Power Management and Battery Performance for the FTD1 and FT2D

This document discusses how power is used in the FT1D and FT2D HT's so that you can better optimize your radio's configuration to get the best battery life for your intended use of the radio.

Coming soon: Compare power consumption of various features on different HTs!

Bottom Line

Use the battery voltage, not the battery indicator to indicate remaining battery life. Stop using the battery when the voltage falls below 7.4 volts. Note that your maximum output does go down as the voltage goes down.

Good and bad news: First the bad, some 3rd party batteries don't fit in the CD-41 drop-in charger. The good news is that you can use the CD-15A charger and it will support the VX-5 -> VX8 and the Fusion HT's.

Abstract

This document addresses battery performance in the Yaesu Fusion HT's. It performs a standard test using the radios and measures run time for various batteries. Use of the radio for battery drain was chosen so that these tests can be done by any Ham owning an HT.

This test allows us to estimate the relative performance of a battery and to determine if the battery has deteriorated over time. This information can be helpful when selecting a battery and deciding when to replace it.

Furthermore, recommendations are made to achieve maximum battery life. Historical data is provided to give an idea of battery performance over time.

Additional data is given regarding chargers and possible modifications.

Document History

Revision	Date	Description
1	24-Dec-2014	Initial release
2	2-Jan-2015	Added “Bottom Line”
3	14-Jan-2015	Added text requesting document not be reposted, made link permanent
4	30-Jul-2015	Retested Batteries America battery for decrease in capacity of time and usage. Note on CT-41 modification. Removed power management test procedure.
5	21-Oct-2015	● Added data on the Yaesu 2,200 mAh battery ● Tested all batteries on the FT2DR ● Added historical battery longevity data on the VX-1 and VX-5 ● Reformatted the performance tables
6	18-Jan-2016	Updated CT-41 information
7	15-Apr-2016	- Added FT2 power consumption - Added Table of Contents - Added CT-41 charge current detail
8	4-Jun-2016	- Added FT1DR power consumption for comparison to the FT2 - Added FT60 and VX-8DR for reference

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FT1DR Battery Measurements

Bottom Line

Turn stuff off you don't need (like GPS). Set the Rx Save to pulse the receiver on and off to reduce average power. Don't leave both receivers on if they're not necessary. Digital takes more power than analog.

Measurement Procedure

An FTD1 is programmed as follows:

1. Both receivers are on.
2. Both receivers are tuned to a UHF frequency.
3. The 'A' side is set to DN.
4. The GPS receiver is turned on.
5. Rx Save is turned off.
6. APO is turned off.
7. The APRS modem is disabled - there are no conditions under which the radio will transmit.
8. The antenna is removed.
9. Measurements are taken at room temperature (20 C).
10. The display is set to the sensor info page.
11. The battery is fully charged in the drop-in charger (green light is on).
12. The radio is turned on and monitored until it shuts off. Voltage, voltage indicator, time, and temperature are recorded.

Measurement Results FT1DR

The procedure was performed on two FT1Ds with new Yaesu 1,100 mAh and 1,800 mAh batteries. The procedure was also performed with a Batteries America new 2,000 mAh battery.

The Table 1 summarizes the performance of the batteries.

Table 1 Summary of battery performance

ID	Battery	Discharge Time (hours)	Norm	Performance Rating Larger implies greater capacity
1	1,100 mAh Yaesu	4.1	1.01	3.72
2	1,800 mAh Yaesu	6.6	1.0[1]	3.67
3	2,000 mAh Batteries America	8.0	1.09	1.09

The two Yaesu batteries were nearly identical in performance. Extrapolating using the Yaesu figures, the BA battery would be rated at 2,164 mAh. This does not mean that the Yaesu batteries are worse or that the BA battery is better. The real test comes after the batteries have been in use for a couple of years. It's possible to increase battery capacity in the near term by sacrificing the number of charge cycles.

A long term analysis of battery performance is beyond the scope of this document.

