



VEHICLE POWER SYSTEMS

MIKE PAPPAS, W9CN

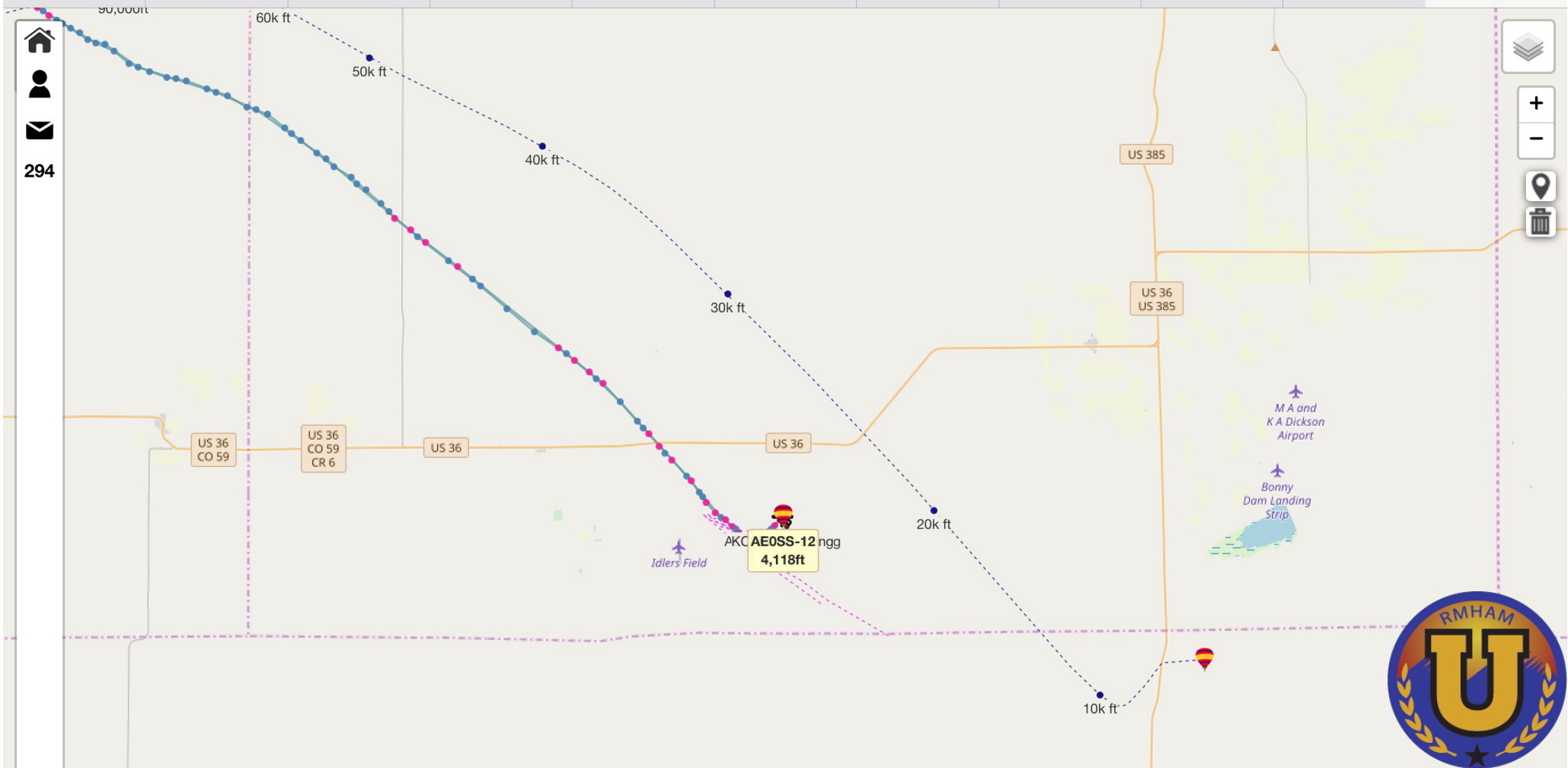


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- Membershi...
- RDX Series...
- AF-S NIKK...
- Med Forma...
- Schneider L...
- Denver Pha...
- EOSS-294...
- Shopping C...
- NMO Magn...
- APRS: Home
- APRS: Map















EVERYTHING YOU WANTED TO KNOW ABOUT VEHICLE POWER SYSTEMS, BUT WERE AFRAID TO ASK

- The ABC's of Vehicle Power Systems

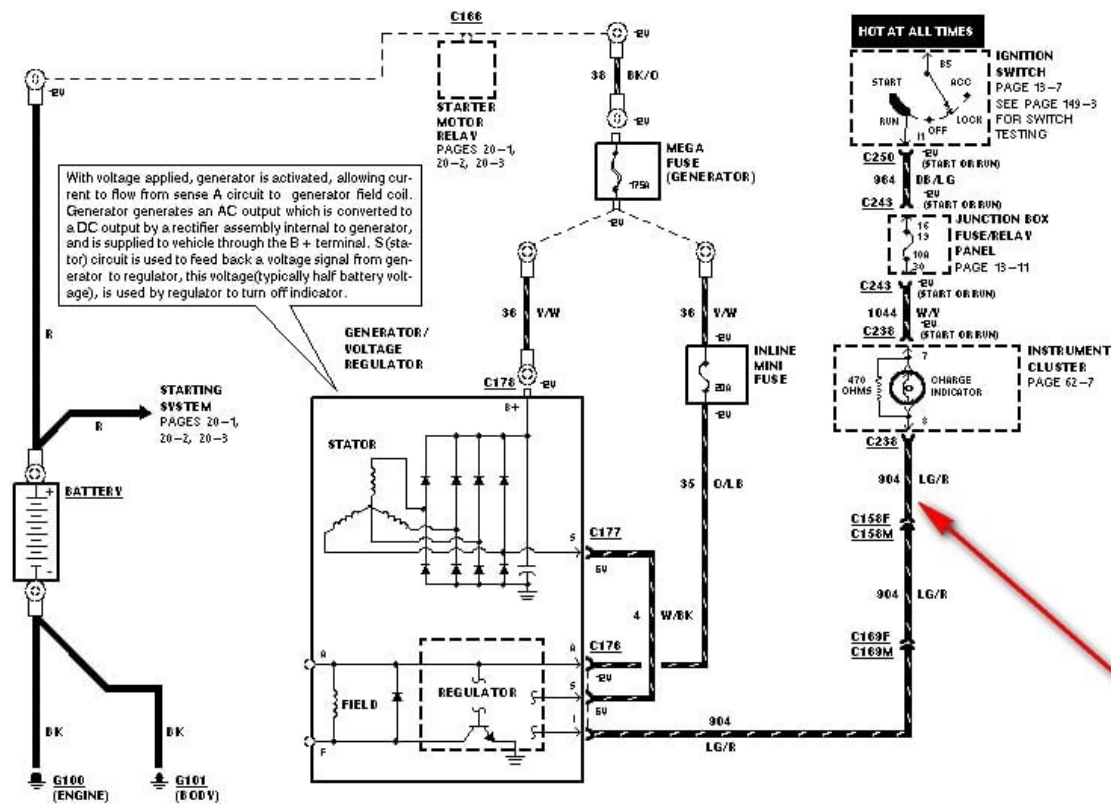


EVERYTHING YOU WANTED TO KNOW ABOUT VEHICLE POWER SYSTEMS, BUT WERE AFRAID TO ASK

- Vehicle power systems consist of
 - **Alternator**
 - **Battery**
 - **Control system**



Charging System (012-1)



ALTERNATOR 101

- 3 Phase Stator
- Rotor Field coil
- Rectifiers (8)
- Voltage regulator





ALTERNATOR 101

- Alternator Rated output (SAE Specifications)
 - Measured at 6,000 RPM alternator shaft speed
 - Which is typically between 2000 to 3000 RPM engine RPM
 - At idle (1500 RPM alternator shaft speed) its typically half of its “rated” output
 - Your 150 amp alternator at idle will have 75 amp output
- Measured at 72 F
 - Typical engine compartment temps at over 140 degrees
 - Output will be less

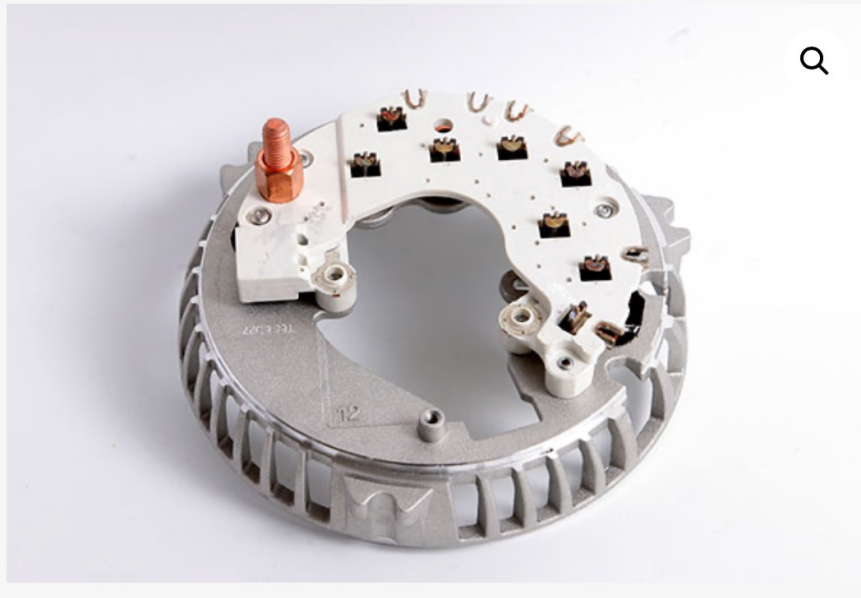


ALTERNATOR 101

- Alternator vulnerabilities
 - Heat is the number one killer of alternators
 - Rectifiers do not like high temperatures and have reduced performance
 - They have gotten better in the last couple of decades
 - Higher electrical loads increase alternator temperature and stress the rectifiers even more
 - Manufacturers put the smallest alternator in most vehicles that they can get away with which increases the load on the rectifiers



ALTERNATOR 101

[HOME](#)[ABOUT US](#)[OE](#)[AFTERMARKET](#)[APPLICATION GUIDE](#)

Ford 6G - T68

\$46.50

SPECIFICATIONS:
RATING: 200AMP
AVALANCHE DIODES

COPPER POSITIVE HEAT SINK
BATTERY POST: 8MM

— 1 +

Add to cart



ALTERNATOR 101

- Alternator vulnerabilities
 - Stators coils
 - Vibration can cause shorts
 - Don't like high temps






ALTERNATOR 101


- Alternator vulnerabilities
 - Regulators
 - Heat
 - Electrical System Faults
 - Wear/Dirt on brushes/slip rings



ALTERNATOR 101



HOME ABOUT US OE AFTERMARKET APPLICATION GUIDE



Ford 6G - T902

\$35.15

Key System Parameters:

- Field Drive Current Limit @ 25°C (min): 8.3 A
- Regulator Setpoint @ 25°C: 14.8 V
- Ambient Temperature Range: -35°C / 150°C
- Thermal Shutdown (min): 160°C
- Initiate Regulation Speed: 610 rpm
- Load Response Control Rate: 40 %/s = 2.5 sec.
- LRC Transition Speed:** 3100 rpm

" A " CIRCUIT - LOW SIDE DRIVE

- 1 +

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Alternator voltage regulator with load response control

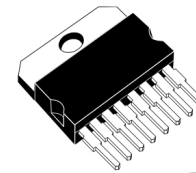
Features

- IC regulator for 12 V type alternator
- Fixed frequency regulation loop
- 130 m Ω high side field driver
- Fail safe device with double sensing of battery voltage (VB and VS)
- Load response control (LRC) function activates after an initial time delay
- Self start function from phase frequency
- “Z” shaped regulation curve compliant with VW specification.
- Key recognition from L input
- Field driver, lamp driver and relay driver short protection
- Complex diagnostics
- Thermal shutdown at 175 °C

Description

The L9409 is a monolithic multifunction alternator voltage regulator intended for use in automotive applications.

The device regulates the output of an automotive generator by controlling the field winding current by means of either an analog fixed frequency PWM signal or digital fixed frequency PWM signal (LRC). The Load Response Control function is activated in order to eliminate IC engine speed fluctuation and vibrations caused by the insertion



Multiwatt8

of sudden electrical loads during alternator low speed operations ($f < 310$ Hz). Both the analog and digital duty cycle are applied to a high side driver.

The device is able to regulate the voltage either using a feedback signal from B pin or from S pin depending on application needs. S pin is intended to have a clear direct connection with the positive terminal of the car battery. If this connection gets lost the device will regulate voltage using B pin giving a fail safe functionality.

