

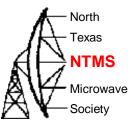
Wavelab 24 GHz project

Converting Surplus Wavelab 23 GHz radios to 24 GHz Ham Band using PA0MHE Wavelab Add On PCB

> June 6, 2023 KM5PO Jim McMasters

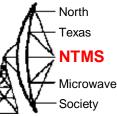
Wavelab 23 GHz ODU





W5HN

Wavelab module



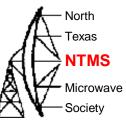
- According to Wavelab ODU brochure, frequency range is 21.2-23.6GHz but original PCB LO can't reach 21.2GHz. TR spacing is 1008 MHz
- Warning: The 23X1008XP module is our unit of interest. Do not purchase the "XN" module.
- The advantage of the XP module is that it can be converted to 24 GHz by simply changing the external input frequencies. It is not necessary to open it up or do any precision surgery on the millimeter wave circuitry.

		23X1008X	Р	
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			770MHz	
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	+ 144 Mhz IF	2364 Mhz
			24192 Mhz

W5HN



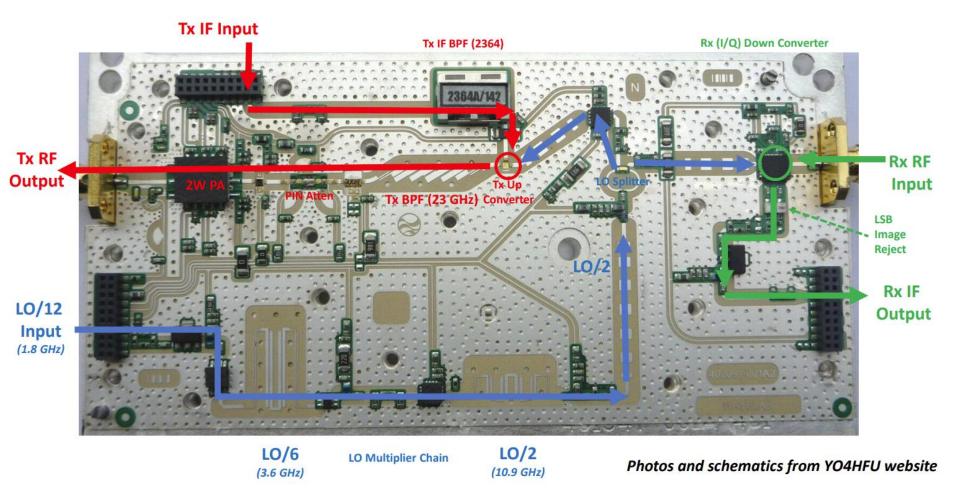
External view of module



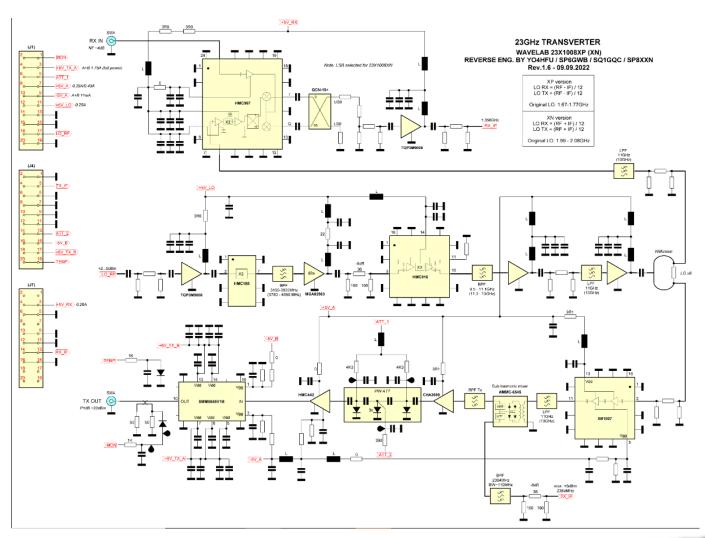
WWW.NTMS.ORG



Signal Flow & Components Inside the Wavelab Module



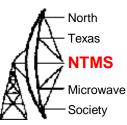
Module schematic



North Texas NTMS Microwave Society

WWW.NTMS.ORG

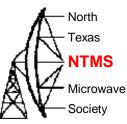
Add on board by PA0MHE



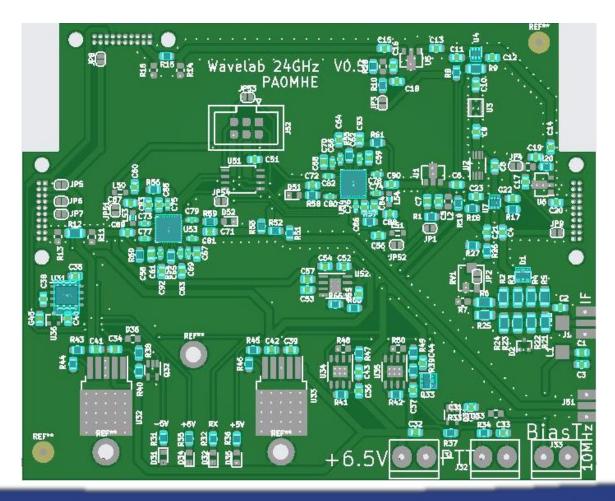
Board provides:

W5HN

- all voltage regulators needed by the wavelab module and the add on circuits; supplied by a single 6.5-7 volt external input
- first LO synthesizer (~1.8 GHz) to drive the wavelab module's 12x LO multiplier chain
- - first IF Tx and Rx amps and first IF (2364 MHz) band pass filter
- up/down conversion mixer from first IF to second IF (144 or 432 MHz ham transceiver)
- - second LO synthesizer (~2.2 GHz) for 1st to 2nd IF conversion mixer
- - second IF attenuators
- - ATTINY microcontroller to program the two synths (both ADF4351)
- Support:
 - NTMS Group PCB order
 - Wavelab groupsio -https://groups.io/g/Wavelab24GHz

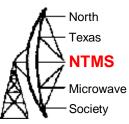


Confirming parts placement via website image



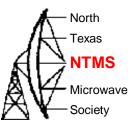
8

Board interest



- History
 - 11/14/2022 20 boards
 - April 2023 eBay seller lists more modules
 - 4/21/2023 5 boards (NTMS#1 build)
 - 4/29/2023 30 boards (NTMS#2 build)
 - 5/31/2023 75 boards (NTMS#3 build)
 - Interest from VE, VK, PA, G, 9H1, ON

W5HN



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 + Customers

W5HN

6 Million +

>99.97%

On-time delivery

* As of January 2021

20,000+

Orders Daily

170⁺

<0.23% Quality Complaint Rate 450,000m²

Factory Area

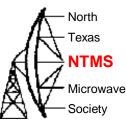
3000 Employees

1 Day PCB Prototype 620,000m² Production Capacity/Month

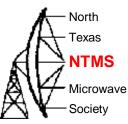
15 Years Founded

24/7 Online Service

WWW.NTMS.ORG



- Create an account on the website
- Upload the gerber, BOM, positions files
 - <u>Wavelab-24G-Addon-module/Kicad/V05 Kicad6/Wavelab24GHz_v05/production</u> <u>at main · PA0MHE/Wavelab-24G-Addon-module · GitHub</u>
- Review component placement and jlcpcb inventory shortages
 - Using search features you may find replacement parts
- Place the order

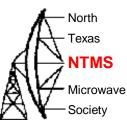


• Initial cost of PCBs was about a buck each.

JLCP	CB Why JLCPCB?	Capabilities Suppo	ort Resources	Order nov
Home / Order History				
Order History	File Manager Parts	Manager Payments	Account Settings Messages	0
Order Type	∨ Date	✓ Orde	er #,Gerber file name Q	
Product Detail		Product File	Price	Order Status
2022-11-14 W20221	1140658438			
	PCB Prototype Order #: Y4-5139041A Build Time: 1-2 days 20 pcs \$20.80 Product Details	gerber_Y4 Production Completed Quality Complaint	Merchandise Total: \$755.89 Shipping Charge: \$26.87 Order Total: \$782.76	C Shipped
	Standard PCBA Order #: SMT0221113102520 Build Time: 2-3 days 20 pcs \$731.34 Product Details	wavelab 24 GHz BOM.xlsx positions.csv DFM Analysis Production Completed Quality Complaint		

WWW.NTMS.ORG

W5HN



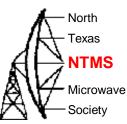
• Shipment timeline. From payment to shipment < 6 days

Submitted	Paid	Reviewed	In Production	Shipped
2022-11-14 06:58	2022-11-14 19:17	2022-11-14 19:17	2022-11-15 12:05	2022-11-20 13:13
Shipped Tracking #: 1248274300 DHL Express Worldwide Photos of package:		2022/11/23 10:43:00 Shipment has CINCINNATI HUB - USA,CINCINN 2022/11/23 07:14:00 Clearance pr CINCINNATI HUB - USA,CINCINN 2022/11/23 06:31:00 Processed at USA,CINCINNATI HUB, OH - USA 2022/11/23 05:21:00 Arrived at DH HUB - USA,CINCINNATI HUB, OH 2022/11/22 21:40:00 Customs clear The Customs clearance process m in transit to the destination.,CINCII 2022/11/22 14:15:00 Shipment has HONG KONG - HONG KONG SAF	IATI HUB, OH - USA ocessing complete at IATI HUB, OH - USA CINCINNATI HUB - IL Sort Facility CINCINNATI H - USA arance status updated. Note - hay start while the shipment is NNATI HUB, OH - USA s departed from a DHL facility	

