Comparison of Power Savings based on the Use of Wireless Charging Systems & Conventional Wired Power Adapters

Professor Ron Hui, Fellow IEEE
Director, Center for Power Electronics
City University of Hong Kong
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1 Introduction:

The use of wireless charging system for a range of portable consumer electronic products has the potential of

(1) forming a common charging platform for a wide range of consumer electronic products,
(2) reducing the number of conventional chargers (i.e. unnecessary chargers) in the future,
(3) reducing the power consumption and natural resources required to manufacture and to package these conventional chargers,
(4) reducing the amount of transportation energy in transporting these conventional chargers,
(5) reducing the amount of toxic and non-biodegradable electronic waste arising from a large variety of conventional chargers due to the lack of common charging platform;
(6) reducing the amount of manpower, resources, facilities and energy (power consumption) in handling and cleaning the electronic waste resulting from the huge amount of electronic waste arising from conventional chargers.

In this article, two scenarios are studied to compare the advantages and disadvantages of the traditional wired power adapters and the wireless chargers in terms of power consumption. Comparisons are made on the following two systems:

(i) An external AC-DC power supply (commonly known as a power adapter).
(ii) The wireless power supply consists of:
- an AC-DC adapter
- transmission electronics
- coils in transmitter
- coils in receiver
- rectification circuit in the receiver.

2 Case Study One – Charging and Standby Power for Single and Multiple Loads

This case study investigates the energy consumption of wired power adapters and the wireless chargers including both (i) the charging power and (ii) the standby power. Since techniques for reducing standby power are already available and can be applied to both wired and wireless chargers, technical data on standby power loss and efficiency from available public information will be used for this study.

The following considerations and assumptions are used in this study:

- Use "no-load or standby power consumption" of AC-DC external power adapters from the energy star website [1].

- From [1], it can be seen that a wired charger of 5W typically consumes 0.14 Watt without load (i.e. standby power is 0.14 Watt). Since the peak power is required only in the initial charging stage and charging power must be reduced when the battery fills up, the average charging power is assumed to be 2W.
- Assume that external power adapters are plugged in 24 hours per day, and used for 1 hour per day.
- Assume that the wireless charger replaces 1, 2, 3, …, 6 wired power adapters.
- Assume that the wireless charger consumes a standby power of 0.14 Watt.
- Assume that the wireless charger is plugged in 24 hours per day and used X hours per day (as devices can be charged in parallel, X has the value ranging from 1 to n, where n is the number of wired power adapters replaced by the wireless charger.).
- Assume that the wired power adapter has an efficiency of 72% during load.
- Due to the extra circuitry and components in the wireless system, it is assumed that the wireless charger has 70% of the efficiency of the wired charger (i.e. about 50%) during load.

Based on the above considerations and assumptions, a comparison is shown in Table 1.

Standby power of wired power adapter (Watt)	0.14
Standby power of wireless charger (Watt)	0.14
Charging time of wired power adapter (hours per day)	1
Standby time of wired power adapter (hours per day)	23
Charging time of wireless charger (hours per day)	X
Standby time of wireless charger (hours per day)	24-X
transfer efficiency wireless charger (% of wired power adapter)	70%
average power supplied during load (Watt)	2
efficiency of wired power adapter during load (%)	72%