Using L pin is possible to sense key switch and a pre-excitation duty cycle is applied on the field coil in order to start phase voltage sensing. In the case L connection gets lost, device starts to generate using residual magnetism of the generator.

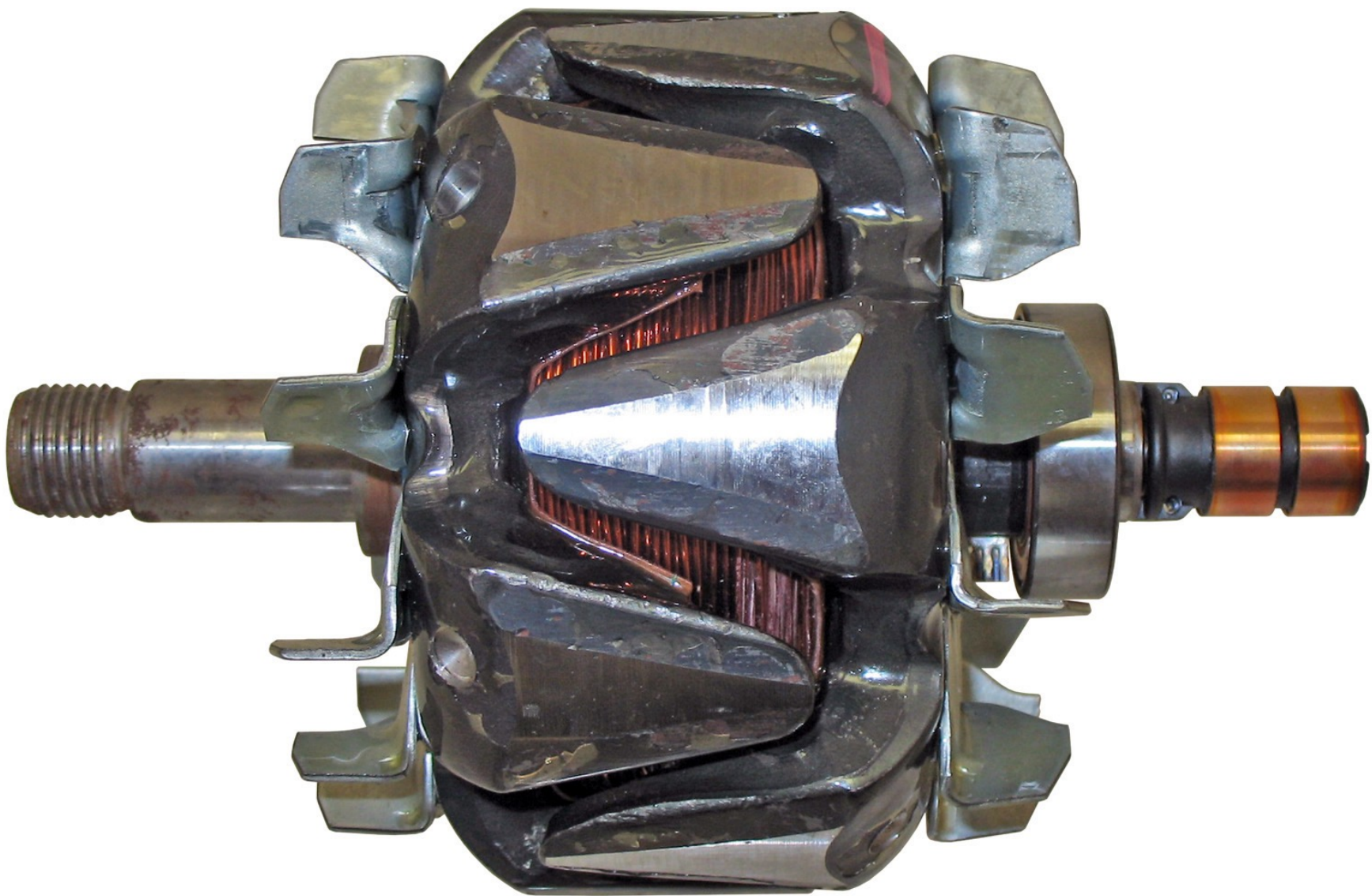
Field, lamp and relay drivers are protected against short circuit.



ALTERNATOR 101

- Alternator vulnerabilities
 - Rotor
 - Wear/Dirt on slip rings
 - Bearings 6000 RPM
 - Significant Rotational mass





ALTERNATOR 101

- Alternator vulnerabilities
 - New alternators use “clutches”



ALTERNATOR 101

- Alternator vulnerabilities
 - Overrunning Alternator Pulley (OAP)
 - Designed to reduce shocks on the front drive belt system
 - PDK transmissions have “lightning fast” shifts
 - Caused by the high rotational force of the alternator rotor going to war with the crankshaft
 - Can seize or decouple the alternator
 - Can require special tools to replace





ALTERNATOR 101



ALTERNATOR 101



BATTERY 101

- A battery is a chemical storage system
 - In automobiles it's referred to as an SLI battery
 - SLI: Starting Lighting Ignition
 - Note: Doesn't say anything about "radios"
 - Usually lead acid design
 - Some manufacturers have switched to AGM



BATTERY 101

- Fully charged lead acid battery
 - 12.5 VDC (measured 24 hours after charging to allow “surface charge” to dissipate)
- 50% discharged lead acid battery
 - 11.5 VDC
- Fully discharged lead acid battery
 - 10.5 VDC
- Note: AGM Batteries voltages are higher



BATTERY 101

- Battery Specs
 - Cold Cranking Amps (CCA):
 - The discharge load in amperes that a new, fully charged battery can deliver at 0 degrees F for 30 seconds while maintaining a voltage of 1.20 volts/cell or higher
 - Cranking Amps (CA):
 - The discharge load in amperes that a new, fully charged battery at 32 degrees F can continuously deliver for 30 seconds while maintaining a terminal voltage equal to or higher than 1.20 volts/cell
 - Note: 0 degrees for CCA vs 32 degrees for CA



BATTERY 101

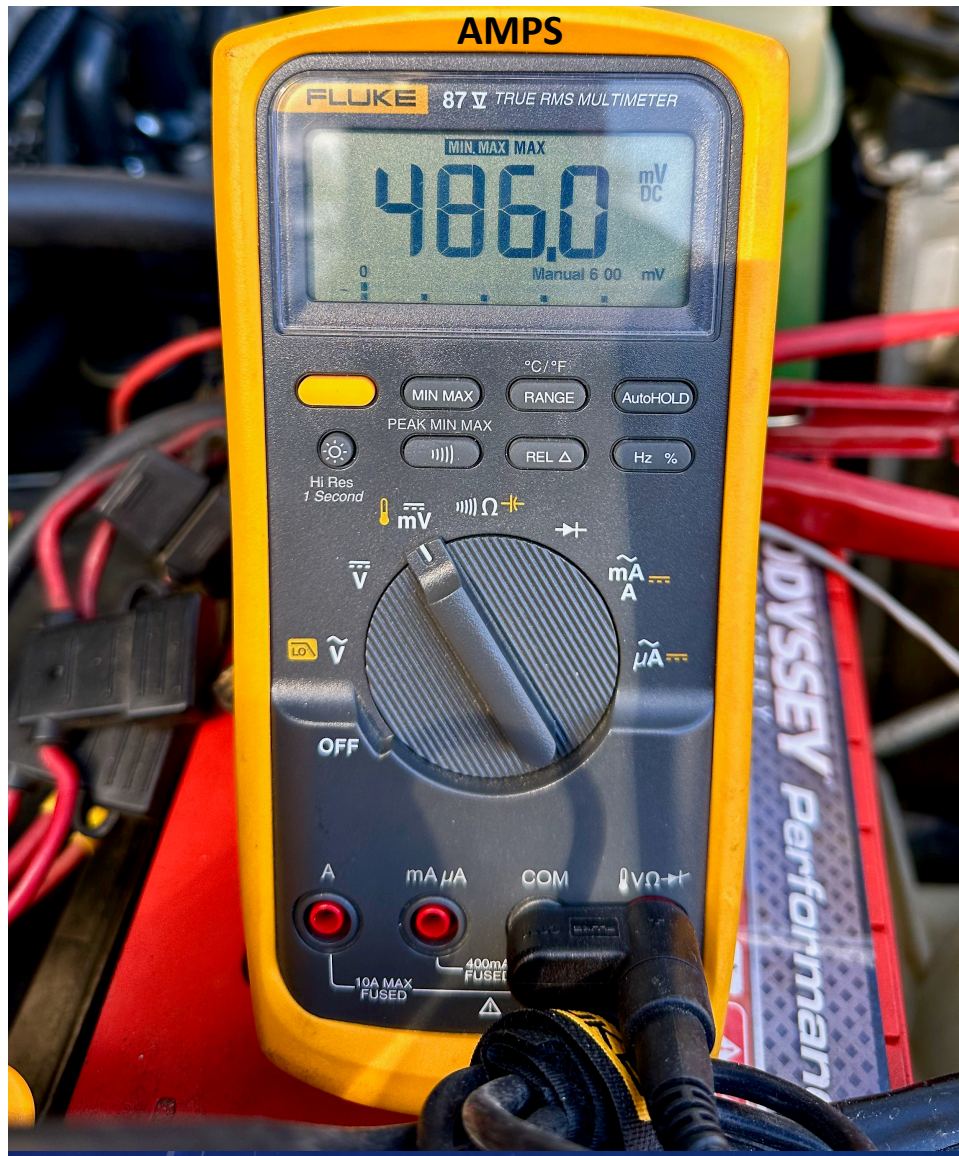
- Battery Specs
 - Reserve Capacity (RC):
 - The number of minutes a new, fully charged battery at 80 degrees F can be discharged at 25 amperes while maintaining a voltage of 1.75 volts/cell or higher.
 - For a 12-volt battery (six cells), RC is the number of minutes it can maintain a voltage of 10.5 volts with a 25-amp draw; therefore, a "75-minute" battery lasts 75 minutes under these conditions

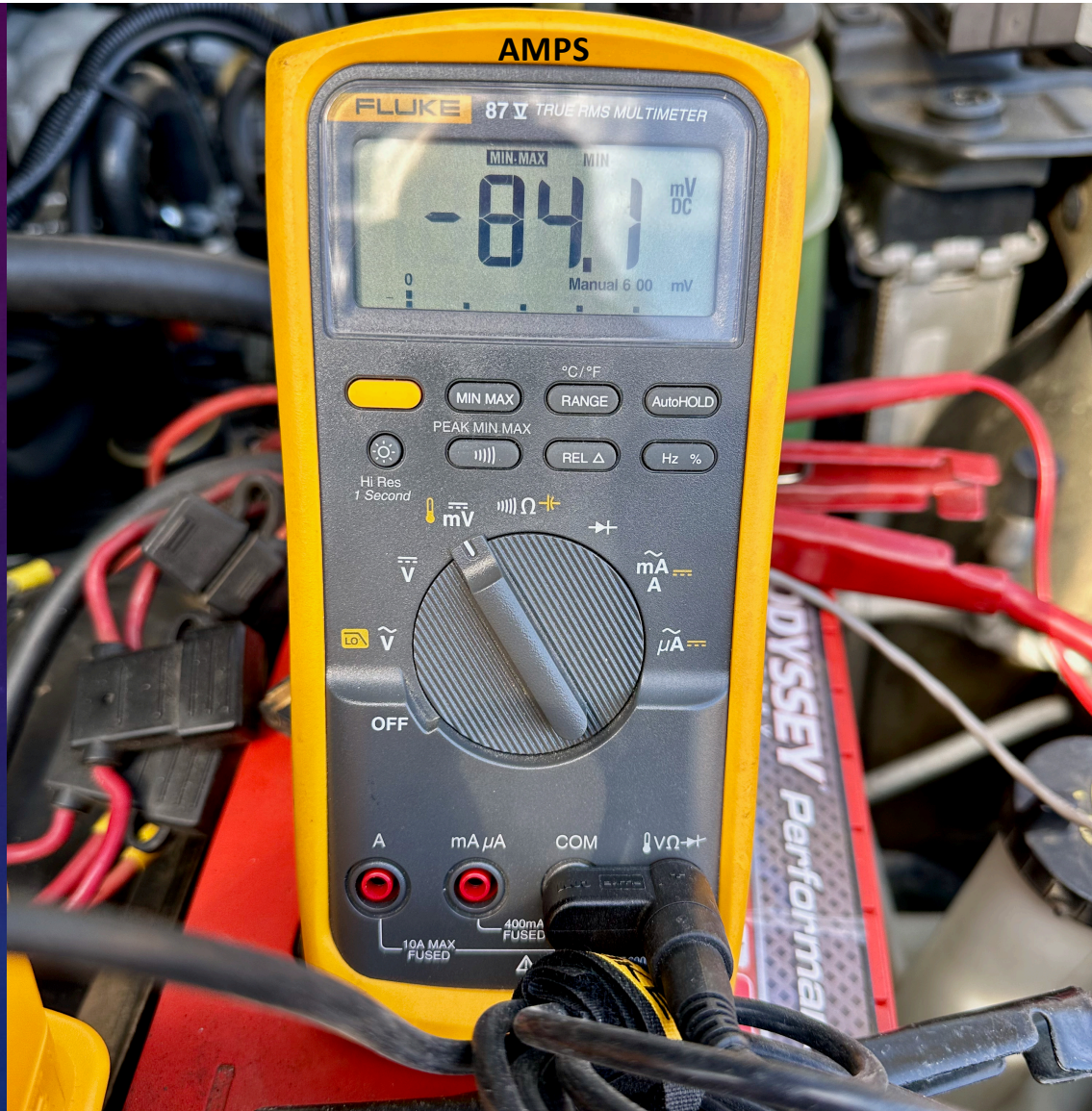


BATTERY 101

- Life Span:
 - Depends upon how much abuse it gets
 - Figure 3 to 5 years
 - Less if you beat it to death
 - High temps are not good for them
 - The engine compartment can hit 160 F in the summer-time
 - Cold temps reduce the available cranking current
 - Hundreds of amps to crank an engine