WWW.NTMS.ORG

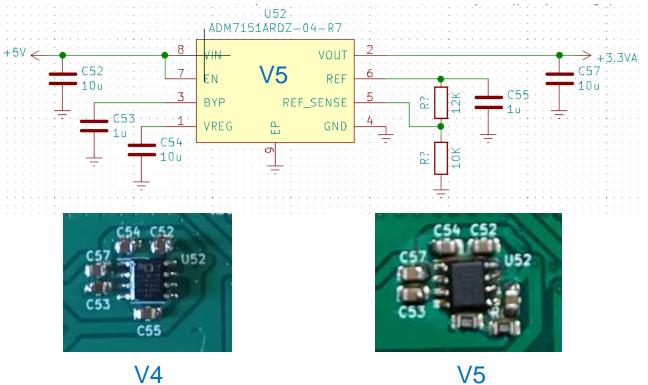
W5HN

V5 changes from V4



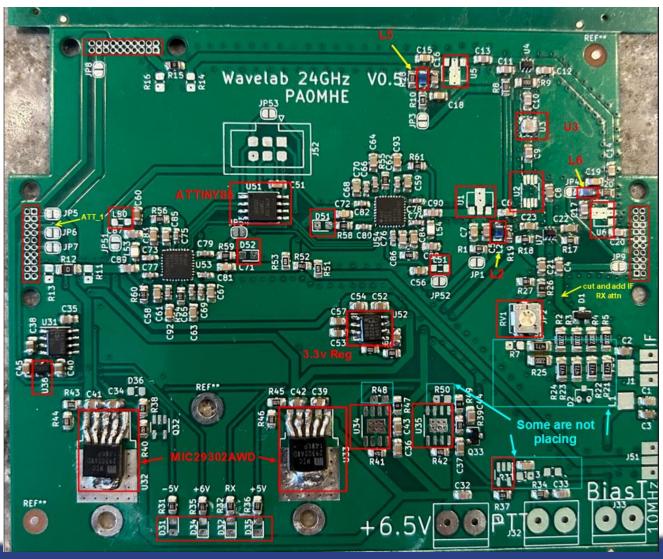
R65, R66 added as option for U52 ADM7151 (chip shortage)

- R36 update service print to "+5V"
- changed footprint to MGA-86576 (still possible to mount PGA103+, but too little gain) U6
- J31, J32, J33, J1, J2, J3 No solder paste



V4

Remaining parts



WWW.NTMS.ORG

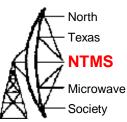
- North

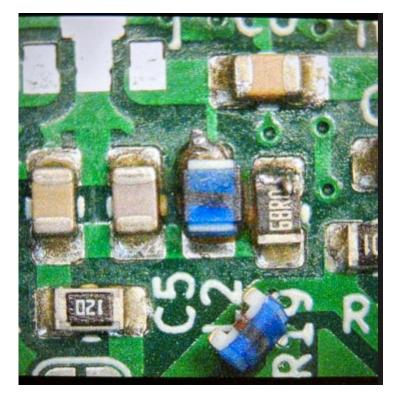
Texas

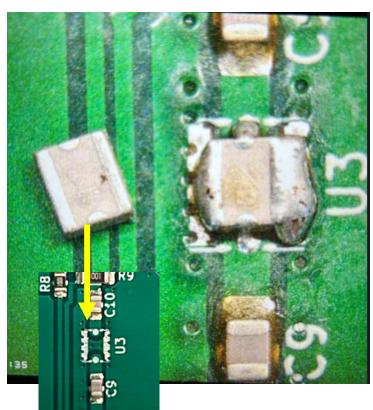
NTMS

Microwave Society

Soldering technique



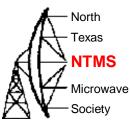




Small I/O footprint before placing

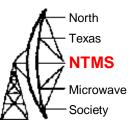
W5HN

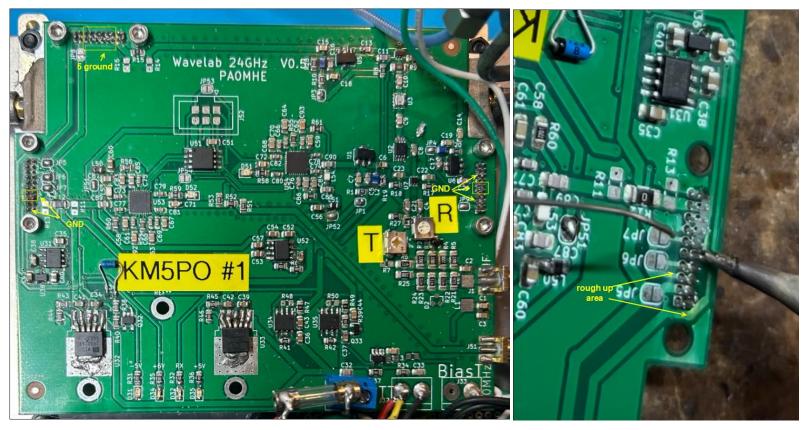
Soldering technique



- Solder pin strip headers after DC checks are performed and validated
 - Rough up pin hole connections with light sandpaper
 - Tack one pin in place while insuring connector is aligned properly.
 - Start with J3/upper left -TX IF. 5 ground conns ganged together. 1 edge n/c and 1 edge ground.
 - Next is J4/right side RX IF. 2 ground conns ganged. 2 other ground, 3 edge are n/c.
 - Last is J2/left side LO. 2 ground conns ganged. 1 edge ground, other edge is MON but "n/c" on schematic.

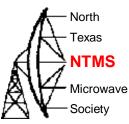
Soldering technique





WWW.NTMS.ORG

Inspect solder joints



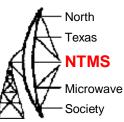
- Ohm out parts from other connecting parts
 - Filter U3 is easy to short to ground.
 - Through filter resistance is slightly lower than filter in/out ports to ground.
 - L2, L5, L6 do not overheat. Verify through coil resistance is ~ .27 ohm
 - I pre-tin the pads but do not leave a build up of solder on the pad
 - The mixer sanity checks:
 - IF port ~ 340 ohms to ground
 - RF port 10-14 ohms to ground
 - LO port 8-9 ohms to ground

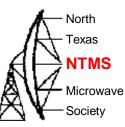
- Use a checklist of parts placement
 - For the NTMS December 2022 PCB order, a checklist is available here:
 - Parts detail v5.pdf (ntms.org)

			mber 2022 JLCPCB boards	
Placed		to bottom, right to		
V,		15	near JP3	Do not overheat. Cont chk=.27 ohm
V,		U5		
V.	-	U3		
V		150		
X		ATTINY85		
¥		D52 LED blue		
N		D51 LED blue		a the second
V,		L51 near JP52	all and the state of the	Constant of the second of the
V,		U1		
V	_	U2		A Stand Strange Strange
-V	/ 11	and the second se	near JP1	Do not overheat. Cont chk=.27 ohm
- M	12		near JP4	Do not overheat. Cont chk=.27 ohm
V,	/ 13			
V		U36		and the second s
Y		D36 zener leaded	DESUGRASSI MAL	
V		U52		
	_	RV1		
V		U32		High heat on ground tab
V		Q32		
V		U33		High heat on ground tab
V		U34		
- 7		U35		
Y	23	Statement of the local division of the local	and the second second	1
V		D31 LED orange		replace drop resistor w/470 ohm
V		D34 LED white	and the second second second	
V		D32 LED red	A A A A A A A A A A A A A A A A A A A	The second s
V		D35 LED green	and the second sec	State From St.
VI	28	B header pins		and the state of the
N		MA connectors	C. Constanting of the second	
V	30	PTT connector	a - Children -	and the second s
N	31 -	6.5v connector		
	32 F	use holder		

WWW.NTMS.ORG







- Use a checklist for initial checkout
 - Test sequence from Maarten/PA0MHE and modified for NTMS PCB with substituted parts is here:
 - https://ntms.org/files/Feb2023/Wavelab power up testing.pdf •