Number of external supplies replaced by wireless power n	**1**	**2**	**3**	**4**	**5**	**6**
total consumed energy during standby mode of wired power adapter (Wh per day)	3.22	6.44	9.66	12.88	16.10	19.32
total consumed energy during standby mode of wireless charger when X=1 (Wh per day) MAXIMUM	3.22	3.22	3.22	3.22	3.22	3.22
total consumed energy during standby mode of wireless charger when X=n (Wh per day) MINIMUM	3.22	3.08	2.94	2.80	2.66	2.52
total energy supplied to one load (Wh per day)	2.00	4.00	6.00	8.00	10.00	12.00
energy consumed by wired power adapter during load (Wh per day)	2.78	5.56	8.33	11.11	13.89	16.67
energy consumed by wireless charger during load (Wh per day)	3.97	7.94	11.90	15.87	19.84	23.81
Daily:						
total energy consumption by wired power adapter (Wh per day)	6.00	12.00	17.99	23.99	29.99	35.99
total energy consumption by wireless charger (Wh per day) MAX	7.19	11.16	15.12	19.09	23.06	27.03
total energy consumption by wireless charger (Wh per day) MIN	7.19	11.02	14.84	18.67	22.50	26.33
Energy saving of wireless charger (Wh per day) MIN	-1.19	0.84	2.87	4.90	6.93	8.96
Energy saving of wireless charger (Wh per day) MAX	-1.19	0.98	3.15	5.32	7.49	9.66
Yearly:						
total energy consumption by wired power adapter (kWh per year)	2.19	4.38	6.57	8.76	10.95	13.14
total energy consumption by wireless charger (kWh per year) MAX	2.62	4.07	5.52	6.97	8.42	9.87
total energy consumption by wireless charger (kWh per year) MIN	2.62	4.02	5.42	6.82	8.21	9.61
Energy saving of wireless charger (kWh per year) MIN	**-0.43**	**0.31**	**1.05**	**1.79**	**2.53**	**3.27**
Energy saving of wireless charger (kWh per year) MAX	**-0.43**	**0.36**	**1.15**	**1.94**	**2.73**	**3.52**

Table 1: Comparison of Charging and Standby Power Consumption of Wired and Wireless chargers

Concluding Remarks:

From Table 1, it can be observed that:

(1) Standby power consumption is not negligible.
(2) The total power consumption is reduced if one wireless charger is used to replace two or more external AC-DC power adapters. This energy-saving advantage becomes more significant when more external power adapters are replaced with one wireless charger, assuming the power adapters are permanently connected to mains power.
(3) Using wireless charging systems with multiple load charging features has a distinctive energy saving advantage over using individual one-to-one wired power adapters.

3 Case Study 2 – Total power consumption and other power consumption for charging One Load

Survey on consumer behavior on IT products indicates that consumers tend to buy new products frequently. The life cycle of portable electronic products such as mobile phones ranges from 12 months to 18 months on average. The following analysis is based on the power consumption between the wired power adapters and wireless charging systems. We will examine the following factors:

(1) The amount of energy consumption for charging ONE load over a period of 5 years.
(2) The amount of energy consumption for making the plastic cases for the two systems.

The assumptions used in the analysis include:
(1) The life cycle of the mobile phone is 1.5- 2 years (due to consumer behavior).
(2) Each sale of new product involves the production of a mobile phone and a wired power adapter if wireless charger is not used.
(3) Within 5 years, 3 conventional wired power adapters are made for the replacement of mobile phones, whilst the same wireless charging system is used for the mobile phones.
(4) The power consumption for making the electronic components is ignored.
(5) The power consumption required for mining for the natural resources for the manufacturing of the products is ignored.
(6) The power consumption required for transporting the products is ignored.
(7) The power consumption and other resources for transporting and cleaning up toxic and non-biodegradable electronic waste are ignored.
(8) The power consumption required for the process of plastic molding.

3.1 Comparison of Energy Transfer Efficiency

In this section we compare the total power consumption in a 5-year period
Case Study:
Average system efficiency of wireless charger $\eta_{sys\text{-}wireless}$ = 0.50 (50%)
Average system efficiency of wired power adapter $\eta_{sys\text{-}wired}$ = 0.72 (72%)
Assume that the average charging power is 2W.

Based on results in Case Study One,

Total energy used by the wireless charger ($P_{used\text{-}wireless}$) over 5 years
= 2.62 x 5 = 13.10 kWh

Total energy used by the wired power adapter ($P_{used\text{-}wired}$) over 5 years
= 2.19 x 5 = 10.95 kWh

3.2 Comparison of energy used for manufacturing of the plastic cases of the charging systems (other electronic components not considered)

From the research study by Renewable Energy Research Group[2], it was found that for the plastic making of every kilogram of Polycarbonate (a common plastic used for charger), an amount of 107MJ (or 29.72 kWh) is needed.

