

HF Transceivers and Battery Operation
by Charles Preston K7TAA, formerly KL7OA Version 2.2

Revised April 18, 2020 to show the updated source for the N8XJK Boost Regulator

<http://www.charlespreston.net/batteryop/HF-Transceivers-and-Battery-Operation.pdf>

Until September, 2008, I assumed that "12 volts is 12 volts" for DC power input. Also that HF transceivers operated at low power would use about 200% of their RF output power as DC input power from a battery. Adding an amp or so of current drain for digital circuitry, this would be 25%-50% efficiency. I assumed that they would output their rated power of about 100 watts using a 12 volt lead acid battery for DC power.

Depending on the transceiver, these assumptions were way off.

My particular interest is in operating at 10-20 watts RF output using high performance digital protocols for portable and emergency use. Even during the present very low sunspot activity I have been able to make NVIS contacts to the same location multiple times per day on 160, 80 or 40 meters.

When I put a digital power meter in line to see simultaneous voltage and current, I was surprised to discover that my Icom IC-7000 was using 6.85 A at 12 volts at its 10% setting. It turned out that I was using about 80 watts from the battery to produce about 5 watts of RF, which is 7% efficiency. Maximum power available from the transmitter when using the battery was 60 watts.

In addition, the IC-7000 radio shut down while sending CW at the 100% power setting, while an Odyssey PC-1750 AGM lead acid battery was only half discharged. This means that a large, new very high quality battery can be used for full power operation for less than half its stated capacity per cycle, without using a DC-DC converter.

Without the higher voltage provided by a converter, approximately double the battery capacity will have to be purchased to provide the same operating time at the same power level.

This has obvious implications if you expect to get a certain number of hours of operation from a certain size battery, as I did. Another aspect of battery operation was that the transceiver RF output was only about 5 watts at the 10% setting, instead of the 10 watts I expected. This probably helps explain some intermittent behavior from an SGC SG-237 antenna coupler, when I tried to tune it using an IC-7000 low power setting of 5 percent, which actually produced about 2.5 watts from the IC-7000.

A DC-DC converter will provide better behavior from the radio, and allow the full capacity of a lead acid battery to be used before recharging. Based on my measurements, it will not provide higher efficiency at low power levels from the transceivers.

The price for an N8XJK Super Booster is now \$249.95 from West Mountain Radio.

http://www.westmountainradio.com/product_info.php?products_id=battery-boost

Every radio is designed to optimize some characteristics and not waste money and weight on those that don't matter. The important thing is to know what these characteristics are so you can pick the right radio for the right task.

I like many aspects of the IC-7000. But based on measurements from a single unit, power consumption for low RF output power levels should be considered for portable and emergency use. I

had this radio checked by an Icom service center, and it was operating within specifications, and putting out its rated power at 13.8 V DC input.

I was so surprised by the performance of the IC-7000, I had to test a couple other radios. I was fortunate in being able to borrow a Yaesu FT-857 for similar testing. I measured 0.62 A power consumption on receive, vs 1.28 A for the IC-7000. Receive power consumption is a specification furnished by all the manufacturers I checked, so this figure is easy to look up before buying a radio.

The FT-857 used 5.38 A to produce 9 watts RF output, so is more efficient at low power than the IC-7000 I tested. It also produced 95 watts RF output when operated from the same battery under the same conditions as the IC-7000.

Reluctant to admit I was this wrong about the power efficiency of HF transceivers, I thought maybe my results were just due to newer radios with more digital components and a change in design goals.

I measured the performance of an Icom IC-735 as a mostly analog radio example. It used 0.95 A on receive. When transmitting, at 10 watts RF output, it used 5.76 A, and it would produce 105 watts RF output using the battery as a power supply.

I looked up the specifications of other amateur HF SSB transceivers. The Elecraft K2 has a listed receive current consumption of 0.15A (this can be as low as 0.12 A with power conservation measures according to an Elecraft spokesperson). Specifications also show 10 watts RF output with a supply current of about 2 A. Being designed with different goals, the K2 doesn't have some of the features of the IC-7000 or FT-857, including the tighter frequency stability specifications desirable for certain digital modes.

I was gratified to find that my assumed "50% power efficiency" wasn't completely unjustified; it just wasn't true for three radios I tested.

See table below for detailed measurements.

Power consumption and battery type

It is tempting to try to pair a small HF transceiver with a rechargeable lithium technology battery pack. For the same power, lithium ion rechargeable batteries can be much smaller and lighter than lead acid batteries. For example, one commercial battery pack, which uses lithium ion polymer technology, is a Tekkeon 3450. It is a 50 Wh battery weighing less than a pound that I thought might be able to power a transceiver for an hour of transmit time, or two hours, with its add-on battery extender in parallel. But one of the characteristics of most lithium ion and lithium ion polymer batteries is that they must be charged relatively slowly and carefully, compared to some lead acid batteries, and they have a comparatively low discharge rate.

The Tekkeon and similar battery packs can provide about 4 A, which isn't enough even for 10 W output on any of the three transceivers I measured.

If the Tekkeon is used to power a low power transceiver, like the Yaesu FT-817ND, required transmit DC current for 5 W RF output is 2 A. Extended transmit periods that require 2 A from the battery result in a tested battery capacity of 42 Wh at 13.2 VDC regulated voltage. Lithium ion/lithium ion polymer battery packs have the highest power to weight ratio available to consumers, but are suitable only for low current applications. Battery pack life may be only about 300 recharge cycles, and less if deep discharged.