VEHICLE 101

- Vehicle manufactures are under intense pressure to hit their EPA CAFÉ milage numbers
- Everything is under a microscope
- The EPA “incentivizes” manufactures to employ various “schemes” to improve gas milage
- The “Auto Start Stop” system in many vehicles gives the manufacture a 0.5 MPG CAFÉ bonus
 - Even though it doesn’t improve gas milage in the EPA MPG test cycle
 - It does in my opinion, beat starters and batteries to death



VEHICLE 101

- Many now use advanced power system management techniques
- Including
 - Cycling the Alternator on and off
 - Discharging the battery to 11.5 VDC (50% discharge) before turning the alternator back on
 - Which kills batteries
 - The cynic in me says that they have these systems setup to just get the battery past the warranty
 - Managing the alternator output and measuring the current output and battery state of charge to reduce engine load and “improve” gas mileage



VEHICLE 101

- The ECM looks at the bus voltage and current being delivered by the alternator and the current in/out of the battery
- It makes some decisions to turn on or off the alternator or decrease/increase its output
- Uses the only battery (until it hits 11.5 VDC)
- EPA gives them a 0.5 MPG CAFÉ credit for this
 - Even though it doesn't improve gas mileage in the EPA MPG test cycle
 - It does beat batteries to death



VEHICLE 101



VEHICLE 101



VEHICLE 101

- This makes using the vehicle electrical systems for amateur radio more “interesting”



RADIO 101

- So now that you have an overview of a vehicles electrical system how do you get clean power to your radio(s)
- Motorola recommends the radio be fed from the Positive Terminal of the battery
- And negative tied to chassis



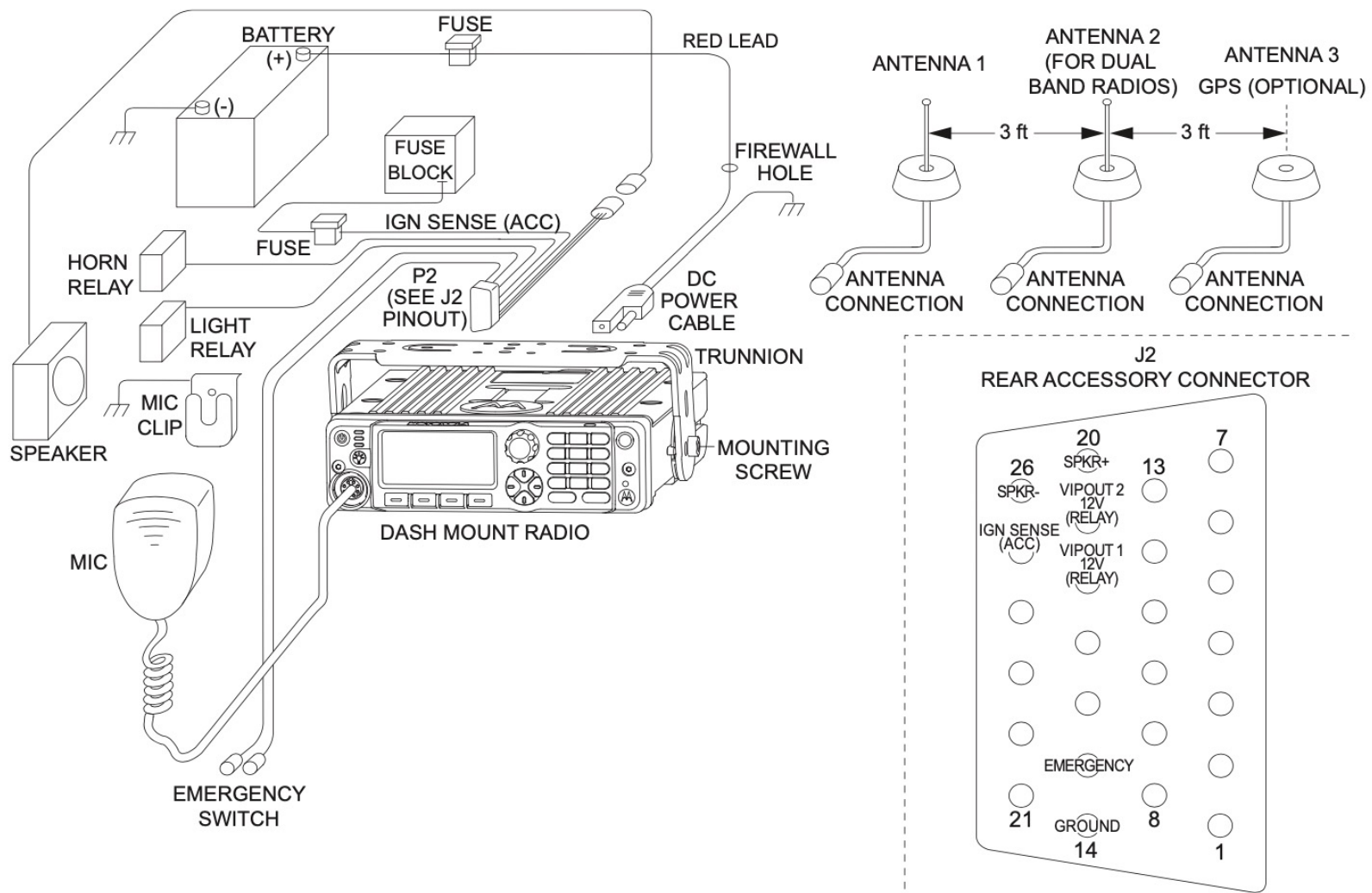


Figure 2-7. Radio Installation (O7 Mid Power Dash Mount)



RADIO 101

- Motorola recommends the radio be fed from the Positive Terminal of the battery
 - Note the fuse in the positive lead near the battery
 - All Motorola power harnesses have a fuse holder with fuse at the far end of the harness
- Negative tied to the chassis
 - I try to put the negative lead as close to the battery as possible
 - This will tend to be the lowest noise point in the system



RADIO 101

- Places not to use
 - Cigarette lighter sockets
 - Those are not designed to be low noise, high current sources
 - They are designed to be cheap
 - No good comes from using them for your radio
 - At the end of any OEM wiring harnesses
 - Those are not designed to be low noise, high current sources
 - They are designed to be cheap
 - No good comes from using them for your radio



RADIO 101

- Battery Boosters
 - I am not fan of battery boosters
 - Significant RFI issues
 - PWM and it varies with load
 - Which means you can be chasing your tail around looking for the RFI problem
 - 90% efficiency
 - Which increases your electrical system load by an additional 10%!
 - Can run your battery down to the point it won't start your car



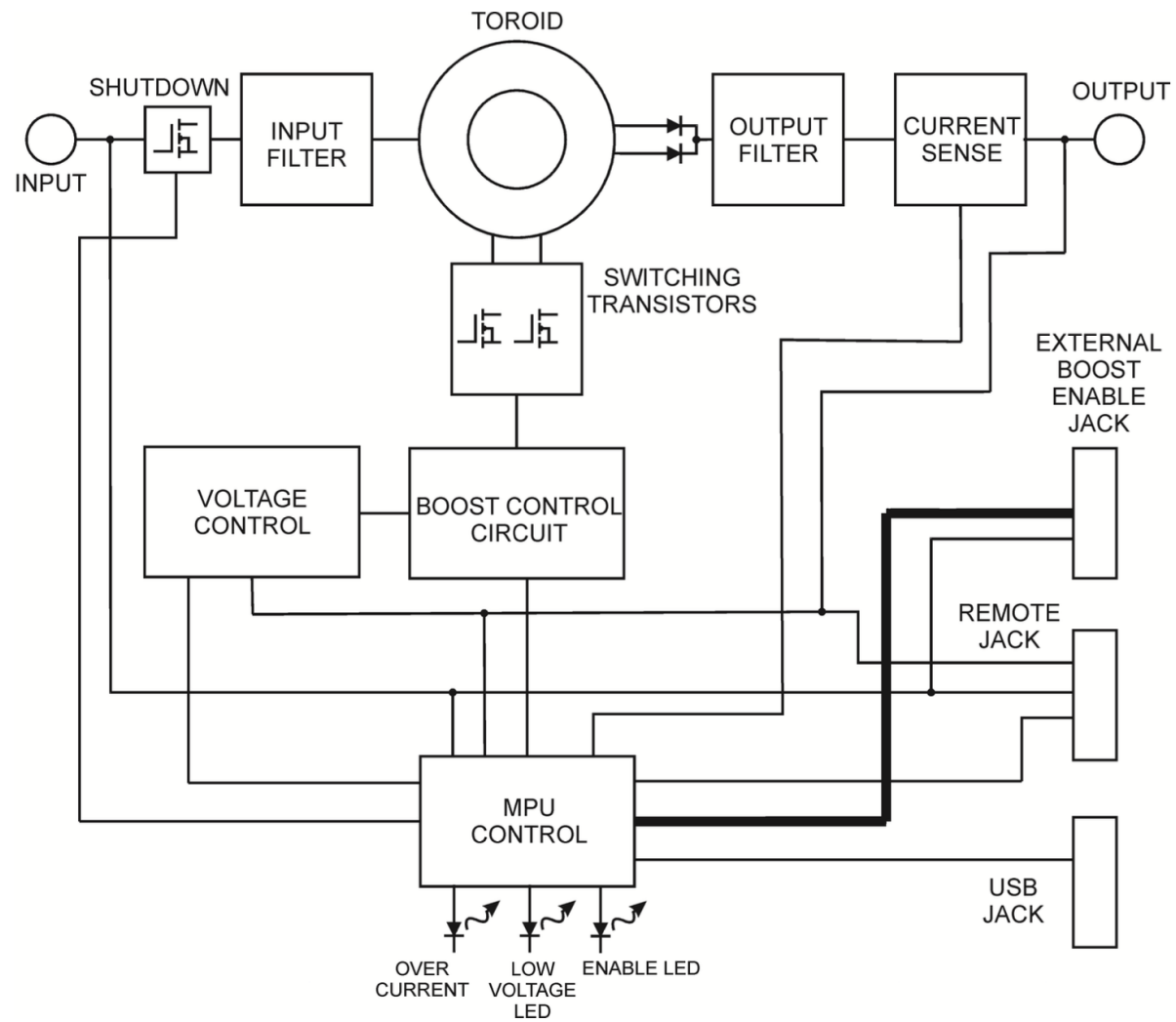
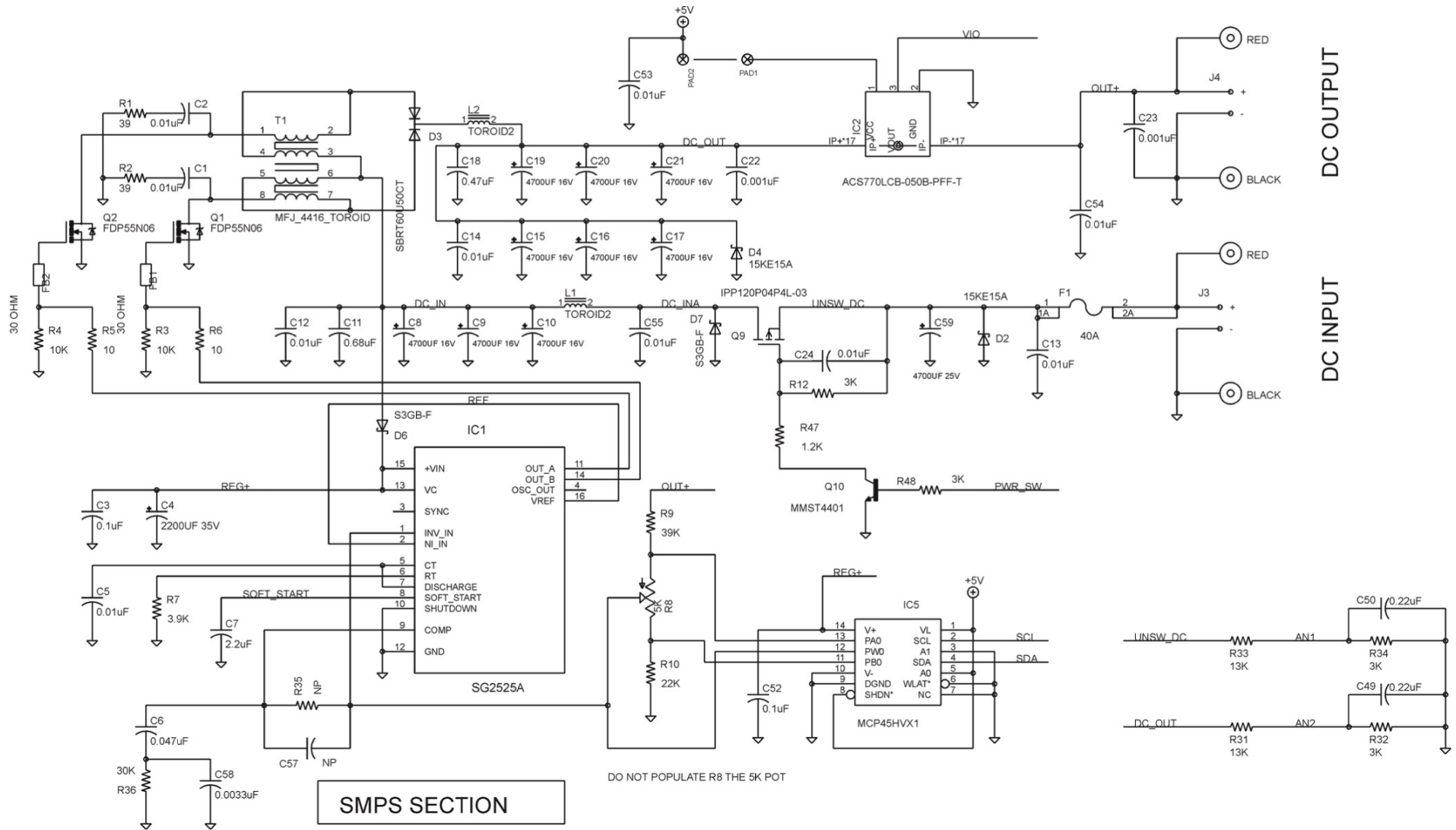