[1] Normalized to the Yaesu 1,800 mAh battery

Discharge Curve

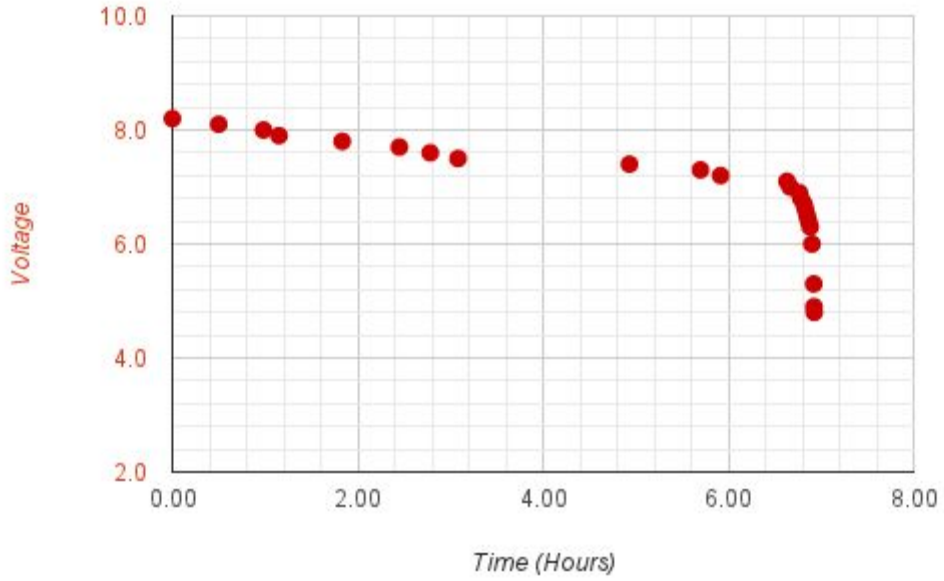
The detailed discharge curve is shown in Table 2. The table lists the elapsed time, battery voltage, accumulated percentage of discharge time, and the status of the displayed battery indicator.

Table 2 Typical discharge curve (1,800 mAh battery)

Voltage	Elapsed Time Hrs	% of Run Time	Indicator Bars
8.2	0.00	0.00%	3
8.1	0.50	7.23%	3
8.0	0.98	14.22%	3
7.9	1.15	16.63%	3
7.8	1.83	26.51%	3
7.7	2.45	35.42%	3
7.6	2.78	40.24%	3
7.5	3.08	44.58%	3
7.4	4.93	71.33%	3
7.3	5.70	82.41%	3
7.2	5.92	85.54%	3
7.1	6.63	95.90%	3
7.0	6.67	96.39%	2
6.9	6.77	97.83%	2
6.8	6.78	98.07%	2
6.7	6.82	98.55%	2
6.6	6.83	98.80%	1
6.5	6.85	99.04%	1
6.4	6.87	99.28%	0
6.3	6.88	99.52%	0
6.0	6.90	99.76%	Flashing
5.3	6.92	100.00%	Flashing
4.9	6.92	100.00%	Dry
4.8	6.92	100.00%	Shutoff

The Figure 1 shows the data graphically. Note the linear discharge until the voltage gets down to about 7.1. Also this is for Rx only. The increased current drain from Tx will drop the voltage even faster.

Figure 1 Battery Voltage Vs. Time



From Table 2 it is clear that the on-screen battery icon is not a predictor of remaining battery life. The first bar doesn't disappear until 97% of the battery has been used! It is recommended that you enable the voltage display ('F', 'A/B') so you can easily check battery voltage while the radio is on.

Battery Performance FT2DR

The FT2DR is programmed as follows:

1. Both receivers are on.
2. Both receivers are tuned to a UHF frequency.
3. ‘A’ and ‘B’ sides are set to DN.
4. The GPS receiver is turned on.
5. Rx Save is turned off.
6. The screen is set to full brightness, continuously on.
7. APO is turned off.
8. The APRS modem is disabled - there are no conditions under which the radio will transmit.
9. The antenna is removed.
10. Measurements are taken at room temperature (20 C).
11. The display is set to the sensor info page.
12. The battery is fully charged in the drop-in charger (green light is on), then verified by charging in the radio until charging shuts off.,
13. The radio is turned on and monitored until it shuts off. Voltage, voltage indicator, and time are recorded.