Based on our practical experience:
Approximate weight of plastic material in one wireless charger ($W_{wireless}$) is 80g
Approximate weight of plastic material in one wired power adapter (W_{wired}) is 50g

Therefore,
Energy used to make one wireless charger is 107 MJ x 0.08 = 8.56 MJ = 2.37 kWh.
Energy used to make one wired power adapter is 107MJ x 0.05 = 5.35 MJ =1.49 kWh

Assuming that the consumer will change their mobile phones three times for every 5 years, so the total energy used to make the corresponding products are:

Wireless charger ($M_{used\text{-}wireless}$) is 2.37 kWh

Wired power adapter ($M_{used\text{-}wired}$) is 3 x 1.49 kWh = 4.47 kWh

3.3 Overall Comparison of Total Energy Consumption of Charging One Load over a Period of 5 Years

Total power used by one wireless charger in 5 years is ($E_{used\text{-}wireless}$) + ($M_{used\text{-}wireless}$) = 13.10 kWh + 2.37 kWh = 15.47 kWh

Total energy used by 3 wired power adapters in 5 years is ($E_{used\text{-}wired}$) + 3($M_{used\text{-}wired}$) = 10.95 kWh + 3 x 1.49 kWh = 15.42 kWh

	Charging Energy Consumed for 5 years (kWh)	Product's Plastic Manufacturing energy (kWh)	Energy for processing e-waste (kWh)	Transportation energy for charger (kWh)	Estimated energy (kWh)
One Wireless charger	13.10	2.37	X	Y	15.47 + (X+Y)
One wired charger	10.95	1.49	X	Y	12.44 + (X+Y)
Two wired chargers	10.95	2.98	2X	2Y	13.93 + (**2**)(X+Y)
Three wired chargers	10.95	4.47	3X	3Y	15.42 + (**3**)(X+Y)

Table 2 Comparison based on charging one load over 5 years.

Note:

(1) The amount of energy for making the electronic components, cables and sockets of the the power supplies is not included.

(2) The wastage of product materials is not included.
(3) X refers to the amount of energy required for handling and cleaning the toxic & non-biodegradable electronic waste.
(4) Y refers to the amount of energy required for shipping the products from the factory to the distribution networks.

Concluding remarks:
From Table 2, it indicates that:
(1) Despite the fact that the Case Study Two focuses on the energy consumption for charging ONE load only, the results in Table 2 indicate that the wireless system, which has the potential of eliminating the necessity of some wired power adapters, could consume less energy and material resources.
(2) As long as (X+Y) > 1.54 kWh (i.e. 15.47 kWh – 13.93 kWh), using one wireless charger to replace two or more wired power adapters can bring the benefit of energy savings.
(3) The more wired power adapters replaced by the wireless charger, the more energy savings one can achieve.
(4) Using a common charging protocol based on the wireless charging system is beneficial is eliminating individual chargers. Table 2 indicates that if a universal wireless charging pad for multiple load can accommodate 3 loads, 3 external power adaptors can be eliminated. Thus environmental goals of energy saving and elimination of electronic waste can be achieved simultaneously.

4 Conclusion:

This study is an attempt to compare the energy consumption of wireless charging systems and traditional power adaptors. Based on the two sets of results in the two Case Studies, it is clear that using one wireless charging system with multiple-load charging feature has distinctive advantages over using individual one-to-one wired power adapters. This advantage is clear and becomes more significant when the wireless charger can replace two or more wired power adapters.

The energy-saving advantages arise from (i) the reduction of the standby power and (ii) the reduction of manufacturing and transportation energy of unnecessary wired power adapters. Besides the energy savings aspects, the potential reduction of huge amount of electronic waste arising from the reduction of the number of conventional power adapters also contributes greatly to environmental protection in the long run. This amount of benefit has not been included in this analysis.

References:
(1) http://www.energystar.gov/index.cfm?c=ext_power_supplies.power_supplies_consumers
(2) **Bruno GERVET, "**The use of crude oil in plastic making, contributes to global warming", May 2007, Renewable Energy Research Group, Département de Génie Energétique et Environnement INSA Lyon, France, http://www.ltu.se/polopoly_fs/1.5035!plastics%20-%20final.pdf