Figure 10 Block Diagram



Figure 11 SMPS Section Schematic





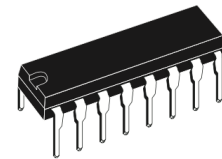
SG2525A
SG3525A

REGULATING PULSE WIDTH MODULATORS

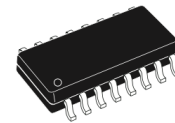
- 8 TO 35 V OPERATION
- 5.1 V REFERENCE TRIMMED TO $\pm 1\%$
- 100 Hz TO 500 KHz OSCILLATOR RANGE
- SEPARATE OSCILLATOR SYNC TERMINAL
- ADJUSTABLE DEADTIME CONTROL
- INTERNAL SOFT-START
- PULSE-BY-PULSE SHUTDOWN
- INPUT UNDERVOLTAGE LOCKOUT WITH HYSTERESIS
- LATCHING PWM TO PREVENT MULTIPLE PULSES
- DUAL SOURCE/SINK OUTPUT DRIVERS

DESCRIPTION

The SG3525A series of pulse width modulator integrated circuits are designed to offer improved performance and lowered external parts count when used in designing all types of switching power supplies. The on-chip + 5.1 V reference is trimmed to $\pm 1\%$ and the input common-mode range of the error amplifier includes the reference voltage eliminating external resistors. A sync input to the oscillator allows multiple units to be slaved or a single unit to be synchronized to an external system clock. A single resistor between the C_T and the discharge terminals provide a wide range of dead time adjustment. These devices also feature built-in soft-start circuitry with only an external timing capacitor required. A shutdown terminal controls both the soft-start circuitry and the output stages, providing instantaneous



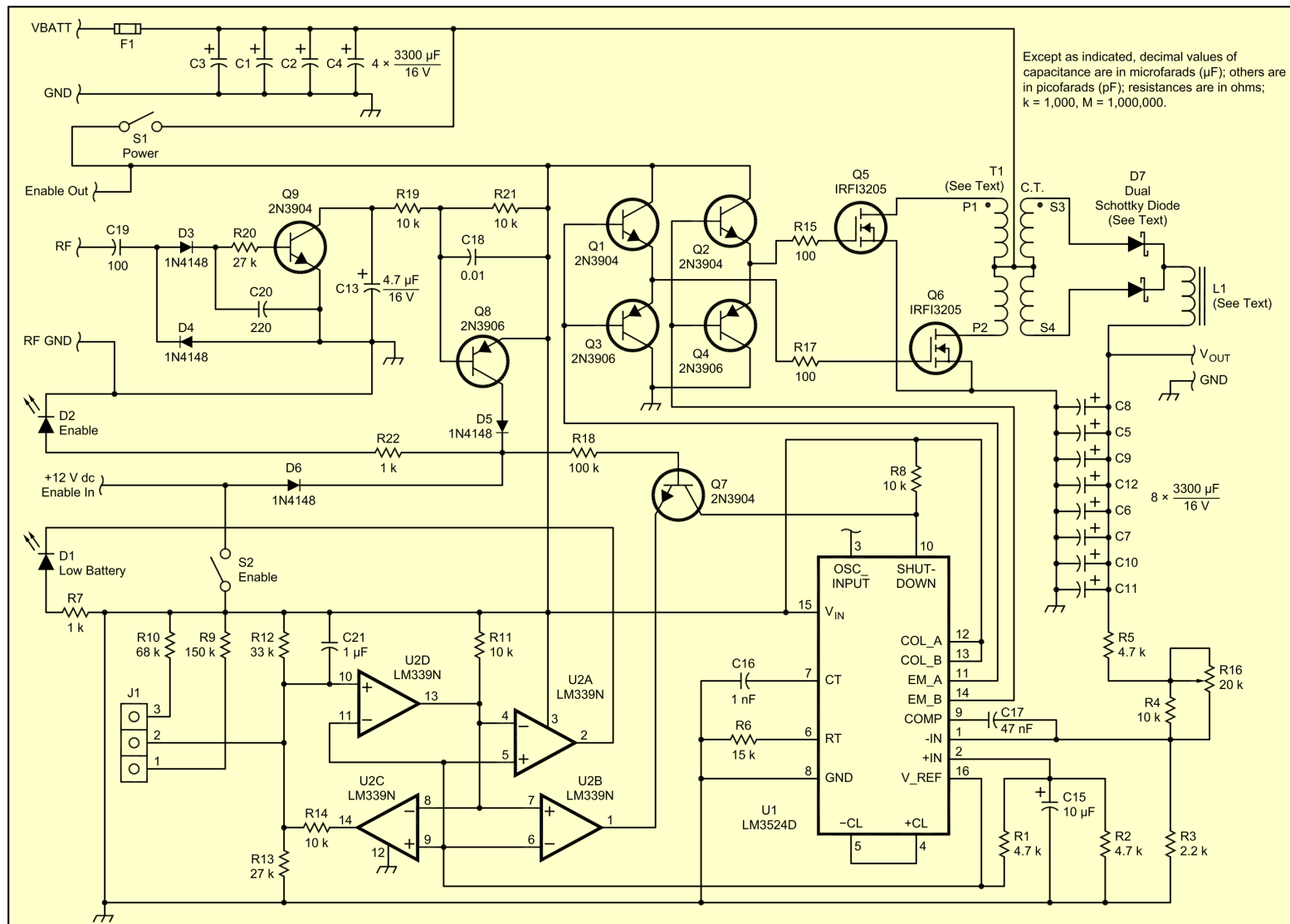
DIP16



16(Narrow)

turn off through the PWM latch with pulsed shutdown, as well as soft-start recycle with longer shutdown commands. These functions are also controlled by an undervoltage lockout which keeps the outputs off and the soft-start capacitor discharged for sub-normal input voltages. This lockout circuitry includes approximately 500 mV of hysteresis for jitter-free operation. Another feature of these PWM circuits is a latch following the comparator. Once a PWM pulses has been terminated for any reason, the outputs will remain off for the duration of the period. The latch is reset with each clock pulse. The output stages are totem-pole designs capable of sourcing or sinking in excess of 200 mA. The SG3525A output stage features NOR logic, giving a LOW output for an OFF state.





LM2524D/LM3524D Regulating Pulse Width Modulator

Check for Samples: [LM2524D](#), [LM3524D](#)

FEATURES

- **Fully Interchangeable With Standard LM3524 Family**
- **$\pm 1\%$ Precision 5V Reference With Thermal Shut-Down**
- **Output Current to 200 mA DC**
- **60V Output Capability**
- **Wide Common Mode Input Range for Error-Amp**
- **One Pulse per Period (Noise Suppression)**
- **Improved Max. Duty Cycle at High Frequencies**
- **Double Pulse Suppression**
- **Synchronize Through Pin 3**

DESCRIPTION

The LM3524D family is an improved version of the industry standard LM3524. It has improved specifications and additional features yet is pin for pin compatible with existing 3524 families. New features reduce the need for additional external circuitry often required in the original version.

The LM3524D has a $\pm 1\%$ precision 5V reference. The current carrying capability of the output drive transistors has been raised to 200 mA while reducing V_{CEsat} and increasing V_{CE} breakdown to 60V. The common mode voltage range of the error-amp has been raised to 5.5V to eliminate the need for a resistive divider from the 5V reference.

In the LM3524D the circuit bias line has been isolated from the shut-down pin. This prevents the oscillator pulse amplitude and frequency from being disturbed by shut-down. Also at high frequencies (≈ 300 kHz) the max. duty cycle per output has been improved to 44% compared to 35% max. duty cycle in other 3524s.

In addition, the LM3524D can now be synchronized externally, through pin 3. Also a latch has been added to insure one pulse per period even in noisy environments. The LM3524D includes double pulse suppression logic that insures when a shut-down condition is removed the state of the T-flip-flop will change only after the first clock pulse has arrived. This feature prevents the same output from being pulsed twice in a row, thus reducing the possibility of core saturation in push-pull designs.



RADIO 101

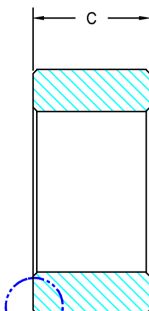
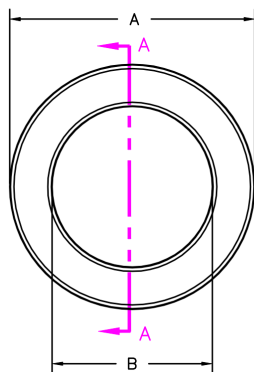
- Battery Boosters
 - There is no free lunch with using a booster
 - The lower the battery voltage the more current the booster will draw from the battery
 - Plus the additional 10% loss in the booster
 - 100 W load plus the loss of the booster is now 110 watt load
 - Ohms law always wins
 - 110 W
 - @ 12.5 VDC is 8.8 A
 - @ 11.5 VDC is 9.56 A
 - @ 10.5 VDC is 10.47 A



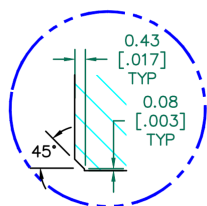
RADIO 101

- Battery Boosters
 - From the MFJ Manual
 - Noise Reduction
 - Although every effort was made to reduce switching noise RF noise is a possibility. **To reduce noise to a minimum ground the case of the MFJ-4418 to the automotive chassis with as short of a wire or grounding braid as possible.** Clamp on ferrite beads can be used on the input and out power leads to further reduce noise. 1 or 2 turns through the bead will help.
 - Clamp on ferrite “beads” only start working above 450 MHz
 - You need big ones to get down to below VHF





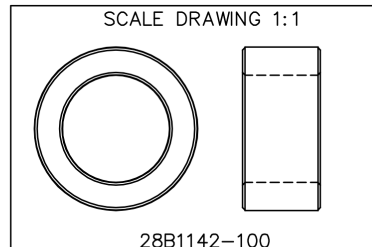
SEE DETAIL "A"
SECTION A-A




DETAIL "A"
CHAMFER
SCALE=4:1

NOTES: UNLESS OTHERWISE SPECIFIED

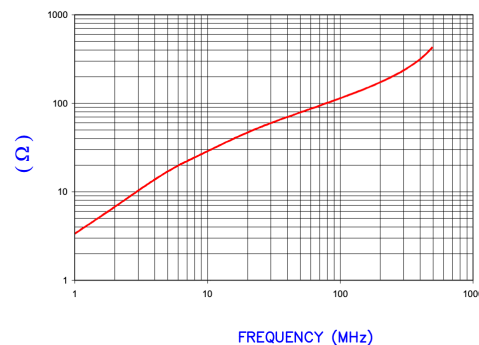
1. COSMETIC SPECIFICATION REFER TO WI-QA-038.



