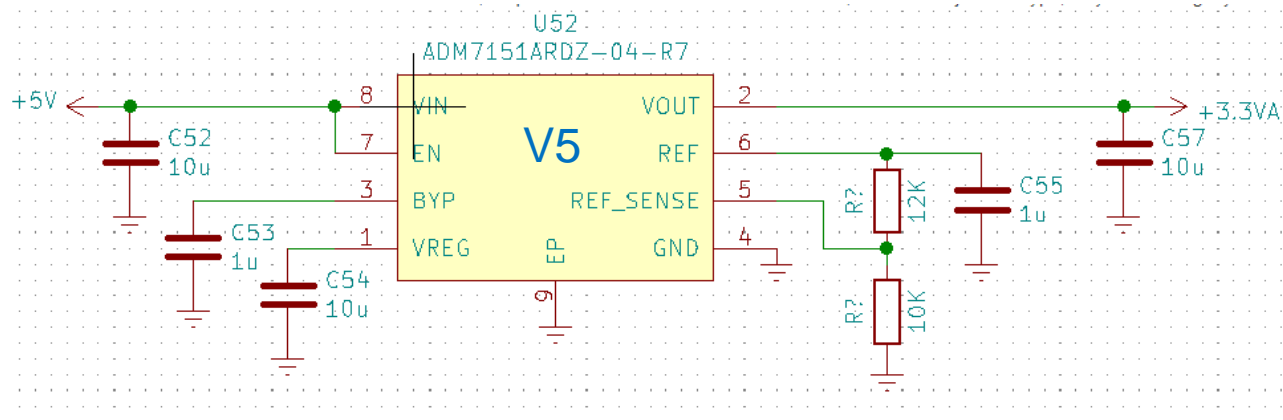
# V5 changes from V4

R65, R66 added as option for U52 ADM7151 (chip shortage)

R36 update service print to "+5V"

U6 changed footprint to MGA-86576 (still possible to mount PGA103+, but too little gain)

J31, J32, J33, J1, J2, J3 No solder paste



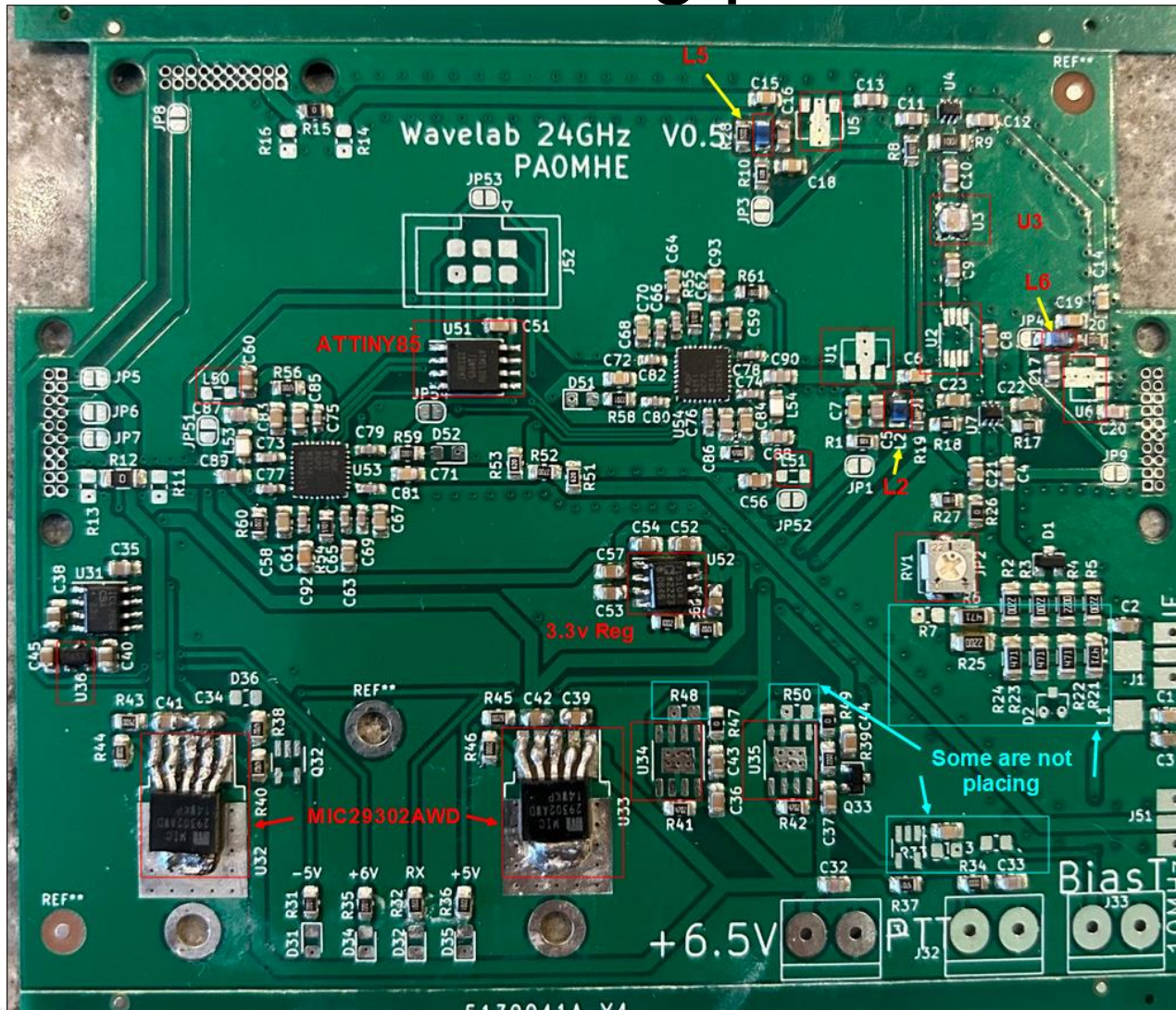
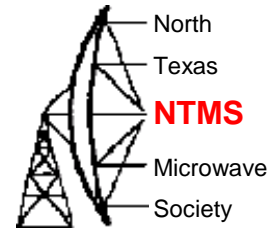
V4