How I did a first time test and measured a	new Wavelab 24GHz add-on mod	ule.	
Supply: +7.4			Pins 5/6 PN JZ
In RX, PTT open, high on pin 1 J32 +6.	25 5/8 1		P123 210 P1
- +5V on C42 + 5. 03 v - +5V on C43 + 4.9 V	KISEM.	11-11/ 1	sound to be
- + 31/2 on CE7 + 13V		VITI	grounded
-6 5V on C45 - 5.0 R La minling	alker & they tan value	When the TAND	1
in TX mode, PTT short to ground, and pin	9 and 10 of 32 temporarily short ci	rouited to simulate the RF n	nodule .
- +6V on C41 +6.3 - +5V on C44 +4A			E
			1
PTT switching:	2	OWN	
In RX: C12 and C22: 0V V			
C12 and C22 0V	470	-07 25 KK	e Attached (or file)
In TX:	-6	-352 W/M/	p Manual officer
C12 and C22: 5V	6	251 DTC	NUT-
C11 and C23: 0V V		surve pro a	
Min circuit programming U51:			
Or directly upload HEX files or compile and	upload.		
Arduino IDE setting for compiling: Board */	ATtiny25/45/85", Processor "ATtin	/85", Clock "internal 1MHz"	
Connect AVRISP MKII to J52 Ensure both U53 and U54 are powered: JF	Y. K		
Leave JP53 and JP54 always open	-51 and JP52 closed.		
Leave 5r 55 and 5r 54 anways open			
Test ADF4351's U53 and U54:			
- Test with a multimeter in ohms if U53 and	U54 are soldered correctly:		
 Open pins: With a multimeter in the did C or R you can measure if the pin is conner 	de range, the plus terminal to gro	und and the other to a con	nected component: e.g.
~0.2V	cted. Example: on Co4 and Co6,	connected to pin 23 054, y	ou should measure
- Check also short circuits: e.g. no short cir	cuit between pin 23 C64 and pin	24 C68.	72md both Los
- Measure currents of U53 and U54 on JP5	1 and JP52, if OK short both jurn	pers JP51 and JP52 you o	an expect 71mA no
code loaded 88mA code loaded			and the second
- with a DC voltmeter I usually check all DC		54, tapping on connected of	components. But
perhaps this step is only needed to find fau - Ensure US1 is programmed	il.		
 Ensure US1 is programmed Ensure 10MHz reference is connected an 	d arrives at inputs of U53 and U	54	3.5v
Connect supply: after 1 second first lock it	ndication should switch on 500m	s later also the other.	
1807MHz should be present at pin 17-18 Check U1: connect a current meter betwee	J2		syma
Check U1: connect a current meter between			- 55 mA, if OK short
JP1 2220	C.8.9	= 1.819 GHZ	197
- 1932MHz (case IF 432MHz) should be pr	A OV CO	+ 7 220 GHz	[al]
- 1832MHz (case IF 432MHz) should be pr Bull and Attaching Media Test 2364MHz TX: Place module in TX, PTT short to ground	le KX arams	are any	817 mA
Place module in TX, PTT short to ground	TX denur 340		92 mA
- Check U5: connect a current meter betwe	en pins 1 and 2 from JP3: you s	hould expect a current of	
1P3			
- 2364MHz should be present on pin 3-4 J3	(As test stimulus I usually conr	ect +2dBm 432MHz on C	8, and measure +1dBm
on 2364MHz)			
Test RX:			
Place module in RX, PTT open - Check U6: connect a current meter between	on nine 1 and 2 from IP4: your	bould expect a current of	~ 15 mA (case
MGA-86576), if OK short JP3-	en parte i della z nom or 4. you c	income expect a current of	in the forme
- As test stumulus I insert -20dBm 2364MH	(e.o. from a Pluto) on pin 13-1	4 J4 and I measure RX o	ain ~4dB 432MHz on J1
- As that storman + + Self - 2000/11 200-444 0			Dentell
Add-on module current consumption:	Pun out tests	AX PTTTX	19T TX MORIL
RX mode: ~~-300mA	4 4m 1941 TILLO	-75 -54	-34 Tx
		12 24	-32 6.3
		5-52	
		-50	-255 6.5

24	4 GHz PAOHME checklist for testing PCB. Modifications by KM5 <u>PO</u>
н	ow I did a <u>first time</u> test and measured a new Waxelab 24GHz add-on module.
- 1	use a <u>step by step</u> approach: The <u>ginstrips</u> 12, 13 and 14 I only mount afterwards. Optically check if everything is present and well soldered.
in m	pphy: <mark>(XMSPO- My supphy was set <u>1</u> 6.8v)</mark> RX, PTT Open, high on pin 1.32 45V on C42 45V on C43 53V on C45 74V on C45 TX mode, PTT short to ground, and pin 9 and 10 of J2 temporarily short circuited to simulate the RF <u>odule_</u> 45V on C44
In Ci Ci In Ci	TT switching: RY: 12 and C22: 0V 11 and C23: 5V TX: 12 and C23: 5V 11 and C23: 5V
OI AI CC Er	circuit programming US1: directly upload HEX files or compile and upload. druin IOE setting for compiling: Board "Artiny25/45/85", Processor "Artiny85", Clock "internal 1MHz onnect AVRISP MKII to JS2 sure both US3 and US4 are powered: JP51 and JP52 closed. (KMSPO: measure current across these to jumpers first - see below - then close jumpers) ave JP53 and JP54 always open
-1 cc cc -(-1 e)	est ADF4351's US3 and US4: "est with a multimeter in ohter if US3 and US4 are soldered correctly: - Open pins: With a multimeter in the diode range, the plus terminal to ground and the other to a - onected to pin 2 US4, you should measure "if the pin is connected. Example: on OS4 and OS6, netced to pin 2 US4, you should measure "if the pin is connected. Example: on OS4 and C66, netced to pin 2 US4, you should measure "if the pin is connected. Example: on OS4 and C66, Netcek lab other Circuits: e.g. no short circuit between pin 23 C64 and pin 24 C68. Weasure currents of US3 and US4 on IPS1 and IPS2; (W S16PT other Jumper; IPS1 and IPS2 you can pect Zinna no code loaded 88ma code loaded (KMSPO: all units have measured 73-75 mA code aded)

- with a DC voltmeter I usually check all DC values on all pins of U53 and U54, tapping on connected components. But perhaps this step is only needed to find fault. - Ensure U51 is programmed

- Ensure 10MHz reference is connected and arrives at inputs of U53 and U54

- Connect supply; after 1 second first lock indication should switch on 500ms later also the other - 1807MHz should be present at pin 17-18 J2 (KM5PO: for U.S. Terrestrial use this should be 1819 MHz) - Check U1: connect a current meter between pins 1 and 2 from JP1: you should expect a current of ~~ 55 mA, if OK short JP1 (KM5PO: expect ~ 80 mA due to substituted part) - 1932MHz (case IF 432MHz) should be present on C6 (KM5PO: 2220 MHz case IF 144 MHz)

Test 2364MHz TX:

Place module in TX, PTT short to ground (KM5PO: apply <= 1 watt 144 MHz IF drive at J1 or inject +5 dBm at C8 note: TX IF attenuation pot is at minimum value fully CCW and placed resistors on pad make up 20 dB of attenuation from J1)

- Check U5: connect a current meter between pins 1 and 2 from JP3: you should expect a current of ~ 55 mA, if OK short JP3 (KM5PO: expect ~ 80 mA due to substituted part) - 2364MHz should be present on pin 3-4 J3 (As test stimulus I usually connect +2dBm 432MHz on CB, and measure +1dBm on 2364MHz) (KMSPO: with drive supplied as noted above, expect ~+5 to +8 dBm 2364 MHz on pin 3-4 J3)

Test RX:

Place module in RX. PTT open - Check U6: connect a current meter between pins 1 and 2 from JP4: you should expect a current of ~~ 15 mA (case MGA-86576), if OK short JP3 (KM5PO; expect ~85-90 mA due to substituted part - As test stimulus I insert -20dBm 2364MHz (e.g. from a Pluto) on pin 13-14 J4 and I measure RX gain ~4dB 432MHz on J1 (KM5PO: inject -20 dBm 2364 MHz on C20 and measure RX 144 MHz output -28dBm at J1 also 2nd test: inject Digit Q 24192.1 harmonic into wavelab module RX port and measure -46 dBm 2364 MHz on C20 and measure -40 dBm 144 MHz at C8

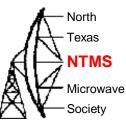
Add-on module current consumption - RX mode: ~~300mA - TX mode: ~~335mA

 \mathbf{O}

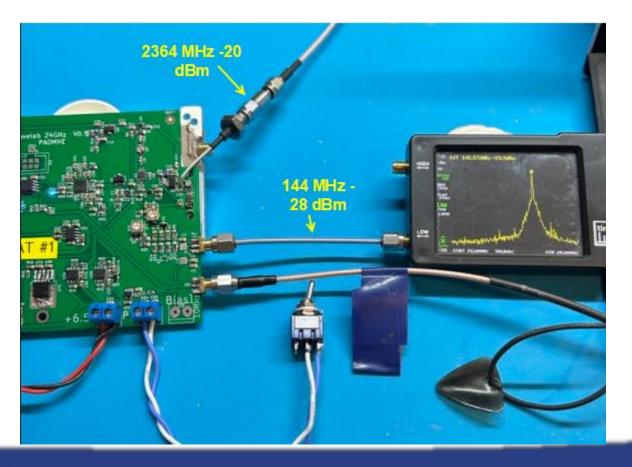
Finally I mount the ginstrips and mate with the RF module. Then step by step I verify the currents via the solder jumpers and close them

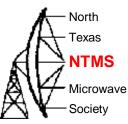
KM5PO: Fully assembled PCB board to module current consumption: RX mode TX mode

W/W/W/NTMS ORG



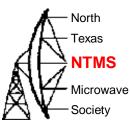
- Use a checklist for initial checkout
 - <u>https://ntms.org/files/Feb2023/Wavelab power up testing.pdf</u>



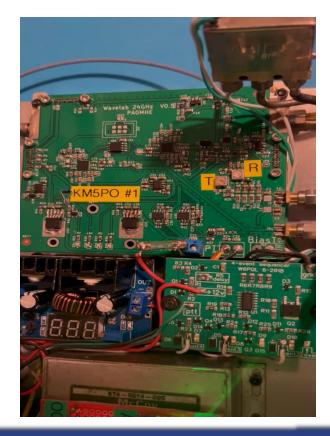


DC power reversal

- Hook up the input DC power backwards and expect to replace:
- U31 Charge pump voltage inverter
- U34 LDO voltage regulator
- U35 LDO voltage regulator
- Many ways to prevent this but at minimum install a 3 A fast blow fuse on +6.5 V line.
- D31 LED (- 5 V sense) place Anode on ground pad!
 - Opposite of the other three voltage sense LEDs...
- Even though LO synth LED "lock" lights up, if you see a big signal ~ 750 Mhz at LO #1 output (*should be 1819 MHz*) then you do not have 10 MHz ref lock.
 - Correct behavior of LO lock LEDs at power on is 1819 MHz lights first (left side of board), then 2220 MHz one second later.
 - I used 15 dBm reference in the shop for initial testing of the PCB boards.
 - Final build used McCoy OCXO with 13 dBm output + 3 dB attenuator ahead of ref input.