DIMENSIONS ARE IN mm [INCHES].				This print is the property of Laird Tech. and is loaned in confidence subject to return upon request and with the understanding that no copies shall be made without the written consent of Laird Tech. All rights to design or invention are reserved.		<div></div>			
F	UPDATE LOGO	05/22/15	QIU						
E	UPDATE PRINT FORMAT, Z SPECS & CURVE CHANGE C TOLERANCE TO 0.35[.014]	07/22/03	JRK	PROJECT/PART NUMBER: 28B1142-100		REV	F	DRAWN BY:	Jcai
D	UPDATE PRINT, REM COATING SPECS CHG P/N FROM 00* ADD Z CURVE UPDATE Z SPECS	11/07/02	JRK			DATE:	12/28/92	SCALE:	1.5 : 1
C	CHG P/N ADD COATING SPECS	03/19/99	IS	CAD #	28B1142-100-F	TOOL #	B1142		
B	UPDATED P/N FOR NEW CATALOG	10/31/95	JBE						
A	ORIGINAL DRAFT	12/28/92	LNK						
REV	DESCRIPTION	DATE	INT						

IMPEDANCE (Z)			
Frequency	25 MHz	100 MHz	300 MHz
Nominal (REF)	54 Ω	114 Ω	235 Ω
Minimum	- Ω	91 Ω	- Ω

Z vs. FREQUENCY
(REF. ONLY)



AGILENT E4991A Impedance/Material Analyzer
HP 16092A Test Fixture

FERRITE CORE DIMENSIONS (SPEC): mm/inches

A	29.01 [1.142]	±	0.51 [.020]
B	19.00 [.748]	±	0.38 [.015]
C	13.84 [.545]	±	0.35 [.014]

WEIGHT/1000 25.67 kgs [56.59 Lbs]

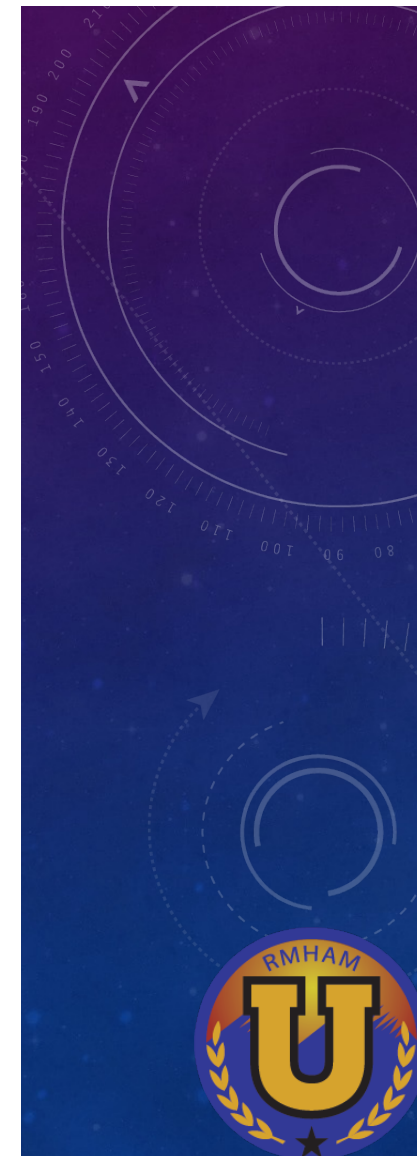




Image shown is a representation only. Exact specifications should be obtained from the product data sheet.



28B1142-100

DigiKey Part Number

240-2314-ND

Manufacturer

[Laird-Signal Integrity Products](#)

Manufacturer Product Number

28B1142-100

Description

FERRITE CORE 114 OHM SOLID 19MM

Manufacturer Standard Lead Time

12 Weeks

Customer Reference

Detailed Description

Solid Free Hanging Ferrite Core 1140Ohm @ 100MHz ID 0.748" Dia (19.00mm) OD 1.142" Dia (29.01mm) Length 0.545" (13.84mm)

Datasheet

[Datasheet](#)

EDA/CAD Models

[28B1142-100 Models](#)

In-Stock: 6,168

Can ship immediately

QUANTITY

Add to List

Add to Cart

All prices are in USD

Tray

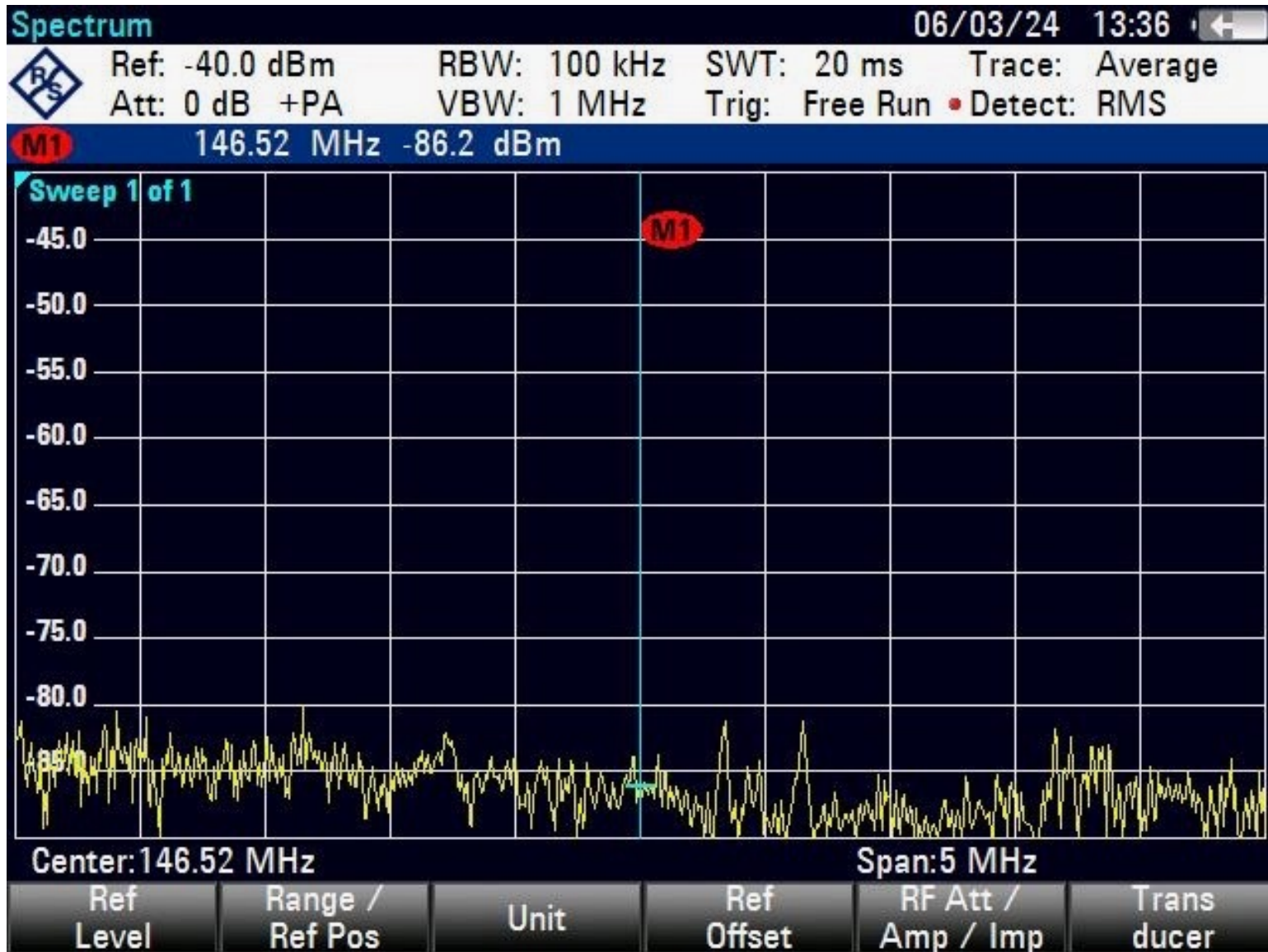
QUANTITY	UNIT PRICE	EXT PRICE
1	\$1.62000	\$1.62
10	\$1.39500	\$13.95
25	\$1.06040	\$26.51