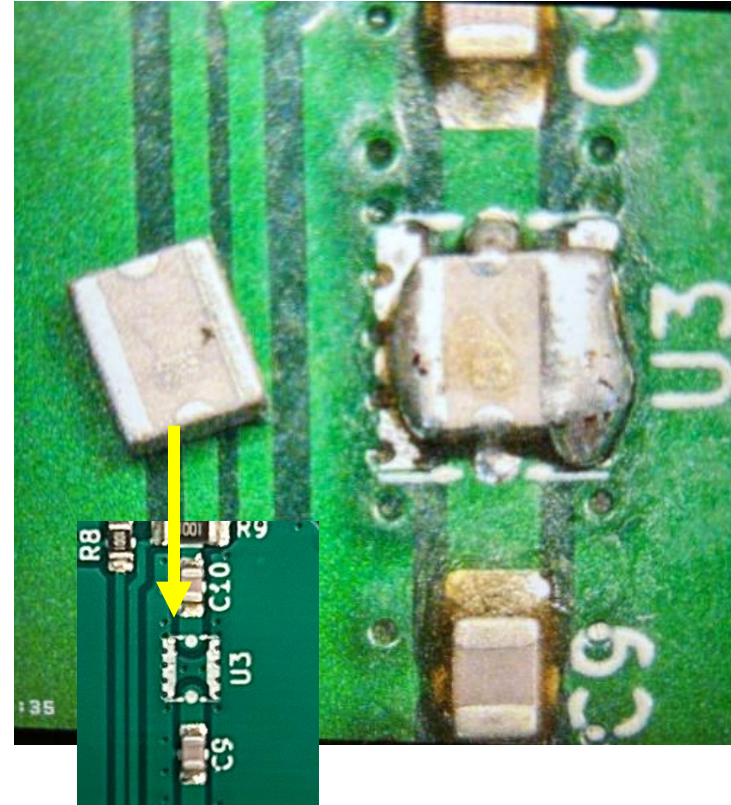
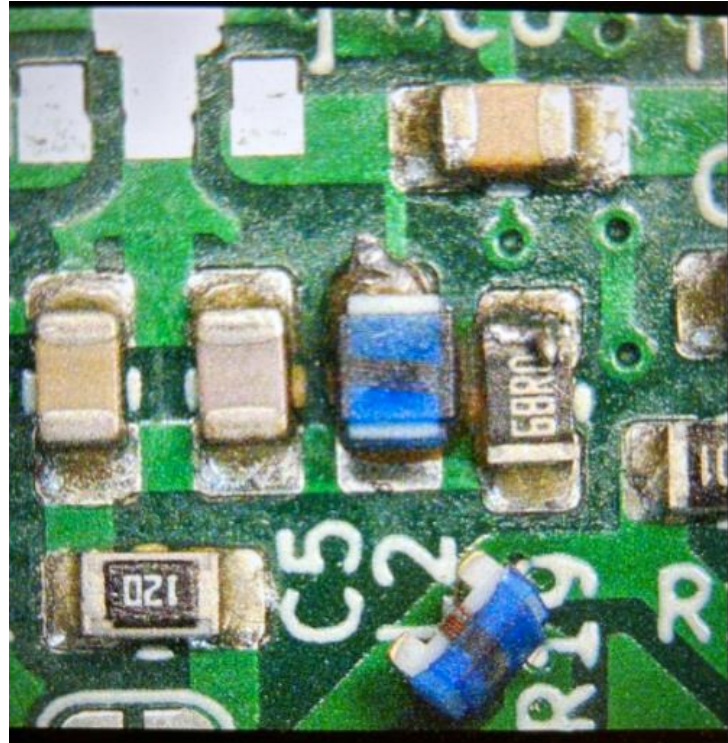
V5