Results

All the batteries were tested with the FT2DR. Table 3 shows the performance of the 1,100 mAh Yaesu battery. One nice thing to see is that Yaesu made improvements with the battery bar graph indicator over the FT1DR.

Table 3 FT2D Discharge of the 1,100 mAh Yaesu Battery

Elapsed Hours	Voltage	Bars
0.00	8.3	7
0.57	8.1	7
1.10	7.9	6
1.50	7.8	5
2.22	7.6	4
3.07	7.5	4
3.85	7.4	3
4.63	7.2	2
4.93	7.0	1
5.10	5.5	0
5.13	4.9	Dry Cell
5.13	4.6	Cutoff

Table 4 compares the performance of the four batteries I have available.

Table 4 Summary of FT2D battery performance

ID	Battery	Discharge Time (hours)	Norm	Performance Rating Larger implies greater capacity
1	1,100 mAh Yaesu[2]	5.13	1.04	4.66
2	1,800 mAh Yaesu[3]	8.1	1.0[4]	4.5
3	2,000 mAh Batteries America	9.9	1.1	4.97
4	2,200 mAh Yaesu[5]	10.6	1.07	4.83

Observations

- The Performance Rating of the FT2D (4.5 vs 3.67 for the Yaesu 1,800 mAh battery) implies that the FT2D consumes less power for it's test vs. the FT1D.
- Battery #3 is the most conservatively rated (lowest performance rating). Battery #2 is the least conservatively rated.

[2] Battery is not new but has received little use
[3] Battery is not new but has received little use
[4] Normalized to the Yaesu 1,800 mAh battery
[5] Battery is not new

FT2DR Power Use

Measurements were taken of the current needed for various FT2DR functions. This can help provide the user with a better idea of which features cause the most drain on the battery. Surprisingly, some HT features that traditionally used a lot of power use very little with the FT2DR.

The table below provides FT2DR current measurements along with selected FT1DR measurements for comparison.

Table 5 FT1/2DR Rx Feature Power Consumption

Feature	**Description**	**FT2 Current (mA) at 8.4V**	**FT1 Current (mA) at 8.4V**
Radio off	Static battery drain	6.5uA[6]	6.5 uA
Radio off, display on	I.e., during charging	23	25
Rx, FM save[7]	Rx in standby, 1 or 2 receivers enabled!	64	52
Rx FM VHF	Rx active (save off)	74	97
Rx DN or AMS[8] VHF		91	136
Rx FM UHF		82	107
Rx DN or AMS UHF		99	146
GPS		18	23
Backlighting L1	Also dim mode when save is off	5	0 (Off)
Backlighting L2		17	15
Backlighting L3		28	32
Backlighting L4		38	51
Backlighting L5		45	71
Backlighting L6		52	97
Squelch open, no audio		18	19
Squelch open, max audio		186	196
2nd receiver enabled[9]		16	46
Battery charging	10.3 volts (supplied adapter)	225	242
Battery charging	12.5 volts	275	276

[6] This is the continuous drain from the battery when the radio is off in uA. For example, if the radio is not used for a month(720 hours), it will deplete the battery by 4.7 mAh or 0.2% of a 2,200 mAh battery.
[7] The actual average Rx current can be calculated by using this standby current and the active current in proportion to the selected ratio.
[8] This indicates that the DSP must be running whenever DN, VW, or DW reception is possible in order to avoid missing the initial part of a transmission.
[9] This is amazing! In the past running the 2nd Rx would double the Rx current consumption.

The radio appears to use a buck converter, reducing the input voltage to the necessary operating voltage. As the supply voltage increased, the current decreases. As a result the above currents (except battery charging) will be less when operating on a 12.5V supply.