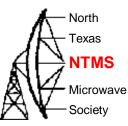


• Correct behavior of LO lock LEDs at power on is 1819 MHz lights first (left side of board), then 2220 MHz one second later.

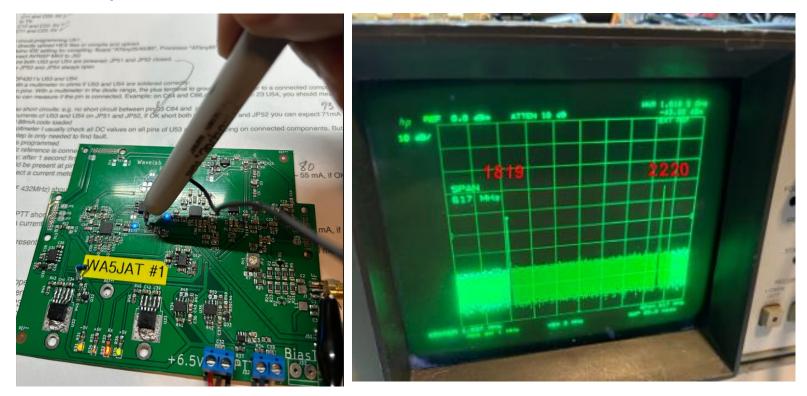


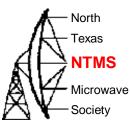
WWW.NTMS.ORG

W5HN

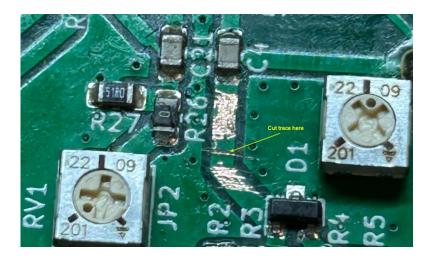


 Placing a probe between the LO LEDs will sample both LO frequencies



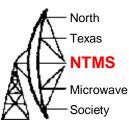


If you want to add receive side IF attenuation prepare the trace below C4

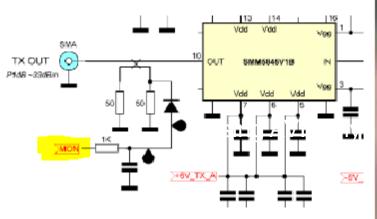




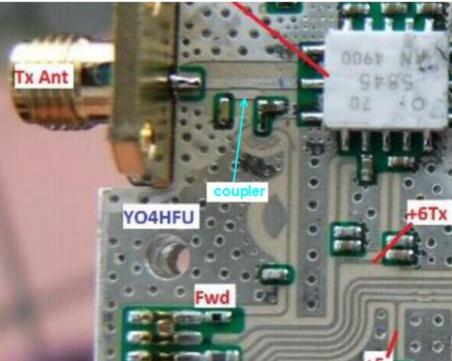
Monitor port



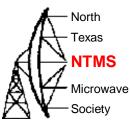
• Mon(itor) port



Measure varies from -.5 to -3.5v (J2 pin 1)



Program ATTINY

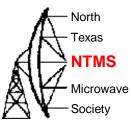


• Arduino sketch is on GitHub

W5HN

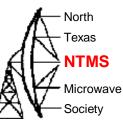
- <u>Wavelab-24G-Addon-module/ADF4351_fixed_tiny_24GHz.ino at main ·</u> <u>PA0MHE/Wavelab-24G-Addon-module · GitHub</u>
- Arduino integrated development environment needed (Free)
- Use Arduino IDE to burn bootloader to Uno and then upload Wavelab sketch to ATTINY
 - Uno required, breadboards, patch 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

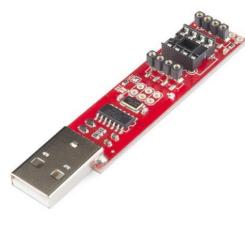
Programming tools

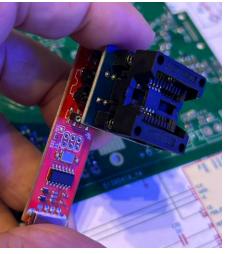


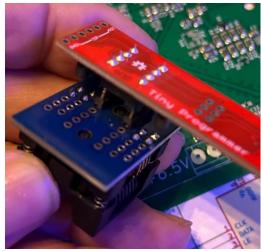
- Using AVR tiny programmer (windows)
 - Plug the programmer into your USB
 - If drivers are not found then download Zadig USBTiny drivers
 - Ref:https://learn.sparkfun.com/tutorials/tiny-avr-programmer-hookup-guide/all
 - Download the ATTINY addon to your Arduino IDE from GitHub
 - Configure IDE to 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 1st time)

Programming tools

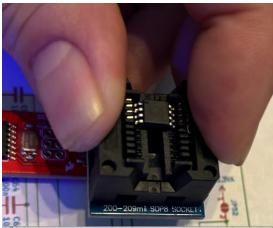






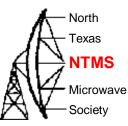


- On Amazon
 - AVR Tiny Programmer
 - SOIC8 SOP8 to DIP8 IC Programmer Socket Converter (verify the device will handle 200+ mil sizing)



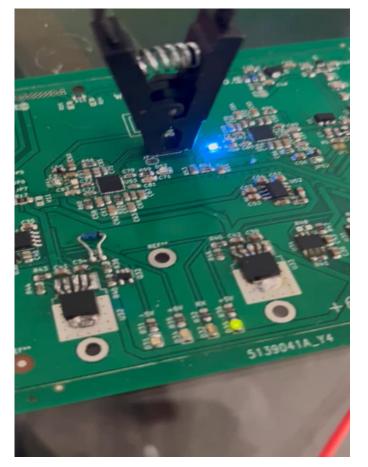
W5HN

In circuit programmer (clip)



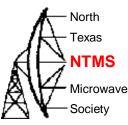


- I use the TinyProgrammer and plug in a cable with clip.
- Red wire in cable orients to pin 1 of the on-board chip to be programmed.



Video: +5v LED lights, #2 LO blinks, #1 LO blinks, then pause and #2 LO steady on.

LO frequencies



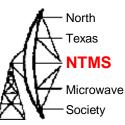
• The plan to put the module on USA terrestrial 24192 MHz

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, 0x483, 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, 0x483, 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, 0x483, 0x9A003C, 0x580005}; // 1819MHz, ref 10MHz x2, 5dBm, Muxout: digital lock detect
25	//uint32_t reg2[6] = {0x378000, 0x8008011, 0x1A004E42, 0x483, 0x8A003C, 0x580005} ; // 2m, 2220MHz, ref 10MHz x2, 5dBm, Muxout: digital lock detect
26	+ //uint32_t reg2[6] = { 0x600018, 0x8008029, 0x1A004E42, 0x483, 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

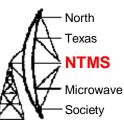
	Enter hex number			Enter hex number	
Reg 1 will	5A8048	16	Reg 2 controls	8008051	16
control Integer and Fractional	= Convert × Reset N Swap Binary number		Phase adjust, prescaler (8/9),	E Convert × Reset N Swap	
values	01011010100000001001000	2	Modulus value	10000000000100000001010001	2

ADF4351 Data She

REGISTER MAPS

									INTEGER REGISTER 0									FRACTION													
8								Dec: 181								Dec: 009															
RESERV						16-8/1	INTEG	0 IER VA	1 LUE (II	0	1	1	0	1	0	1	0	0	0	0 2-BIT F	0 RACTI	0 Onal	0 VALU	0 E (FR/	1	0	0	1	Q		ຸ 0
DB31	0830	D829	DB28	0827	DB26	0825	DB24	0823	D822	D821	D820	DB19	DB18	DB17	0616	DB15	DB14	0813	DB12	0811	DB10	089	DB8	D87	D86	DB5	DB4	DB3	D82	DB1	DBO
•	N16	N15	N14	N13	N12	N11	N10	N9	NB	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)