# Remaining parts



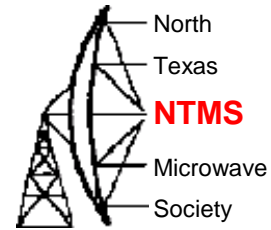
# Soldering technique



Small I/O footprint before placing

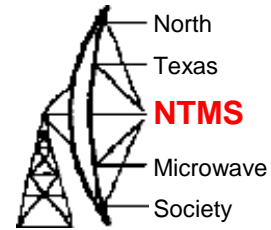


# Program ATTINY



- Arduino sketch is on GitHub
  - [Wavelab-24G-Addon-module/ADF4351\\_fixed\\_tiny\\_24GHz.ino at main · PA0MHE/Wavelab-24G-Addon-module · GitHub](#)
  - Arduino integrated development environment needed (Free)
- Use Arduino IDE to burn bootloader to Uno and then upload Wavelab sketch to ATTINY
  - Uno required, breadboards, patch wiring
  - [Program an ATtiny With Arduino : 7 Steps \(with Pictures\) - Instructables](#)
- Use sparkfun “AVR tiny programmer” and SOIC chip holder, install drivers, upload Wavelab sketch directly to ATTINY
  - This will be explained in the following slides

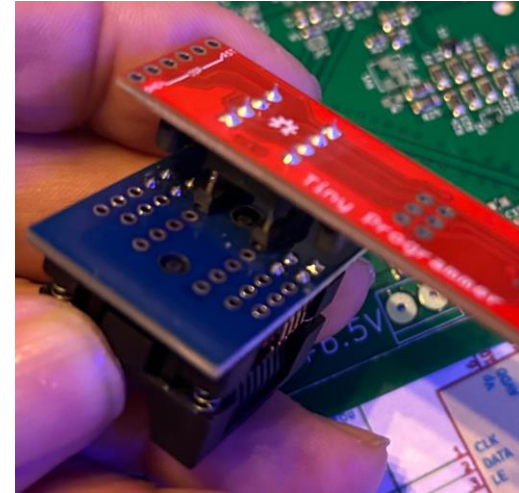
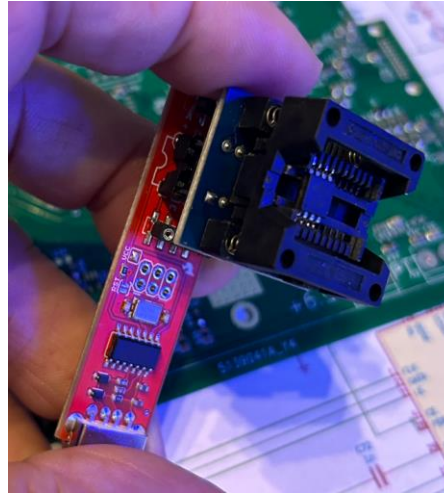
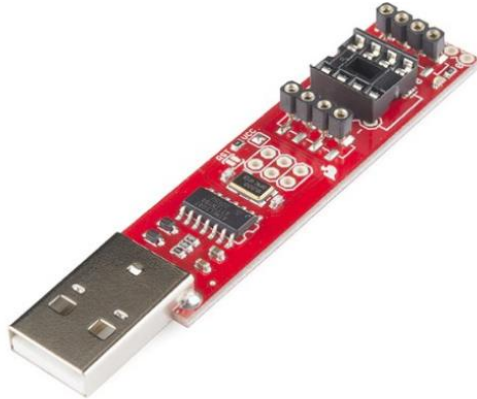
# Programming tools