FT2DR Tx Current

It is more difficult to measure the Tx power. The current can vary dramatically depending on the antenna. For example, I have a “stubby duck” where the VHF high power current is 400 mA, but goes up to 1,100 mA with a Comet HT-224. This indicates that the HT is rolling back its power due to high SWR.

Also note that the full power is only possible when the supply voltage is 7.4 or greater (7.8 for the FT1DR).

Table 6 FT2DR Tx Current

Feature	**FT2DR Current (mA) at 8.4 V[10]**	**FT1DR Current (mA) at 8.4V**
VHF/UHF FM Low 1	305 / 365	408 / 371
VHF/UHF FM Low 2	620 / 683	735 / 750
VHF/UHF FM Low 3	966 / 1,165	1,056 / 1,123
VHF/UHF FM High	1,344 / 1,777	1,373/1,490
Digital	Add 33 mA	Add 67 mA

[10] Measured while transmitting into a 50 ohm resistive load. Voltage measured by radio.

Power Use by Legacy Radios

For the fun of it, measurements were made on some legacy radios for additional comparisons.

Table 7 Legacy Radio Current Comparison Rx

Feature	Description	FT60 Current (mA) at 8.4V	VX8 Current (mA) at 8.4V
Radio off	Static battery drain		6.5 uA
Radio off, display on	I.e., during charging		31
Rx, FM save[11]	Rx in standby, 1 or 2 receivers enabled!	17	34
Rx, 50 MHz FM			89
Rx FM VHF	Rx active (save off)	50	94
Rx DN or AMS[12] VHF			
FM 220 MHz Rx			95
Rx FM UHF		51	106
Rx DN or AMS UHF			
GPS			27[13]
Backlighting L1		0 (Off)	0 (Off)
Backlighting L2		27 (On)	7
Backlighting L3			45
Backlighting L4			111 (max)
Backlighting L5			
Backlighting L6			
Squelch open, no audio		10	10
Squelch open, max audio[14]		140	157
2nd receiver enabled[15]			
Battery charging	10.3 volts (supplied adapter)		230
Battery charging	12.5 volts	350[16]	280

[11] The actual average Rx current can be calculated by using this standby current and the active current in proportion to the selected ratio.
[12] This indicates that the DSP must be running whenever DN, VW, or DW reception is possible in order to avoid missing the initial part of a transmission.
[13] With external microphone.
[14] No signal, so FM open-squelch noise.
[15] This is amazing! In the past running the 2nd Rx would double the Rx current consumption.
[16] Using drop-in charger. USA version cannot charge NiMH battery through radio.

Table 8 Legacy Radio Comparison Tx

Feature	**FT60 Current (mA) at 8.4 V**[17]	**VX8 Current (mA) at 8.4V**
6/VHF/220/UHF FM Low 1	636 / 578	222 / 275 / 247 / 303
6/VHF/220/UHF FM Low 2	N/A	595 / 717 / 476 / 818
6/VHF/220/UHF FM Low 3	NA / 1,014 / NA / 1,055	998 / 979 / 635 / 1,190
6/VHF/220/UHF High	NA / 1,606 / NA / 1,800	1,473 / 1,327 / 777 / 1,690
Digital	N/A	N/A

[17] Measured while transmitting into a 50 ohm resistive load. Voltage measured by radio.

Battery Performance over Time and Use

All rechargeable batteries degrade over time and with use. Each type of battery is subject to different factors that impact life. In this section, the three test batteries are re-tested over time to determine how much capacity loss they have suffered. Note that I do not keep track of battery cycles. I'm generally "nice" to my batteries and follow the recommendations posted in this paper. Your milage will be different from mine, but this should at least provide some confidence (or lack thereof) in the quality of the batteries.

I can't test everything, so I welcome others to set up their own testing program. I will gladly post (and credit) data from other Hams! (We're all in this together.)

I won't include the complete discharge curve again, but it is very similar to the data already posted - just with different times

Table 9 Battery Capacity History

Battery	**Date**	**Run-Time (hours) to 0 bars[18]**	**Age (Years)**
BA 2000 mAh	24-Dec-2014	6.85	0
BA 2000 mAh	29-Jul-2015	8:07[19]	0.59

[18] Since the Yaesu software may change, I define "zero bars" as 6.5 volts while under the test load.