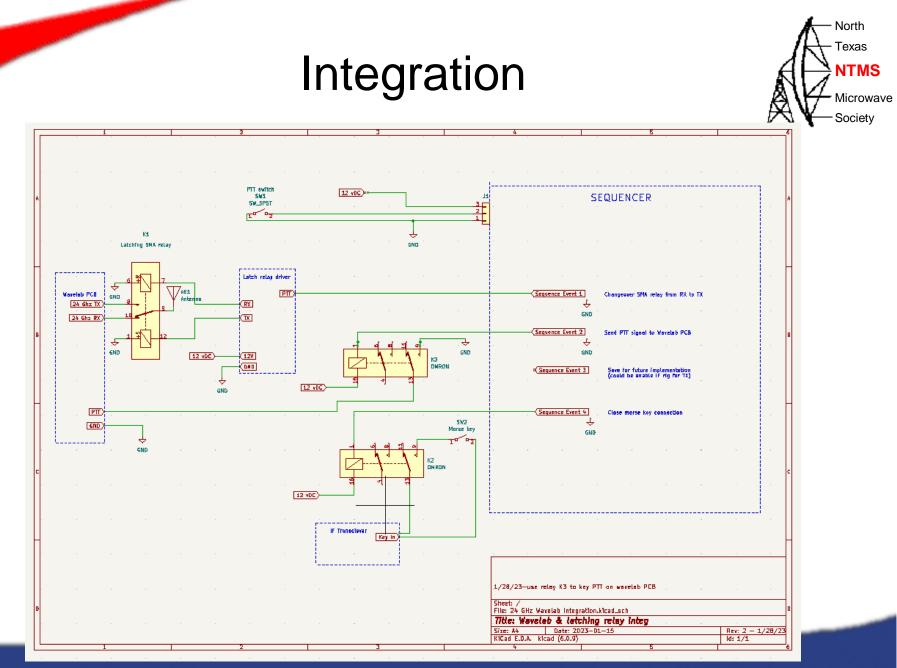
LO frequencies



• There's an app for that!!

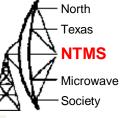
Feedback	g: 1 ar: 2 juency: 10 1 ♣ Ref Doul juency: 20 escaler: 8/9 signal: Fundamental FRAC 9 10)x 20 x 20 x 20 x 10 PFD (MHz) N = 181.9	2 = 1819	Muxout Double buff Charge pump current LDF Register 3 Band Select Clock Mo Charge Cancellati Clock Divider Val	:: Digital Look dete ∨ PD :: Disabled ∨ Pov :: 2.50 ∨ Cf :: FRAC-N ∨ Count :: Disabled ∨ :: Disabled ∨ :: 150 ÷ : de:: Clock Divider Off ∨	Polarity: verdown: 3-state: ter reset: ABP: 6 r	10 ns ~ Positive ~ Disabled ~ Disabled ~ Disabled ~ Disabled ~ Disabled ~ Disabled ~			
sters		8008051	0x 1A004E42 (0x 4B3	0x	9A003C	0x 58	0005	Write All
sters 5A	8048 0x								Registers

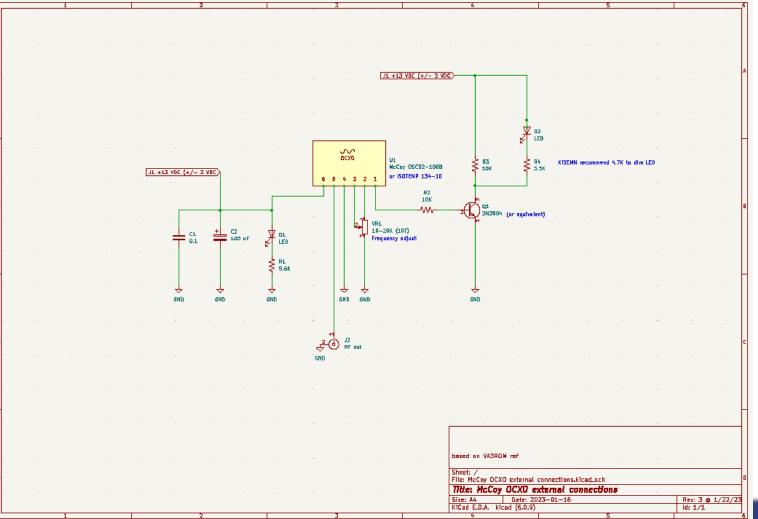
W5HN



WWW.NTMS.ORG

OCXO



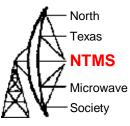


WWW.NTMS.ORG

High Hawk proving ground – Feb 3, 2023



WA5JAT unit

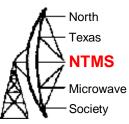


 Passes all tests and measured +32 dBm output



WWW.NTMS.ORG

KI5EMN unit

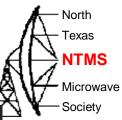




Uses latching relay driver with SMA latching relay



KM5PO unit

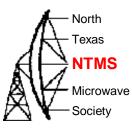




KI5EMN – Blue Ridge, Texas

 Recent on-theair operation – NTMS MAD May 21, 2023



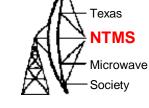


- Wavelab, PA0MHE addon board, 18" dish.
- 30 km 599 contacts

W5HN

W5HN

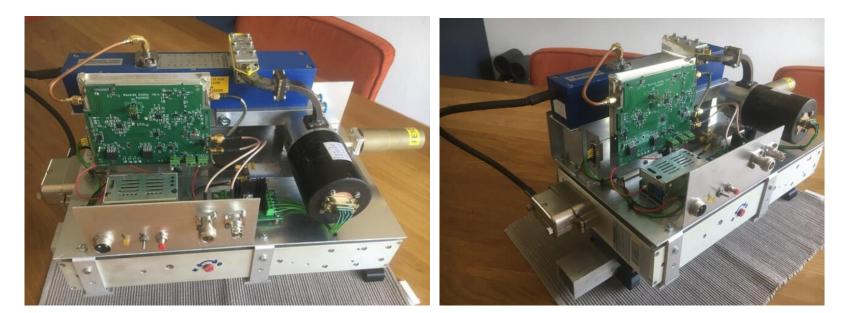
Wavelab 24 GHz EME



· North

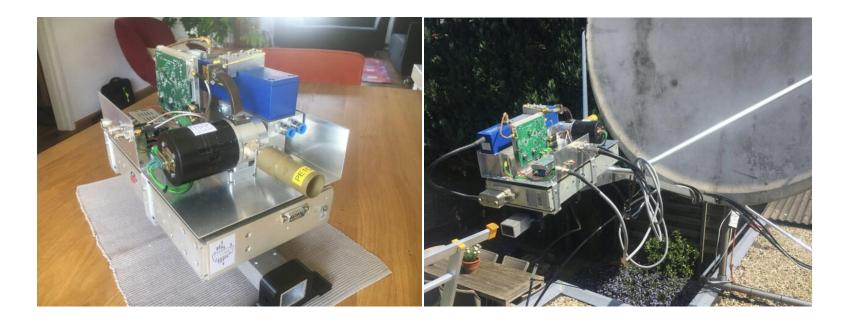
May 18, 2023- Hans PE1CKK worked PA0BAT via EME

- •Wavelab with PA0MHE addon board •RW1127 TWT 30W converted to 24G •DU3T preamp nf 1dB
- WG switch
- Dualmode feedhorn calculated for f/D 0,8
- 1.8m Prodelin offest dish

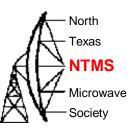


Wavelab 24 GHz EME

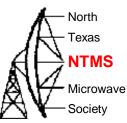
May 18, 2023- Hans PE1CKK worked PA0BAT via EME



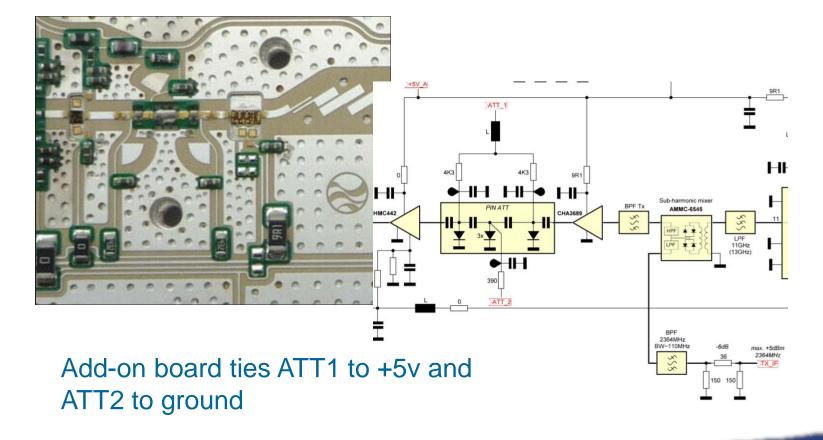




Improving RF output



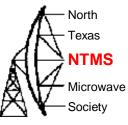
Recall previous discussions around module-based PIN attenuator