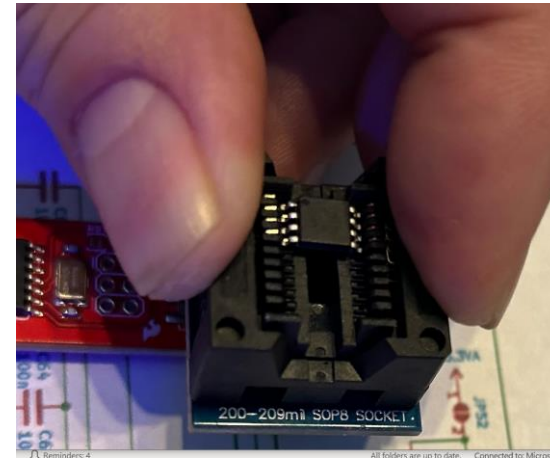
- Using AVR tiny programmer (windows)
  - Plug the programmer into your USB
  - If drivers are not found then download Zadig USBTiny drivers
  - Ref:<https://learn.sparkfun.com/tutorials/tiny-avr-programmer-hookup-guide/all>
  - Download the ATTINY addon to your Arduino IDE from GitHub
  - Configure IDE to use ATTINY85 (internal 1 MHz clock)
    - *Tools>Board>ATtiny85 (internal 1 MHz clock)*
  - Configure IDE to use ATTINY85 processor
    - *Tools>Processor>ATTINY85*
  - Configure IDE to use programmer USBtinyISP
    - *Tools>Programmer>USBtinyISP*
  - Plug in the ATTINY
  - Upload the code. (Use a blink sample sketch if you want to test 1<sup>st</sup> time)



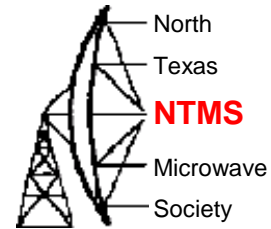
# Programming tools



- On Amazon
  - AVR Tiny Programmer
  - SOIC8 SOP8 to DIP8 IC Programmer Socket Converter (verify the device will handle 200+ mil sizing)



# LO frequencies



- The plan to put the module on USA terrestrial 24192 MHz

Synthesizer 1 ADF 1	1819 MHz	x 12 mult	21828 MHz	
Synthesizer 2 ADF 2	2220 MHz		2220 MHz	
			24048 MHz	
			144 MHz	IF
			24192 MHz	Final

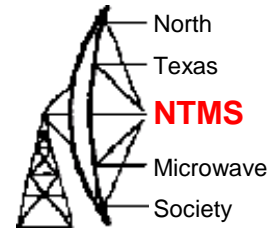
- For 144 MHz IF use the reg1 & reg2 lines below highlighted and comment out all others.

```

23 uint32_t reg1[6] = {0x5A0038, 0x8008051, 0x1A004E42, 0x4B3, 0x9A003C, 0x580005} ; // 1807MHz, ref 10MHz x2, 5dBm, Muxout: digital lock detect
24 + //uint32_t reg1[6] = {0x5A8048, 0x8008051, 0x1A004E42, 0x4B3, 0x9A003C, 0x580005} ; // 1819MHz, ref 10MHz x2, 5dBm, Muxout: digital lock detect
25 //uint32_t reg2[6] = {0x378000, 0x8008011, 0x1A004E42, 0x4B3, 0x8A003C, 0x580005} ; // 2m, 2220MHz, ref 10MHz x2, 5dBm, Muxout: digital lock detect
26 + //uint32_t reg2[6] = { 0x600018, 0x8008029, 0x1A004E42, 0x4B3, 0x9A003C, 0x580005 } ; //438MHz, 1926MHz, ref 10MHz x2, 5dBm, Muxout: digital lock detect
27 uint32_t reg2[6] = {0x608008, 0x8008029, 0x1A004E42, 0x4B3, 0x9A003C, 0x580005} ; // 70cm, 1932MHz, ref 10MHz x2, 5dBm, Muxout: digital lock detect