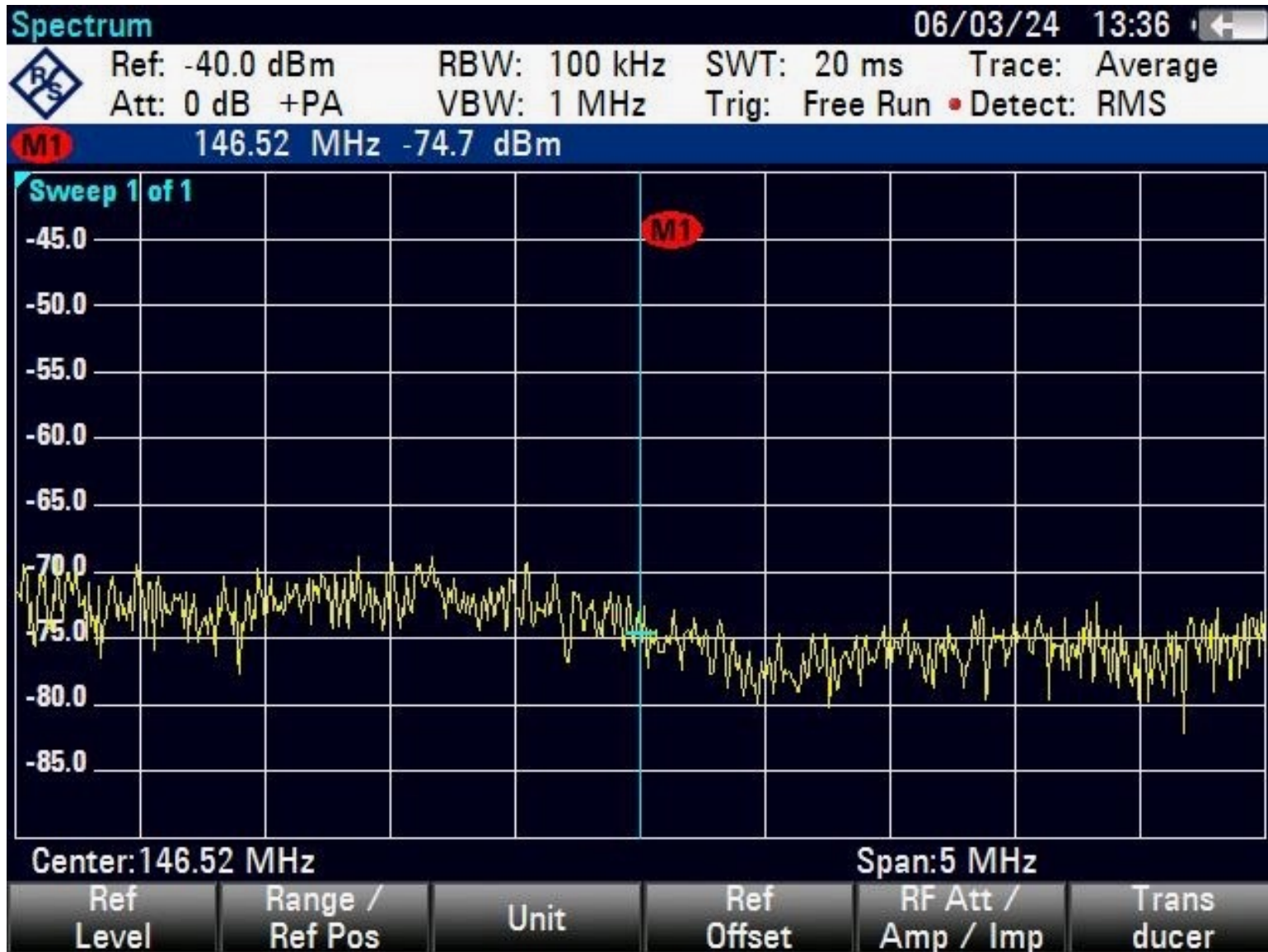


RADIO 101

- Battery Boosters
 - RFI Testing VHF 146.520





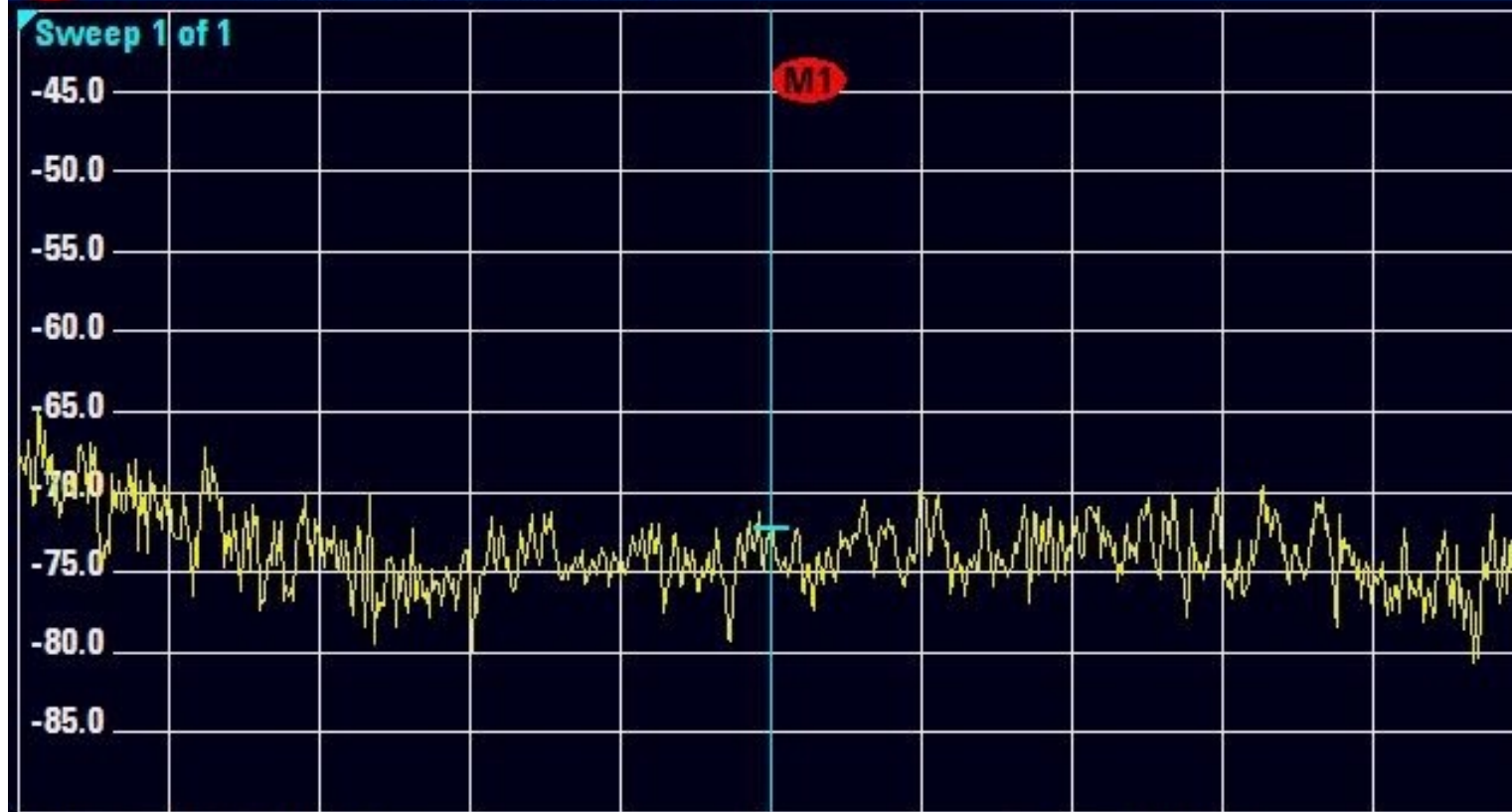


Spectrum

06/03/24 13:37

Ref: -40.0 dBm RBW: 100 kHz SWT: 20 ms Trace: Average
Att: 0 dB +PA VBW: 1 MHz Trig: Free Run Detect: RMS