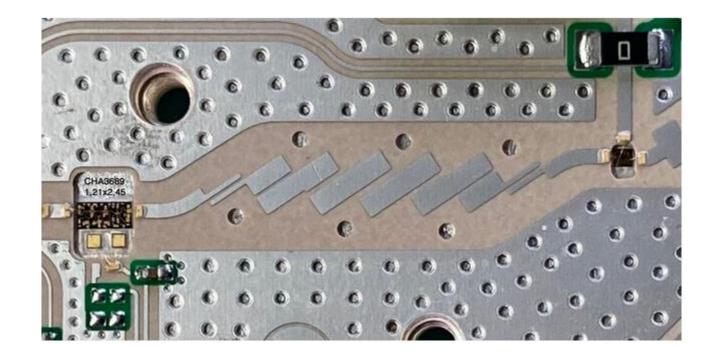


WWW.NTMS.ORG

W5HN

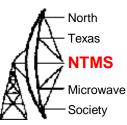
Inside the module





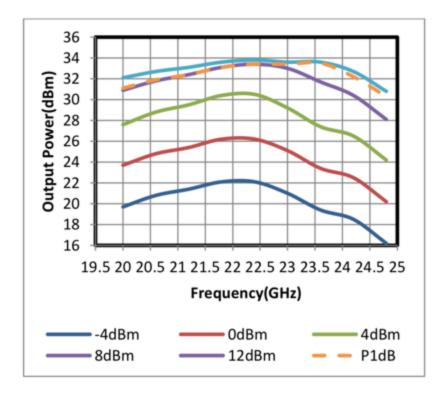
12x1700+2364=22764		Ref
12x1633+2364=21960	down 804	-3db
12x1774+2364=23652	up 888	-3db
12x1807+2364=24048	up 1284	-6db

W5HN



SMM5845

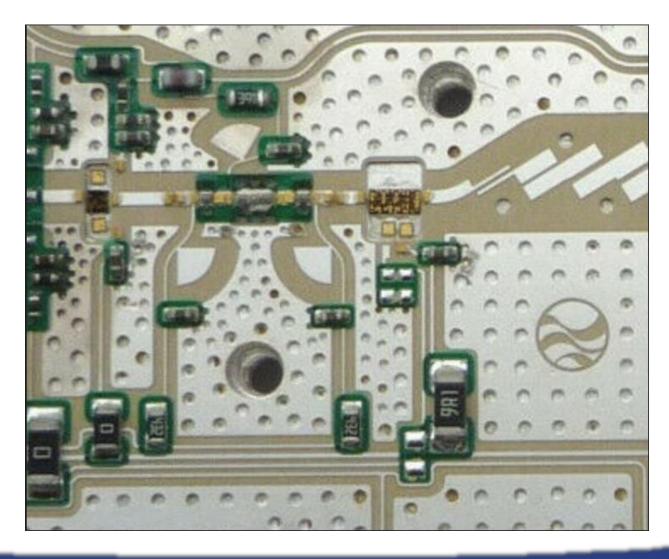
Output Power vs. Frequency VDD=6V, IDD(DC)=1400mA

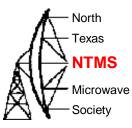


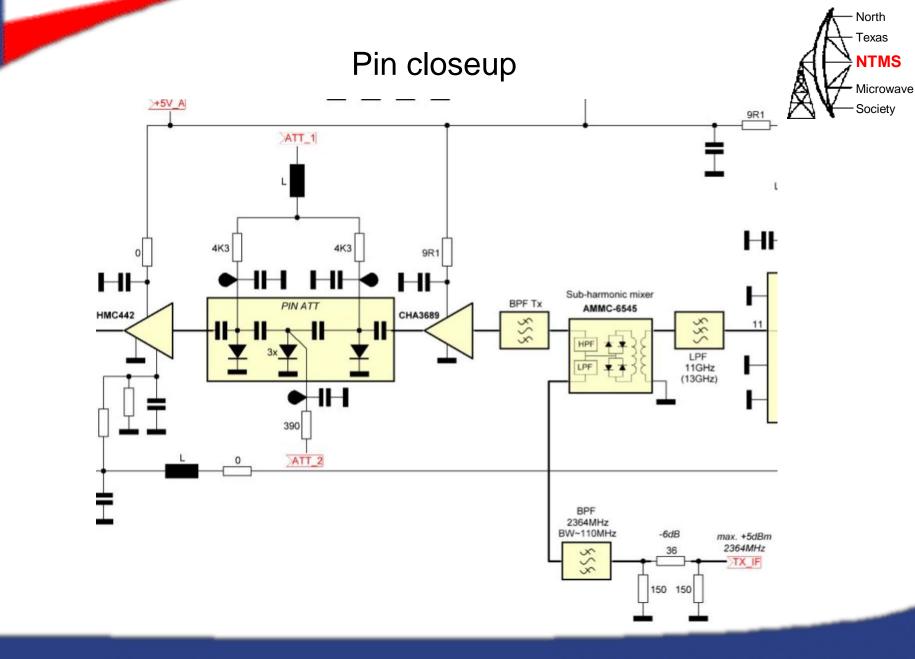
W5HN

WWW.NTMS.ORG

PIN attenuator

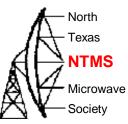






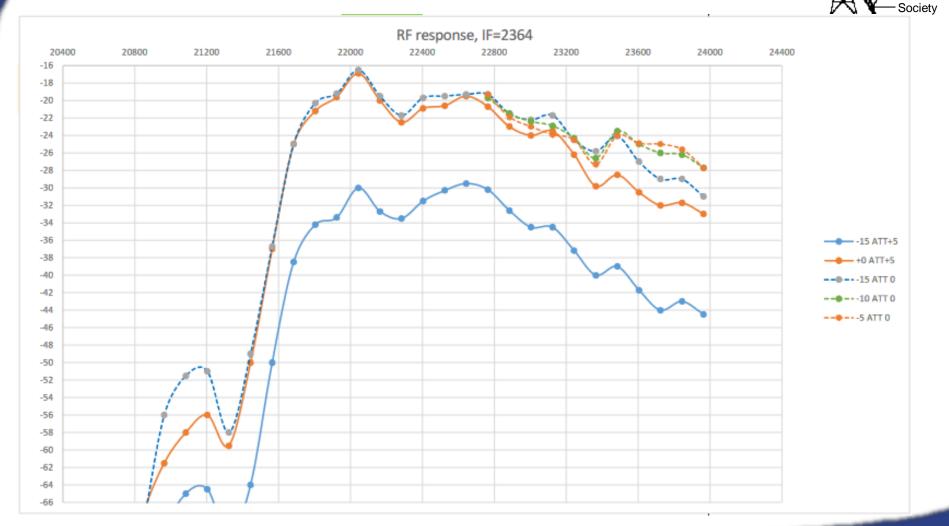
W5HN

Improving RF output



- Mike Lavelle K6ML ran tests on the PA0MHE add-on board and Wavelab 23 GHz ODU module
 - He swept the LO1 frequency to determine the frequency response of the Wavelab's TX IF and RF band pass filters as well as the TX mixer and PA saturation points.
 - He then measured power in (after the PCB mixer) versus power out from the module to find the saturation point for the Wavelab module upconverter AMMC-6545 mixer for both conditions of ATT1 tied to +5v (stock PCB board design) and for ATT1 allowed to float.
 - The measurements demonstrate that eliminating most or all of the internal pin attenuation allows more drive in the transmit pipeline which provides full saturation of the final PA with less drive from the PCB. In theory this would enable more linear operation.
 - The modification will be described here and the measurement procedure if you would like to experiment with your Wavelab system on your own.

K6ML swept LO1



W5HN

WWW.NTMS.ORG

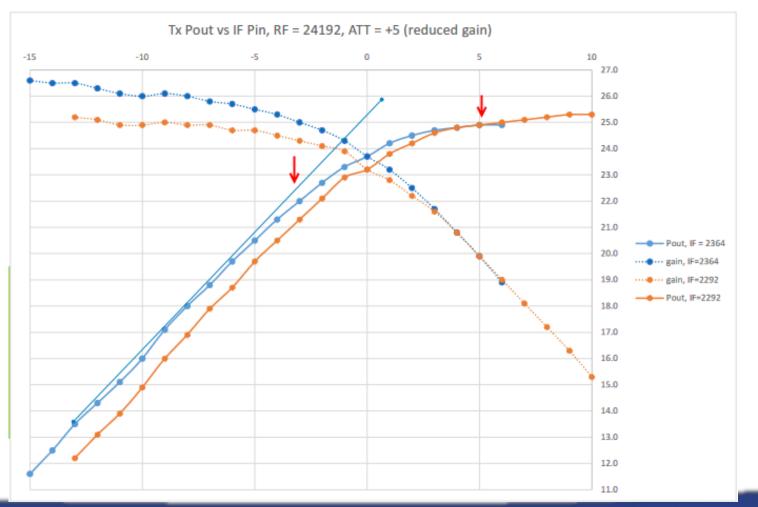
- North

Texas

NTMS

Microwave

K6ML upconverter saturation test – ATT1=+5v



WWW.NTMS.ORG

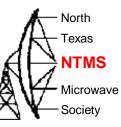
51

· North

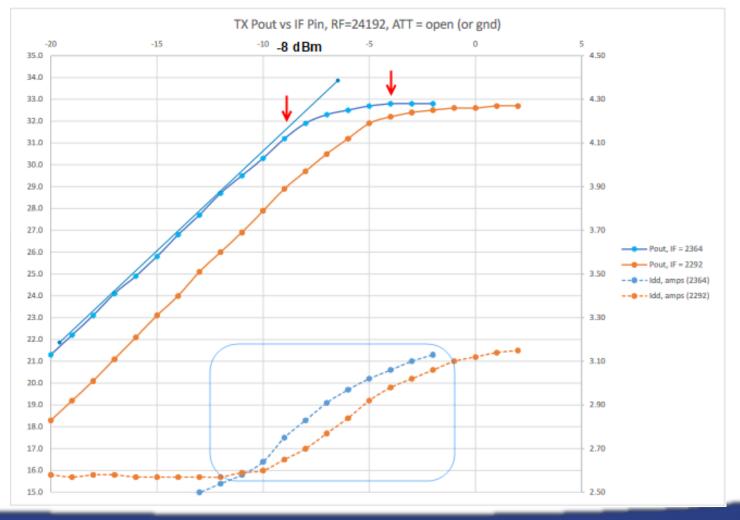
Texas

Microwave

Societv



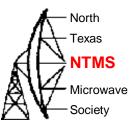
K6ML Pout/Pin ATT1 open



WWW.NTMS.ORG

W5HN

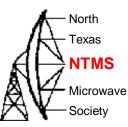
Improving RF output

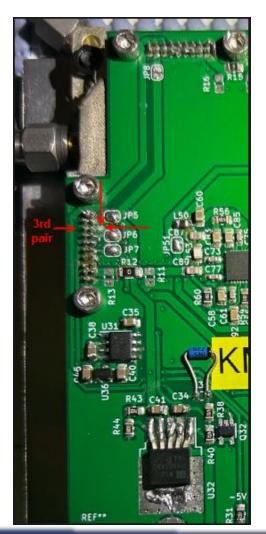


Cutting ATT1 jumper adds about 14 dB gain to the internal path from Tx up converter to the PA input.