```

# LO frequencies



- Pertinent register values are the first two hex strings

```

23 uint32_t reg1[6] = {0x5A0038, 0x8008051, 0x1A004E42, 0x4B3, 0x9A003C, 0x580005} ; // 1807MHz, ref 10MHz x2, 5dBm, Muxout: digital lock detect
24 + //uint32_t reg1[6] = {0x5A8048, 0x8008051, 0x1A004E42, 0x4B3, 0x9A003C, 0x580005} ; // 1819MHz, ref 10MHz x2, 5dBm, Muxout: digital lock detect
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27 uint32_t reg2[6] = {0x608008, 0x8008029, 0x1A004E42, 0x4B3, 0x9A003C, 0x580005} ; // 70cm, 1932MHz, ref 10MHz x2, 5dBm, Muxout: digital lock detect
    
```

Reg 1 will control Integer and Fractional values

Enter hex number

 16
   
  

Binary number

 2

Reg 2 controls Phase adjust, prescaler (8/9), Modulus value

Enter hex number

 16
   
  

Binary number

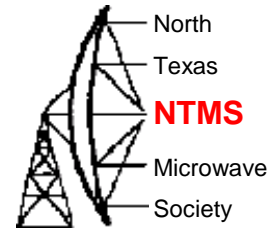
 2

**ADF4351**
Data Sheet

## REGISTER MAPS

INTEGER REGISTER 0																FRACTION															
Dec: 181																Dec: 009															
0 1 0 1 1 0 1 0 1 0 0 0 0 0 0 0 1 0 0 1																												0 0 0			
16-BIT INTEGER VALUE (INT)																12-BIT FRACTIONAL VALUE (FRAC)												CONTROL BITS			
DB31	DB30	DB29	DB28	DB27	DB26	DB25	DB24	DB23	DB22	DB21	DB20	DB19	DB18	DB17	DB16	DB15	DB14	DB13	DB12	DB11	DB10	DB9	DB8	DB7	DB6	DB5	DB4	DB3	DB2	DB1	DB0
0	N16	N15	N14	N13	N12	N11	N10	N9	N8	N7	N6	N5	N4	N3	N2	N1	F12	F11	F10	F9	F8	F7	F6	F5	F4	F3	F2	F1	C3(0)	C2(0)	C1(0)

# LO frequencies



- There's an app for that!!

Analog Devices ADF435x Software

File Tools Help

Select Device and Connection Main Controls Registers Sweep and Hop Other Functions Features

**RF Settings**

RF Frequency: 1819 MHz

Channel spacing: 1 kHz

Output divider: 2

Reference Frequency: 10 MHz

R counter: 1 Ref Doubler:  Ref /2:

PFD Frequency: 20 MHz

Prescaler: 8/9

Feedback signal: Fundamental 3638 MHz

INT: 181, FRAC: 9, MOD: 10, PFD (MHz): 20, Div: 2, RFout (MHz): 1819

$$\left( \frac{181}{10} + \frac{9}{10} \right) \times 20 / 2 = 1819$$

N = 181.9

Phase adjust: 0. Off Phase Value: 1

**Register 2**

Low Noise/Spur Mode: Low noise mode LDP: 10 ns

Muxout: Digital Lock dete PD Polarity: Positive

Double buff: Disabled Powerdown: Disabled

Charge pump current: 2.50 CP 3-state: Disabled

LDF: FRAC-N Counter reset: Disabled

**Register 3**

Band Select Clock Mode: Low ABP: 6 ns (FRAC-N)

Charge Cancellation: Disabled CSR: Disabled

Clock Divider Value: 150

CLK Div Mode: Clock Divider Off

**Register 5**

LD Pin Mode: Digital Lock Detect

**Register 4**

VCO Powerdown: Disabled

MTLD: Disabled

Aux Output Select: Divided

Aux Output Enable: 0. Disabled

Aux Output Power: -4 dBm

RF Output Enable: 1. Enabled

RF Output Power: +5 dBm

**Band Select Clock**

Auto set Divider: 160

Freq (kHz): 125.000

**Registers**

0x 5A8048	0x 8008051	0x 1A004E42	0x 4B3	0x 9A003C	0x 580005
Write R0	Write R1	Write R2	Write R3	Write R4	Write R5