[19] Okay, that's odd. The battery actually lasted longer after it was aged. I checked my tests and they were okay. It's not uncommon that Li-ion batteries may actually gain capacity when they are new and are getting used. Go figure. We'll test it again soon.

VX-1 Battery Historical Performance

So, how do old Li-ion batteries perform. I have a Yaesu VX-1 which was purchased in 1997 with two batteries. It got heavy use with one of the batteries and, fortunately, I performed battery run time tests periodically. The radio has not been used much in the last 8 years because the PTT switch wore out.

Table 10 VX-1 Battery Performance Over Time

Date	Runtime	Capacity % of Original
1/31/1998	14.20	100.00%
4/8/1998	13.00	91.55%
7/15/2000	12.75	89.79%
6/27/2001	12.30	86.62%
8/5/2002	12.10	85.21%
9/28/2015	11.37	80.07%

Impressive that a battery 17 years old still has 80% of its initial capacity!

VX-5 Battery Historical Performance

I've had a VX-5 since 2001 and performed and performed the battery test when I got it. The radio got quite a bit of use and I never purchased a replacement. The radio has not gotten a lot of use in the last 5 years (but still works great).

Table 11 VX-5 Battery Performance Over Time

Date	Runtime	Capacity % of Original
12/8/2001	19.98	100.00%
8/30/2015	17.65	88.34%

Also very impressive that a well-used Li-ion battery that is over 13 years old has retained 88% of its capacity!

Table 8 shows the discharge curve of the VX-5 (2015 data). What's interesting is that the VX-5 battery bar graph has the same problem that the FT1D - the indicator doesn't go down until over 90% of the battery has been used.

Table 12 VX-5 Battery Discharge (2015)

Elapsed Hours	Voltage	Bars
0.00	8.3	4
2.40	8.1	4
9.68	7.5	4
17.70	6.5	3
17.73	6.4	2
17.80	6.2	2
17.83	5.9	1
17.90	5.4	0

Recommendations for longer battery cycle life

It is recommended to recharge the battery whenever convenient, particularly if the battery is below 7.8 volts. At 7.4 volts you should consider replacing the battery with one that's fully charged.

Over discharging a Li-ion battery can permanently damage it. At the very least, it will dramatically reduce the number of charge/discharge cycles. The battery should never be operated below 6.5 volts and never below 7.0 for longer life.

Li-ion batteries are very sensitive to temperature. In particular, the battery can be permanently damaged if charged at too high a temperature. If the radio is getting hot, consider disconnecting it from any external power source that may be charging the battery. Charging a Li-ion battery when its internal temperature is above 130 F can permanently damage the battery. The best battery life will be achieved by charging it at room temperature. It is recommended to use the drop-in charger to charge the battery with the radio off or the battery by itself.

Notes on the Yaesu Charger

The charging current is 250 mA when the battery is charged through the radio. You can figure out how long it will take to fully charge a completely discharged battery:

Charging Hours = (Battery Capacity mAh / Charge Current mA) * 1.15

A 1,800 mAh battery therefore takes a maximum 8.3 hours.

The CD-41 drop in charger works differently. It charges the battery at about 500 mA thus cutting the charging time in half. The charge current is applied when the red LED is on. Near the end of the cycle, the red LED will flash off and on. When it is off, no charge current is applied to the battery thus reducing the effective charge rate.

Non-Yaesu batteries may not fit in the CD-41! The Batteries America battery I tested can't be charged in the CD-41 while connected to the radio - I need to remove it from the radio to charge it. That problem is solved with the CD-15 and the appropriate shim to lift the radio up where it won't interfere with the front of the radio well.

The CD-41 charge current is based on the input voltage. The CD-41 uses a fixed resistor to limit the charging current. If you use the 10.3V power adapter supplied with the radio, the charge current will low, less than 200 mA. The charge current will be between 500 and 600 mA when the supply voltage is between 12 and 16V.

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