Without this extra gain, most units cannot reach full power at 24192. We can put a resistor across the cut trace to adjust the extra Tx gain by anywhere form 0 to 14 dB. Running wide open, we can supply less drive to the up converter and still drive the PA to P1dB (or Psat), but we might start to see LO leak thru at 21828 MHz. If we don't see too much LO leakage, an open trace is fine, but we can put some resistance across the cut to reduce the PA drive. The sweet spot would be to run the 2364 MHz Tx drive to the up converter at or just shy of P1dB for max LO rejection and then add enough gain using resistance at ATT1 to get the PA to P1dB (or Psat).

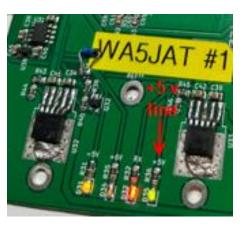
The modification





Turn the power off.

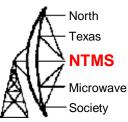
Make a vertical cut to the horizontal trace tied to the 3rd pair of pins on left side of board.



Check continuity from a +5v point like the +5v LED.

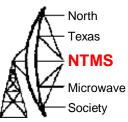
The 3rd pair of pins should now be open (not tied to +5v or grounded-although grounded will give the same results)

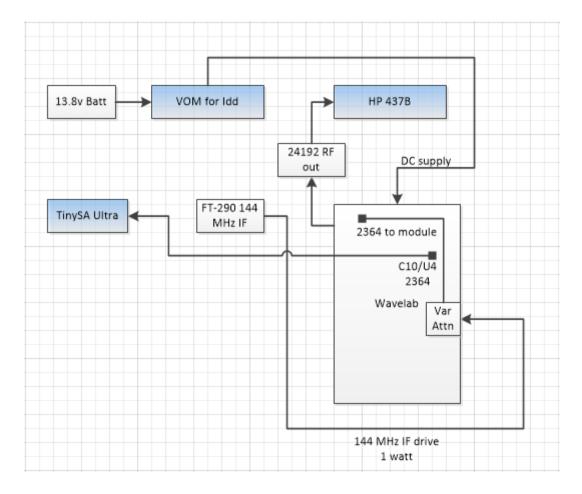
Testing



- Calibrate power meter to known source
 - DB6NT 24 GHz transverter = 2.5 watts = 34 dBm
 - 60dB attenuation to pad down to safe power head readings
- Calibrate or feel good about S.A.s for IF drive power readings
 - I tested a DigiLO (+2 dBm) an ADF 4351 development board (various outputs) using both the HP8566A and a TinySA Ultra.
- Attach a pigtail to C10 to read power levels of 2364 MHz drive
- Use RV1 pot to vary the drive level at approx. 1 dBm steps
- Record current, IF drive level, RF (24192 MHz) output level.

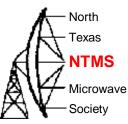
Testing

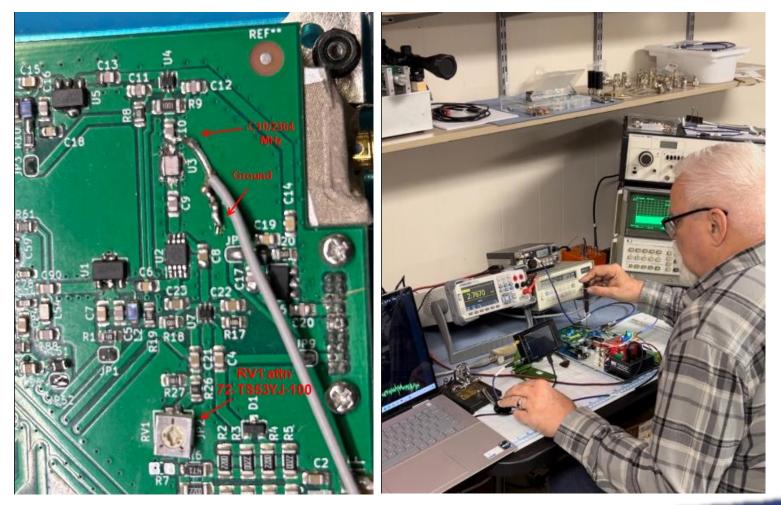


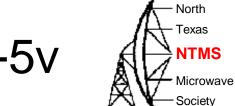


WWW.NTMS.ORG

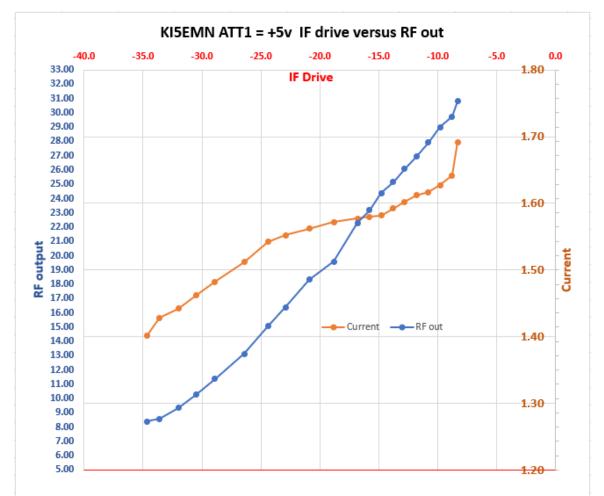
Testing







IF drive vs RF out ATT1=+5v

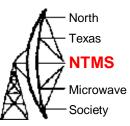


WWW.NTMS.ORG

58

W5HN

IF drive vs RF out ATT1=05v

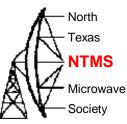




W5HN

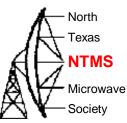
WWW.NTMS.ORG

Next steps



- Obtain second set of accurate measurements:
 - Check spectral RF output
 - Verify power output
 - Measure receive sensitivity, noise figure
- Integrate improvements/optimizations.
 - More improvements may be coming as the user group expands
- In-field tests
 - Extend DX success
- Build a Wavelab beacon

Resources



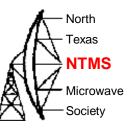
Wavelab24GHz@groups.io | Home

GitHub - PA0MHE/Wavelab-24G-Addon-module

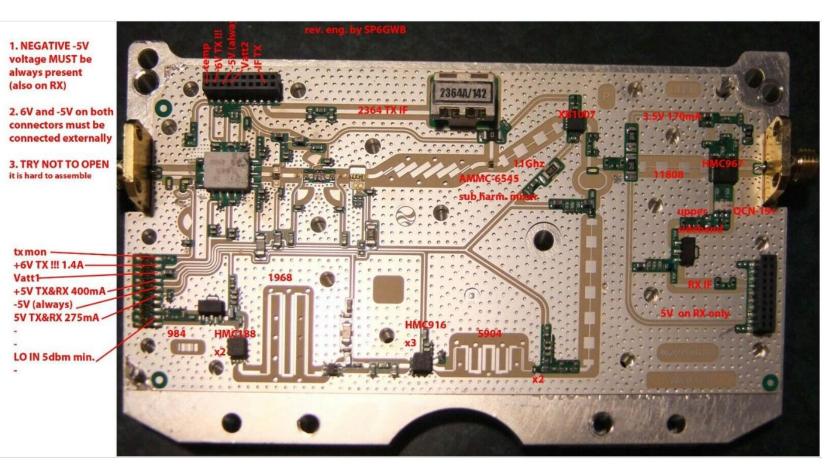
YO4HFU Wavelab 23 specs, schems, photos, reverse engineering: <u>https://www-qsl-</u> <u>net.translate.goog/yo4hfu/Link_23GHz.html?_x_tr_sl=pl&_x_tr_tl=</u> <u>en&_x_tr_hl=en-US&_x_tr_pto=wapp</u>