Write All Registers

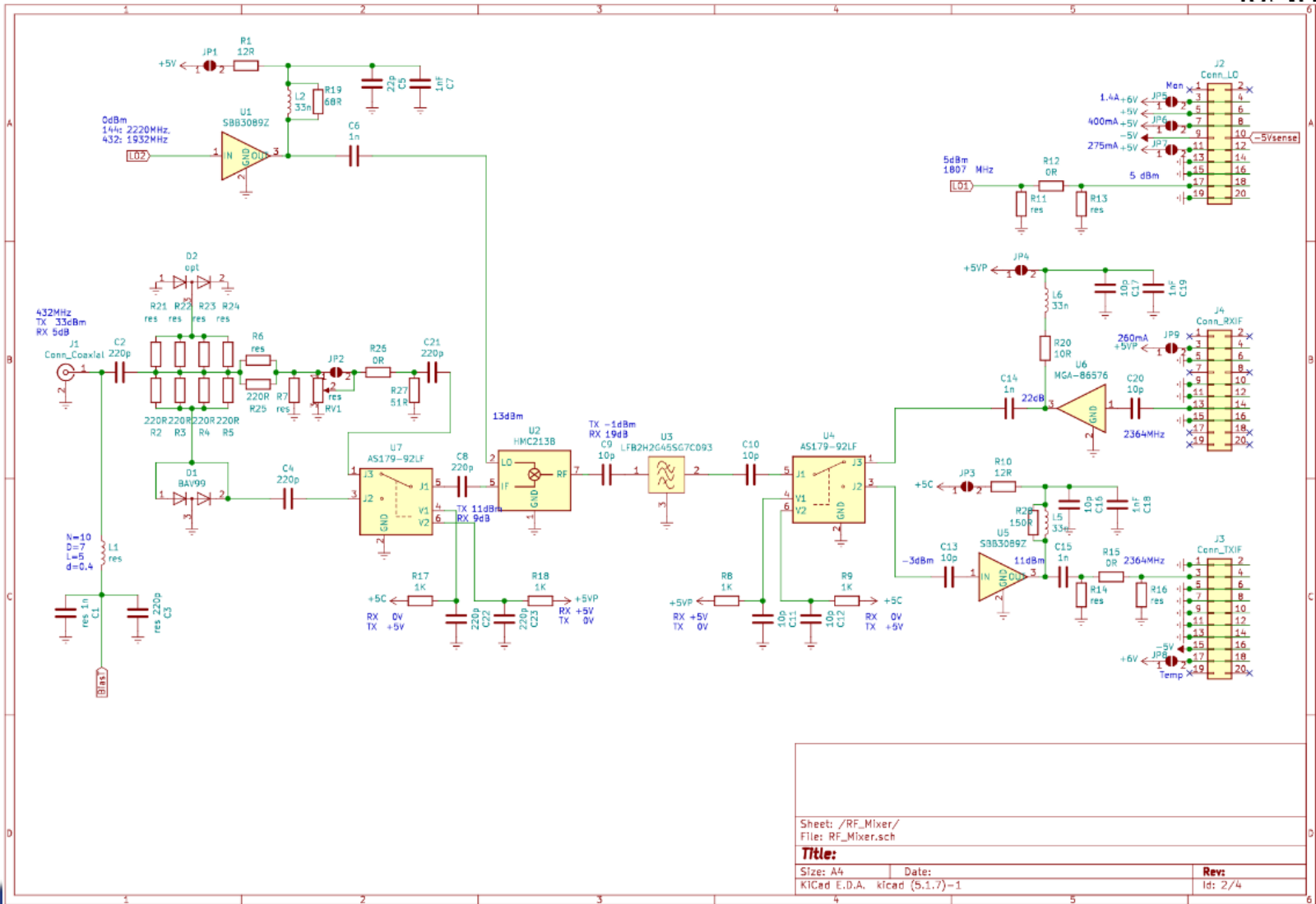
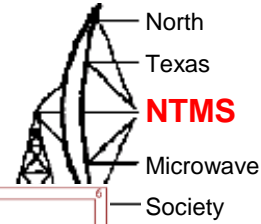
Application started.  
 15:09:44: No USB adapter board attached. Try unplugging and re-plugging the USB cable.  
 17:41:02: No USB adapter board attached. Try unplugging and re-plugging the USB cable.