M1 146.52 MHz -72.3 dBm

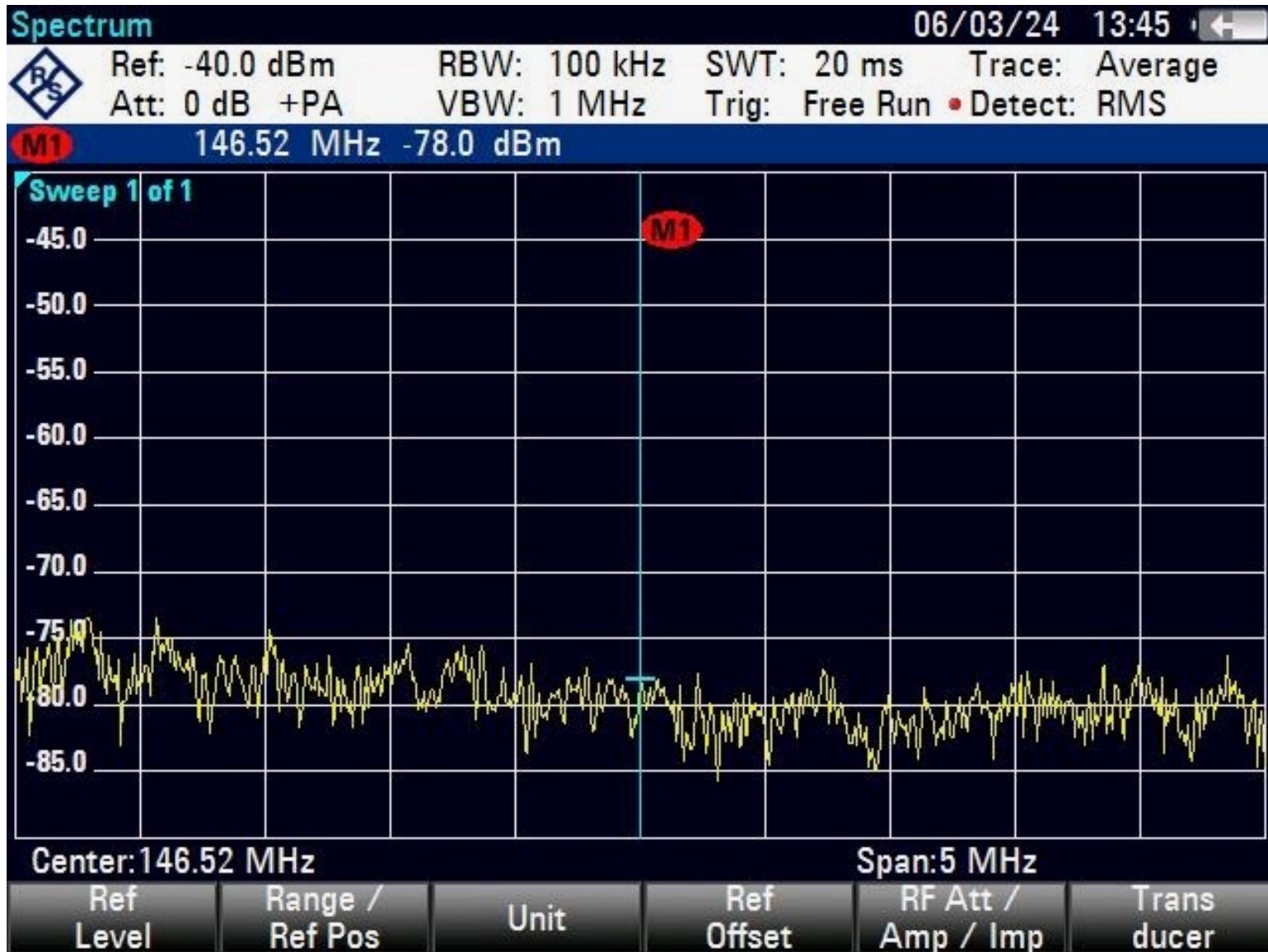


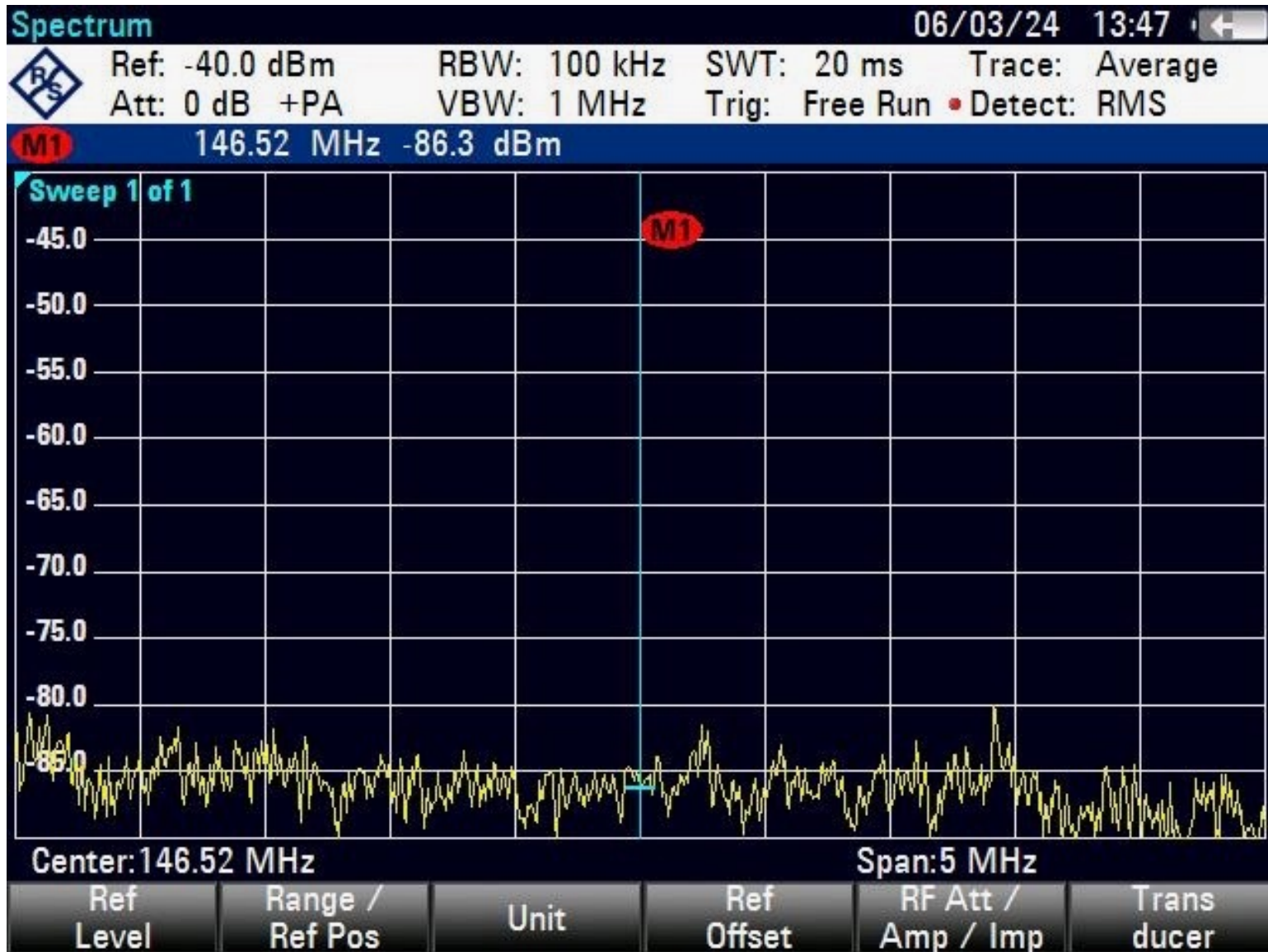
Center: 146.52 MHz Span: 5 MHz

Ref Level	Range / Ref Pos	Unit	Ref Offset	RF Att / Amp / Imp	Trans ducer





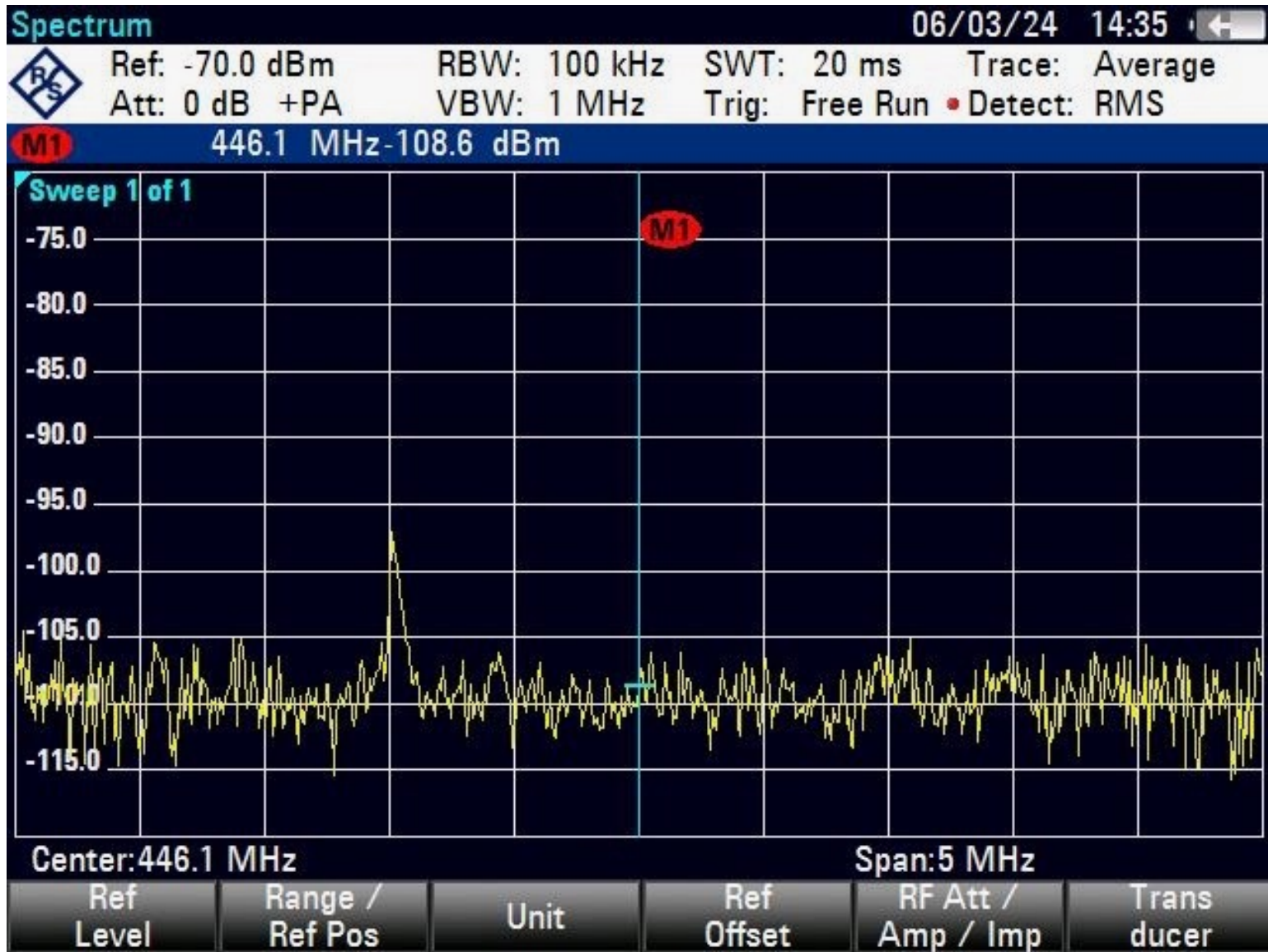


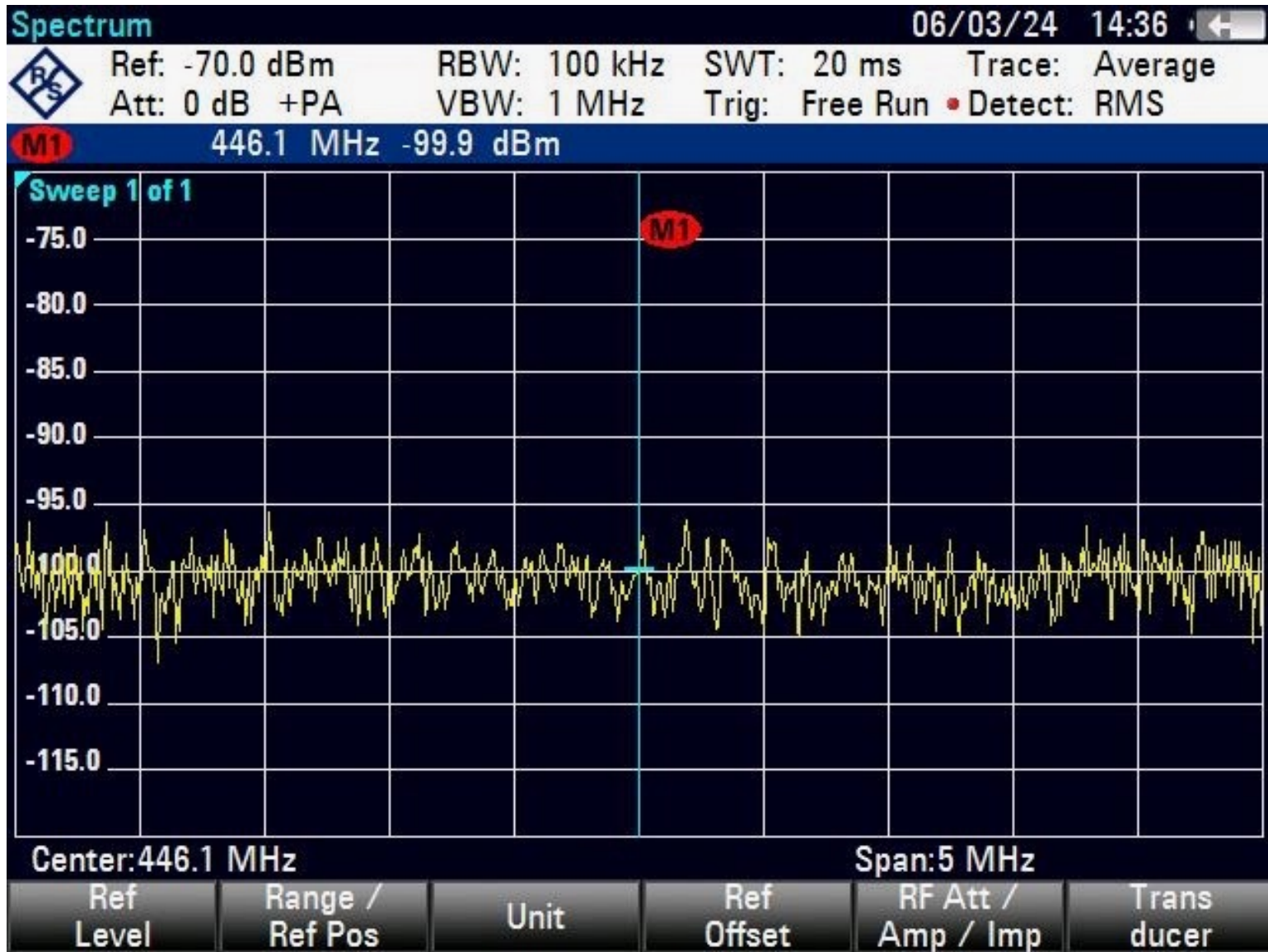


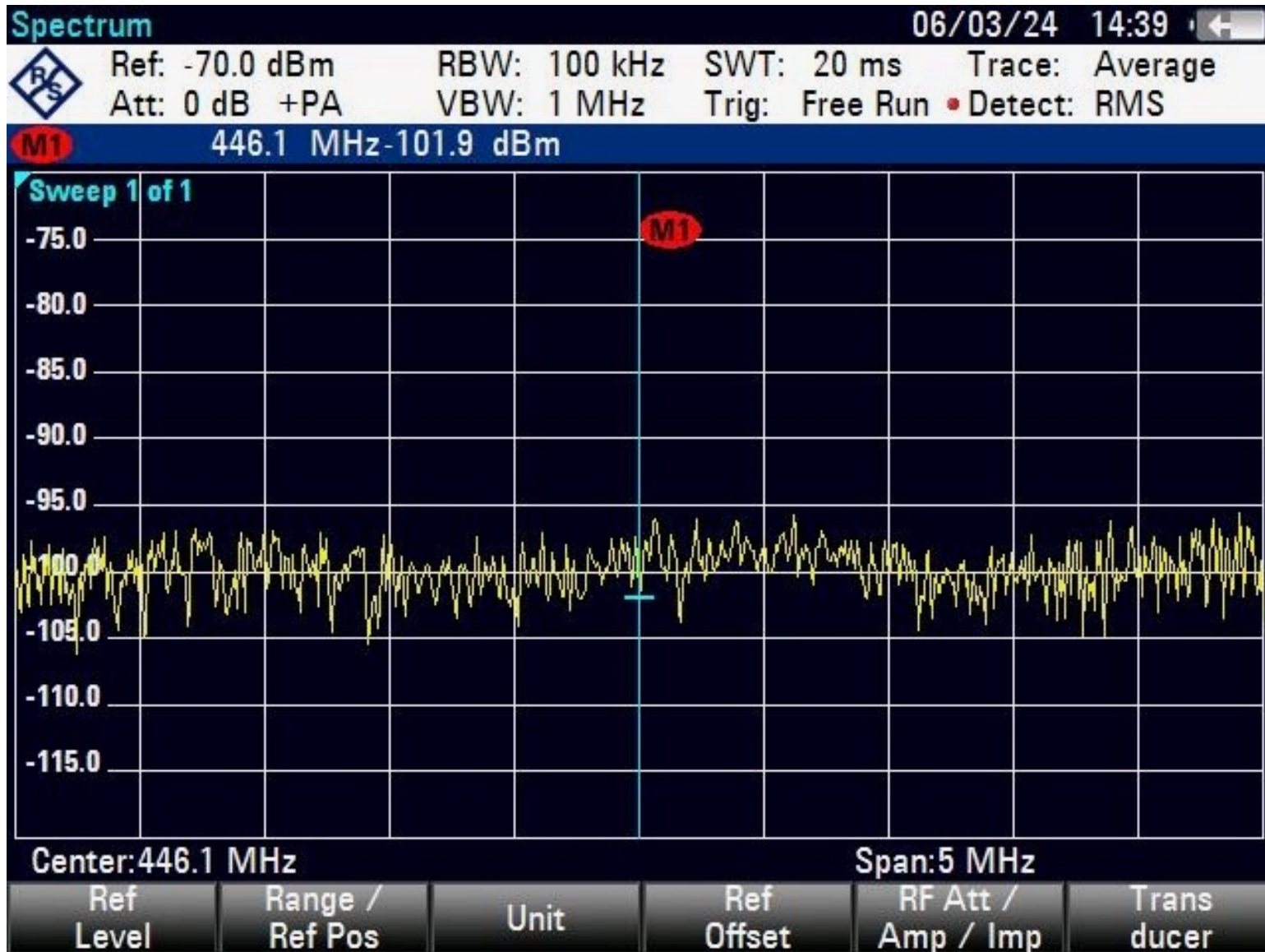
RADIO 101

- Battery Boosters
 - RFI Testing UHF 446.100







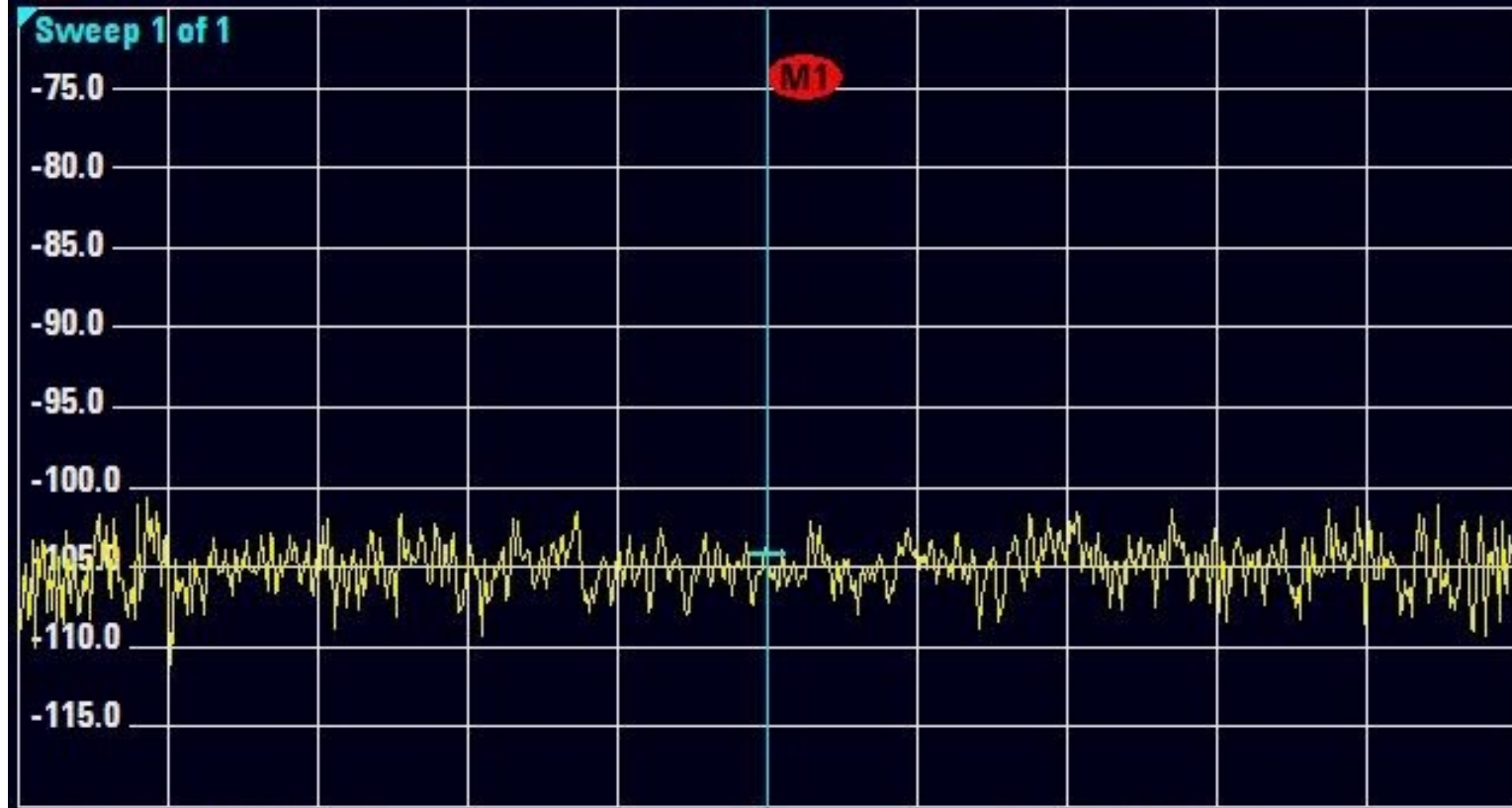


Spectrum

06/03/24 14:40

Ref: -70.0 dBm RBW: 100 kHz SWT: 20 ms Trace: Average
Att: 0 dB +PA VBW: 1 MHz Trig: Free Run Detect: RMS