← C _ @ https:/	/groups.io/g/Wavelab24GHz	H	← C	0MHE/Wavelab-24G-Addon-module	
Groups	Your Groups - Q. Find or Create a Group			uninc/ wavelab-24G-Addon-module	
A Home	Provide the Provide of the Provideo of the Provide	Post of The	Product ~ Solutions ~ Open Source ~ Pricing PAOMHE / Wavelab-24G-Addon-module Public <> Code O Issues 11 Pull requests O Actions E Projects O Security I Insights		
Subscription	at a start of the	A Design value of a set of a s			
Messages	and the second				
# Hashtags					
New Topic					
			🐉 main 🚽 🤔 1 branch 🚫 0 tag	25 Go to	
	Wavelab24GHz@groups.io		PA0MHE Deleted old V5 project fi	le ac64517 2 weeks ago	
	This group like to link all Ham radio amateurs who are building the Wavelab 24G Addon module from PA0MHE. Here we can pose questions, publish results, share improvements or modifications.				
The design files are on the GRHub page: https://github.com/PRAMHE/Mavelat Group Information # https://github.com/PRAMHE/Wavelab-24G-Addon-module # 66 Membery 9 33 Topics 1, Last Post. Jan 8 9 Stanted on 06/02/22	ab-24G-Addon-module	ADF4351_fixed_tiny_24GHz	Update ADF4351_fixed_tiny_24GHz.ino		
	Group Information	Group Settings	HEX files	Added the HEX files	
	A https://github.com/PA0MHE/Wavelab-24G-Addon-module	 All members can post to the group. Posts to this group do not require approva 	Kicad	Deleted old V5 project file	
	S 33 Topics , Last Post. Jan 8	 Posts to this group do not require approval Posts from new users require approval from Messages are set to reply to group. Subscriptions to this group do not require 	V5_documentation	V5 information	
	Group Email Addresses	 Subscriptions to mis group do not require Archive is visible to anyone. Wilki is visible to members only. 	gitattributes	Initial commit	
	Post: Wavelab24GHz@groups.io S Members cannot edit their met	 Wild is visible to members only. Members cannot edit their messages. Members can set their subscriptions to no 	BOM_v04_2.xlsx	Update BOM_v04_2.xlsx	
			ChangeList_V4.txt	Updated schematic	

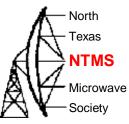




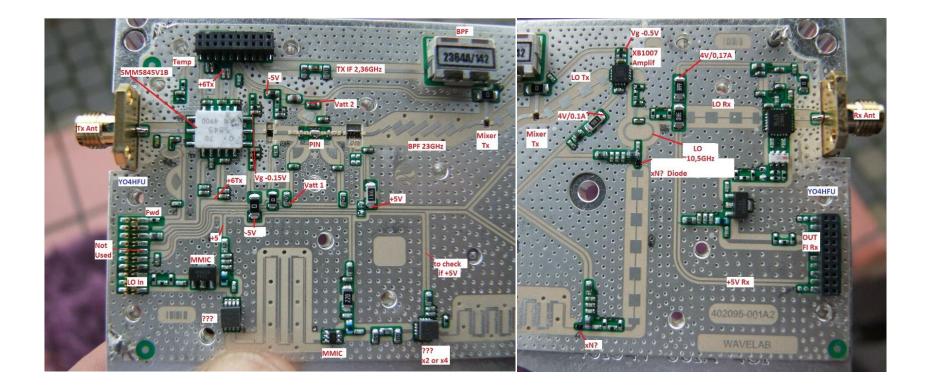
Additional rev eng by SP6GWB

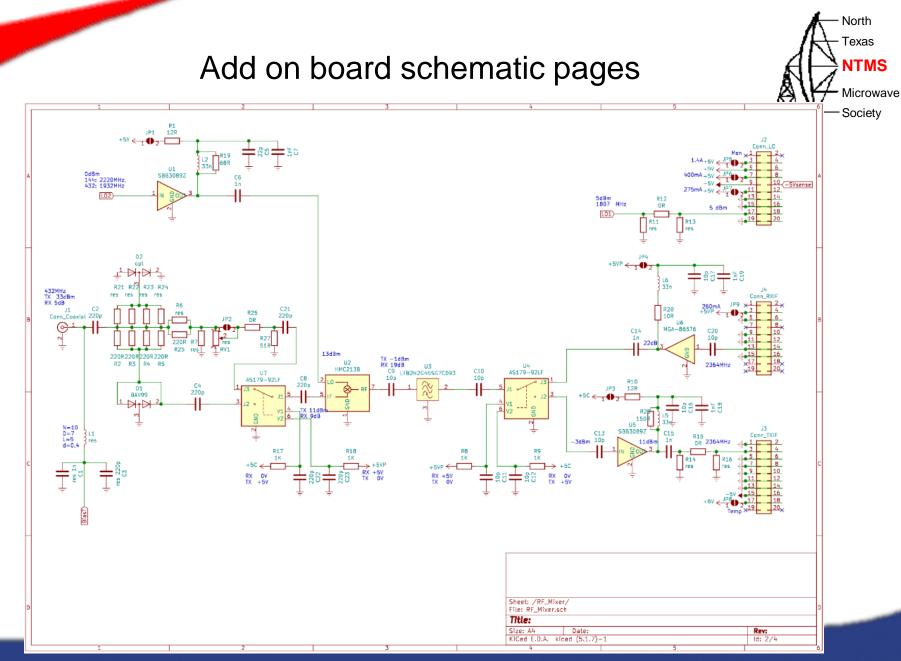


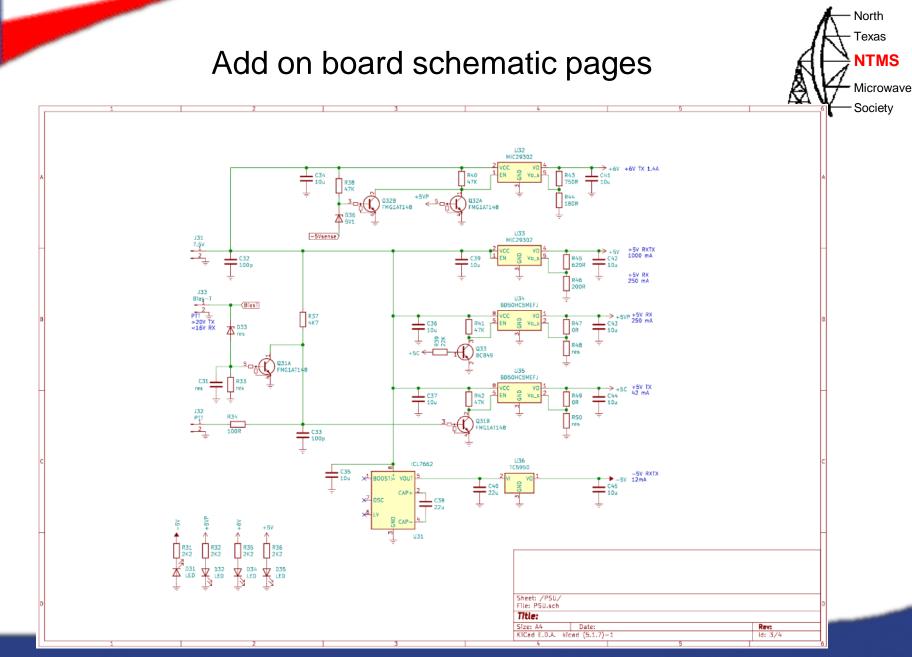
W5HN

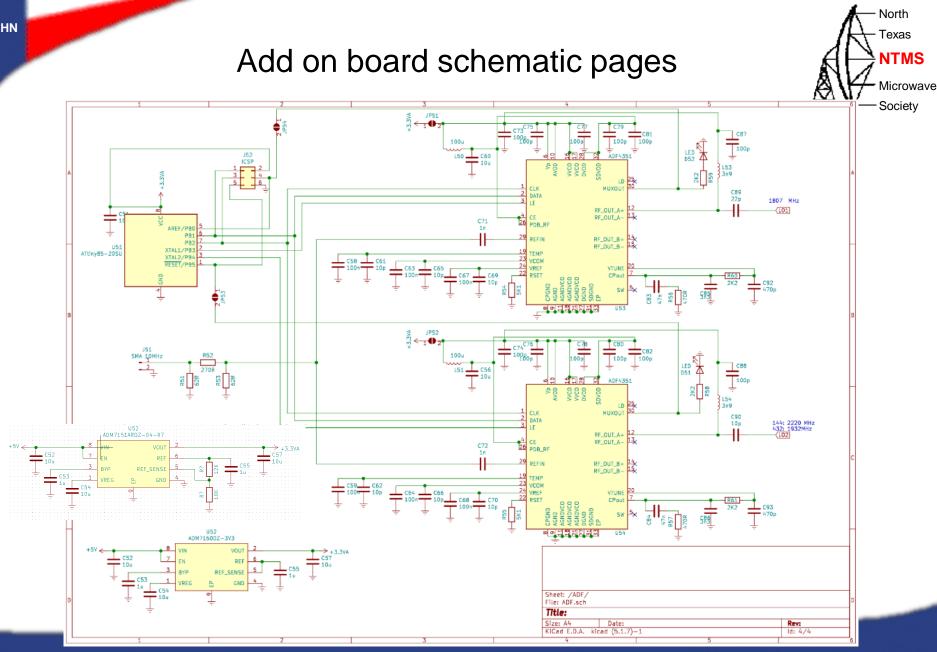


Additional resource





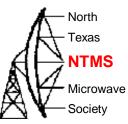




66

W5HN

Questions?





WWW.NTMS.ORG