Device in use: ADF4351  
 Software version: 4.5.1

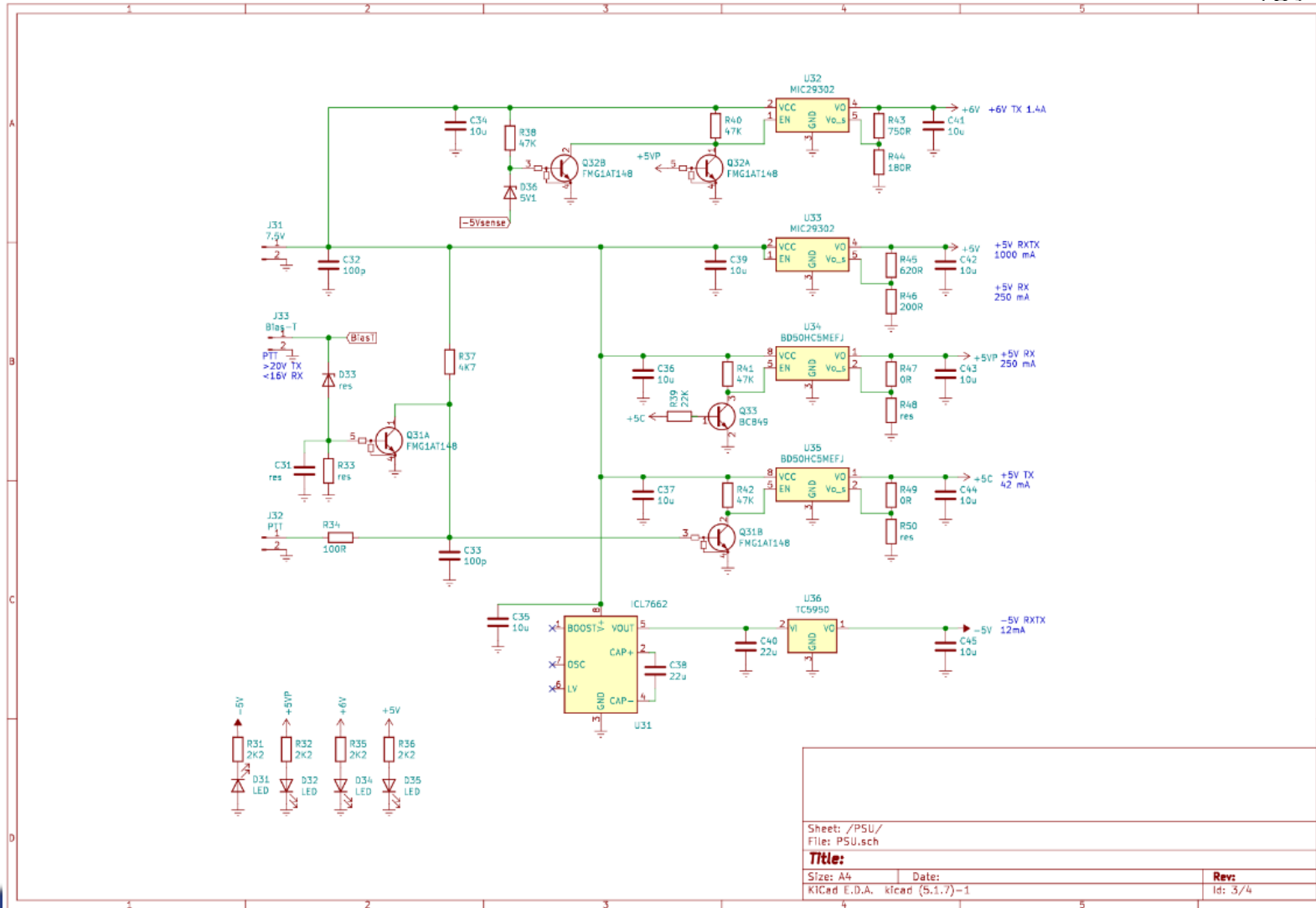
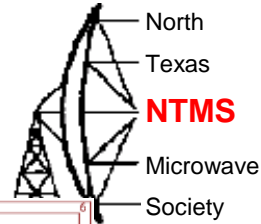
**ANALOG DEVICES**