There is another lithium battery technology that is about 1/3 of the weight of lead acid for the same power capacity. It is lithium iron phosphate, LiFePO_4 . In the HF Projects battery packs it can be charged at 10 A, and discharged at a much higher rate. HF Projects is packaging these cells from the A123 company into battery packs suitable for radio use. They use nanoparticles to provide improved battery characteristics. <http://www.hfprojectsyahoo.com/powerpack.html>

They are quite expensive per Ah or Wh. But if the projections for battery life prove to be true, they will have a much longer cycle life than other lithium ion or even lead acid batteries.

I tested the HFP 4 battery pack for capacity and for any loss in capacity caused by storing it discharged for up to a week. I also stored it discharged for 24 hours at -20 to -5 degrees F. There was no decrease in capacity due to this treatment. Actual capacity, at a steady discharge current of 2 A, was about 27 Wh. Discharge voltage, under a 2 A load, was between 13.5 VDC and 12 VDC, at the 25 Wh discharge point.

These batteries have a claimed life of 1000 cycles even when 100% deep cycle discharged. That is better deep cycle life than Odyssey AGM lead acid, which is the next best battery I've found for surviving abuse. But what many people would call abuse, some of us would consider expected or desirable working conditions for a radio battery used in field or emergency operations.

For more information about choosing a battery type, see <http://www.charlespreston.net/batteryop/Quick-Analysis-of-Battery-Types.pdf> .

HF Transceiver Power Efficiency 8-5-2008 Charles Preston

IC-7000 12 V battery operation

RF Set (W)	RF Meas.(W)	Volts DC	Current (A)	DC Pwr. (W)	Efficiency %
5	2.5	12.02	6.11	73.44	3
10	5.5	12.01	6.85	82.27	7
20	12	11.95	8.54	102.05	12
50	36	11.85	10.89	129.05	28
100	60	11.78	13.08	154.08	39

IC-7000 AC pwr supply

RF Set (W)	RF Meas.(W)	Volts DC	Current (A)	DC Pwr. (W)	Efficiency %
5	4.2	13.68	6.36	87	5
10	8	13.67	7.44	101.7	8
20	17	13.65	9.20	125.58	14
50	52	13.60	12.57	170.95	30
100	92	13.57	15.51	210.47	44

FT-857 12 V battery operation

RF Set (W)	RF Meas.(W)	Volts DC	Current (A)	DC Pwr. (W)	Efficiency %
5	4.5	12.13	4.01	48.64	9
10	9	12.07	5.38	64.94	14
20	15	12.02	6.69	80.41	19
50	50	11.86	11.03	130.82	38
100	95	11.74	16.41	192.65	49

FT-857 AC pwr supply

RF Set (W)	RF Meas.(W)	Volts DC	Current (A)	DC Pwr. (W)	Efficiency %
5	5	13.72	4.07	55.84	9
10	9.5	13.71	5.44	74.58	13
20	15	13.69	6.75	92.41	16
50	50	13.64	11.04	150.59	33
100	100	13.58	16.07	218.23	46

IC-735 12 V battery operation

RF Set (W)	RF Meas.(W)	Volts DC	Current (A)	DC Pwr. (W)	Efficiency %
lowest	8	12.07	5.25	63.37	13
	10	12.04	5.76	69.35	14
	20	11.94	7.73	92.3	22
	50	11.86	10.60	125.72	40
highest	105	11.74	15.81	185.61	57

IC-735 AC pwr supply

RF Set (W)	RF Meas.(W)	Volts DC	Current (A)	DC Pwr. (W)	Efficiency %
lowest	8	13.71	5.31	72.8	11
	10	13.70	5.75	78.78	13
	20	13.67	7.70	105.26	19
	50	13.63	10.51	143.25	35
highest	105	13.57	15.66	212.51	49

Notes about these measurements

I didn't use calibrated lab equipment, although the RF power measurements were all with the same unit, so a comparison should be valid. All measurements were made at 3.550 MHz, in CW mode, with a dummy load.

DC power meter	Power Analyzer Pro, from Medusa Research, Inc.
Batteries	Odyssey PC1200 (40 Ah) and PC1700 (65 Ah) high quality AGM lead acid
Power supply	Astron RS-35A
Dummy load	Bird Model 8085
RF power meter	AEA ET-1 with 30 and 300 watt ranges

The DC power meter was inserted between the power supply and the radio power cable. The power cables for the IC-735 and IC-7000 were factory supplied cables. The cable used for the Yaesu FT-857 was larger gauge wire, possibly 8 gauge, and longer than the others by a couple feet.

Battery voltage with just the Power Analyzer Pro as a load was 12.46 to 12.28. According to the voltage chart supplied by Odyssey, this is a 67%-52% state of charge.

I own other radios from both Icom and Yaesu, and have no financial connection with either company, or with Elecraft. Based on my experience with Yaesu and Icom, they do a terrific job of turning out ham gear that will last 20 years or more, and producing this equipment at nearly consumer electronics prices.

Charles Preston
KL7OA
charles.preston@mac.com

Copyright © 2008, 2009, 2019, 2020 Charles Preston
Permission is given to reproduce this article without changes, and with attribution, for any non-profit or amateur radio purpose.