M1 446.1 MHz-104.3 dBm



Center: 446.1 MHz Span: 5 MHz

Ref Level	Range / Ref Pos	Unit	Ref Offset	RF Att / Amp / Imp	Trans ducer



RADIO 101

- Battery Boosters Radio Testing
 - How much TX power do you lose from 13.5 VDC to 12.5 VDC to 11.5 VDC??
 - Let's look at a Motorola XTL 2500 P25 UHF 40 W radio
 - Test Setup
 - HP8920A Communications Test Set Calibrated by Amtronix in 2019
 - Astron RS-35M 25 A power supply



RADIO 101



RADIO 101

- Battery Boosters Radio Testing
- Motorola XTL 2500 P25 UHF Test Frequency 446.100
 - 11.500 VDC 39.9W 8.9A 102.9 W
 - 12.500 VDC 42.6W 8.3A 103.7 W
 - 13.508 VDC 44.1W 7.9A 106.7 W
 - 14.299 VDC 44.2W 7.6A 108.7 W (max voltage out of the Aston)



RADIO 101

- Battery Boosters Radio Testing Power output in dBm
 - 11.500 VDC 39.9W 46.01 dBm
 - 12.500 VDC 42.6W 46.29 dBm
 - 13.508 VDC 44.1W 46.44 dBm
 - 14.299 VDC 44.2W 46.45 dBm (max voltage out of the Aston)
 - **From 11.500 VDC to 14.299 VDC there is 0.44 dBm output power difference.**
 - That's effectively **Zero**.



RADIO 101

- Battery Boosters Radio Testing
 - How much TX power do you lose from 13.5 VDC to 12.5 VDC to 11.5 VDC??
 - Let's look at a Motorola XTL 2500 P25 VHF 50 W radio
 - Test Setup
 - HP8920A Communications Test Set Calibrated by Amtronix in 2019
 - Astron RS-35M 25 A power supply



RADIO 101

- Battery Boosters Radio Testing
- Motorola XTL 2500 P25 VHF 50W Test Frequency 146.520
 - 11.500 VDC 44.5W 8.0A 92.0 W
 - 12.500 VDC 52.1W 8.4A 105.0 W
 - 13.508 VDC 52.1W 7.8A 105.3 W
 - 14.299 VDC 52.1W 7.8A 105.3 W (max voltage out of the Aston)



RADIO 101

- Battery Boosters Radio Testing Power output in dBm
- Motorola XTL 2500 P25 VHF 50 W Test Frequency 146.520
 - 11.500 VDC 44.5W 46.48 dBm
 - 12.500 VDC 52.6W 47.17 dBm
 - 13.508 VDC 52.6W 47.17 dBm
 - 14.299 VDC 52.6W 47.17 dBm (max voltage out of the Aston)
 - **From 11.500 VDC to 14.299 VDC there is 0.69 dBm output power difference.**
 - That's effectively **Zero**.





RADIO 101

- Understanding Vehicle Loads
 - On the 2001 Ford Excursion with 4 radios, DF System, 5G LTE modem, DMR Repeater and upwards of 5 computers the technical load is 29.8 Amps.
 - The Whelen light bar is 40 Amps with the rear “hide-a-away” strobes its 50 Amps
 - The AC running wide open with both front and rear blowers is 30 amps
 - Headlights and sundry loads (SLI) is about 40 amp.
 - Total 149.8 amps





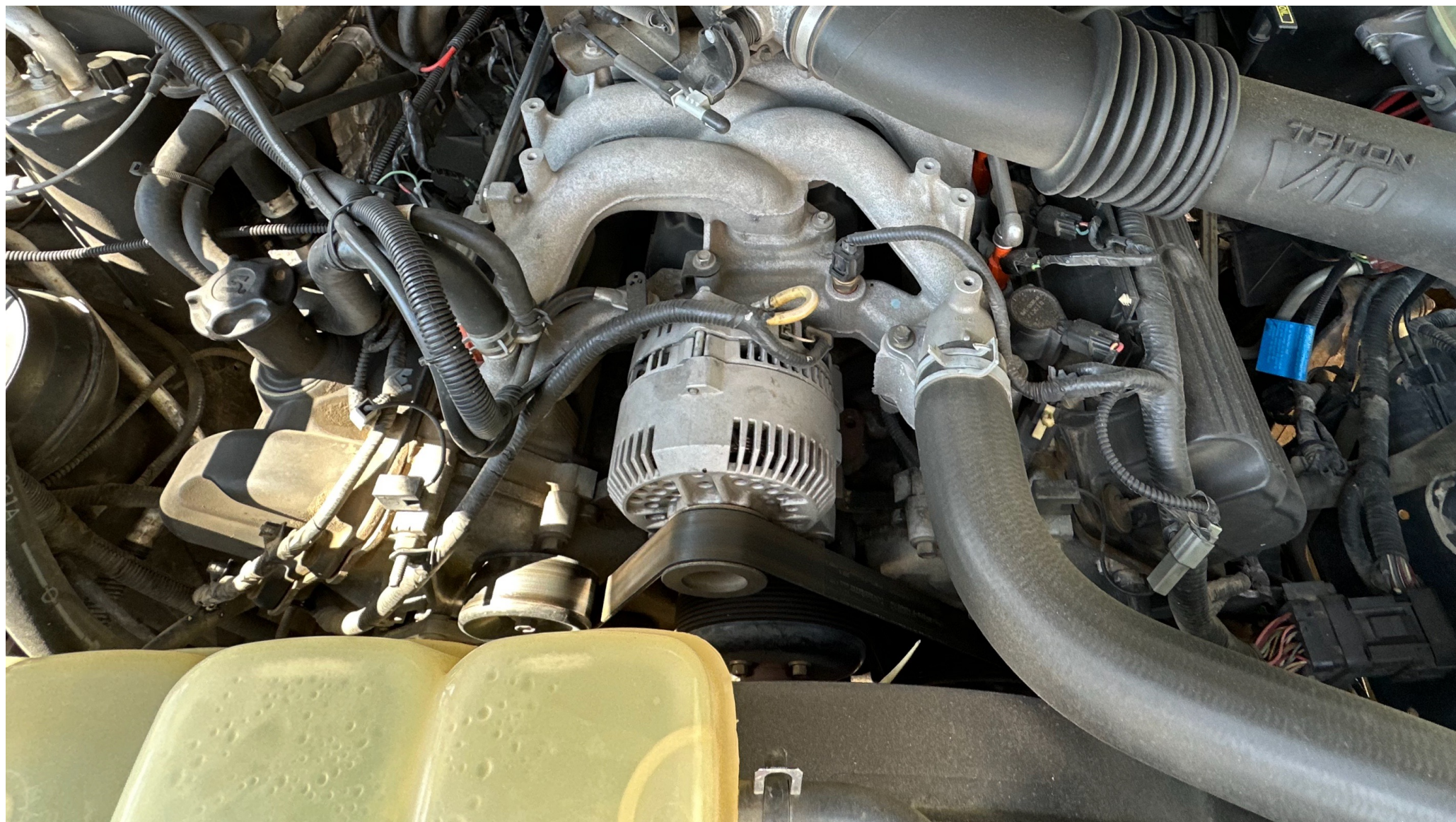
RADIO 101



RADIO 101

- Vehicle Loads
 - Total 149.8 amps
 - Stock alternator 130 Amp
 - At idle its 65 Amp
 - That didn't work
 - We had National Quick Start build a 250 Amp alternator with external rectifier pack
 - We had them put a smaller pulley on it to get us 150 Amp at idle
 - We are right on the ragged edge



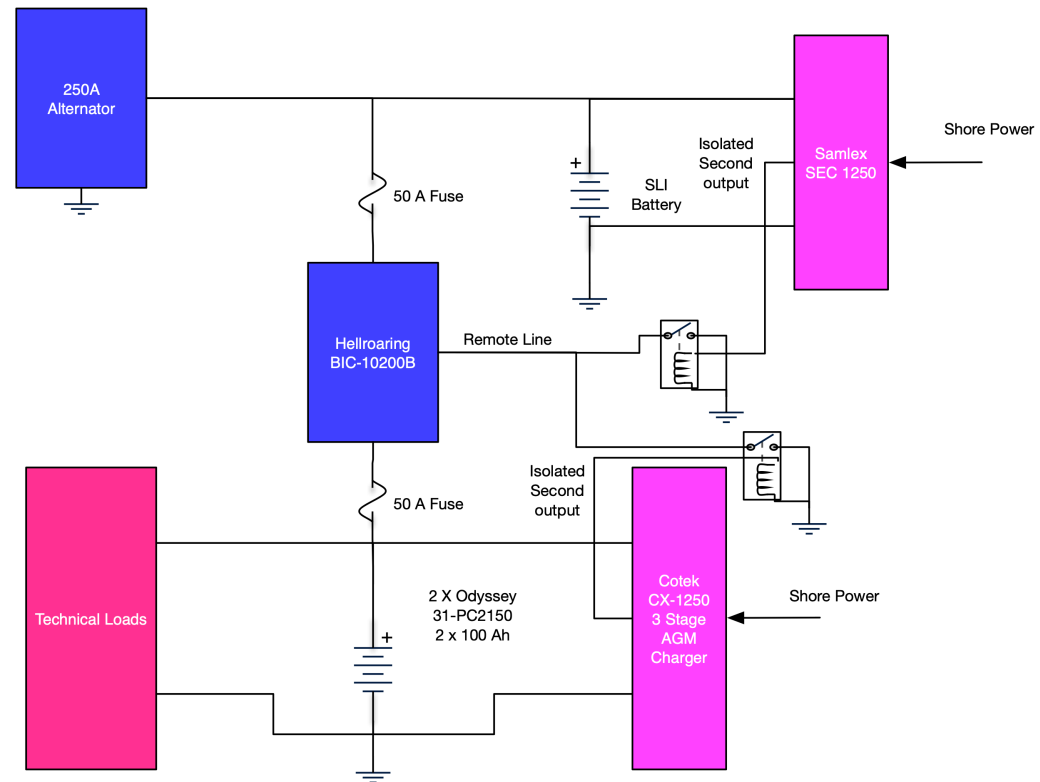




RADIO 101

- Vehicle Loads
 - If we had to do it all over again we would add a second alternator & battery for just the “technical loads”





Excursion Block Diagram
22MAY2023 V4



RADIO 101



RADIO 101

- Problem Diagnostics
 - Alternator “whine” on TX audio
 - Bad battery
 - Bad Alternator
 - Bad wiring
 - Dead Battery
 - Parasitic loads (or left the radio on)
 - Bad Battery
 - Bad or undersized alternator not capable of keeping up with all of the loads



RADIO 101

- Problem Diagnostics
 - RFI
 - Battery booster
 - Ground the booster to the frame of the vehicle with a very short strap.
 - Ferrite cores on both input and output as close to the booster as possible



RADIO 101

- Problem Diagnostics
 - RFI
 - Ground straps on hood and trunk (hinges are notoriously bad ground paths)
 - Ground Straps on exhaust system at both ends



QUESTIONS?



THANK YOU!

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