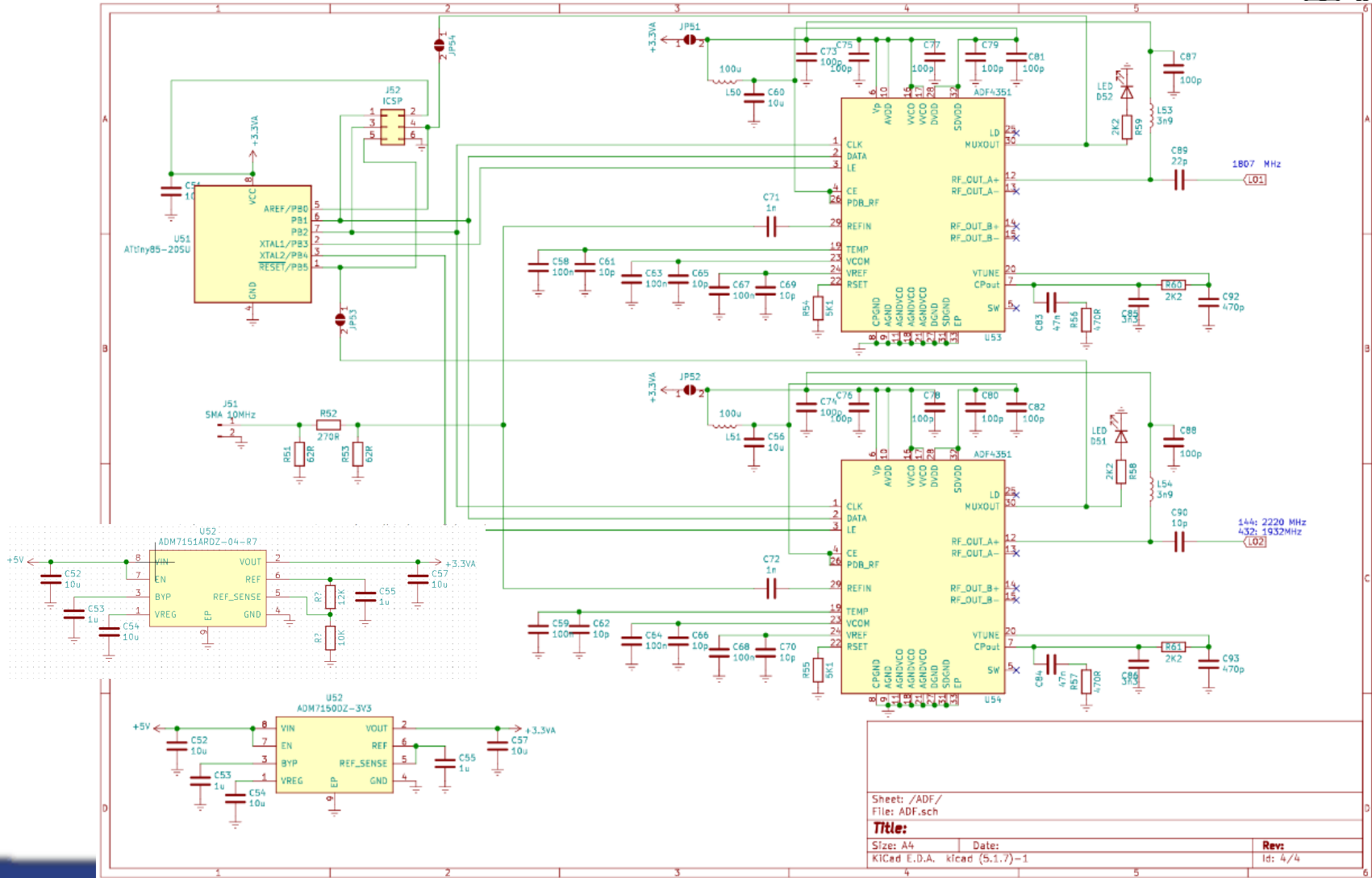
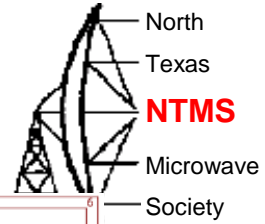
# Add on board schematic pages



# Add on board schematic pages



# Add on board schematic pages



# Questions?

