MAGNETIC ALIGNMENT SYSTEMS WITH PROXIMITY DETECTION FOR ELECTRONIC DEVICES

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Provisional Application No. 62/907,332, filed Sep. 27, 2019, and of U.S. Provisional Application No. 63/061,752, filed Aug. 5, 2020. The disclosures of both provisional applications are incorporated by reference herein for all purposes.

[0002] The following five U.S. patent applications, filed on the same day as this application, also claim the benefit of the above-referenced provisional applications: U.S. application Ser. No. _____ (Attorney Docket No. 090911-P51420US1-1207279), titled "Magnetic Alignment Systems for Electronic Devices"; U.S. application Ser. No. _____ (Attorney Docket No. 090911-P51420US2-1207208), titled "Magnetic Alignment Systems with Rotational Alignment Component for Electronic Devices"; U.S. application Ser. No. _____ (Attorney Docket No. 090911-P42863US1-1159555), titled "Magnetic Alignment Systems with NFC for Electronic Devices"; U.S. application Ser. No. _____ (Attorney Docket No. 090911-P42863US3-1207206), titled "Wireless Charging Modules with Magnetic Alignment Components"; and U.S. application Ser. No. _____ (Attorney Docket No. 090911-P42863US4-1207207), titled "Accessory Insert Modules with Magnetic Alignment Components."

BACKGROUND

[0003] The present disclosure relates generally to consumer electronic devices and more particularly to magnetic alignment components and systems that facilitate establishing and maintaining a desired alignment between two (or more) devices, e.g., for purposes of enabling efficient wireless power transfer between the devices.

[0004] Portable electronic devices (e.g., mobile phones, media players, electronic watches, and the like) operate when there is charge stored in their batteries. Some portable electronic devices include a rechargeable battery that can be recharged by coupling the portable electronic device to a power source through a physical connection, such as through a charging cord. Using a charging cord to charge a battery in a portable electronic device, however, requires the portable electronic device to be physically tethered to a power outlet. Additionally, using a charging cord requires the mobile device to have a connector, typically a receptacle connector, configured to mate with a connector, typically a plug connector, of the charging cord. The receptacle connector includes a cavity in the portable electronic device that provides an avenue via which dust and moisture can intrude and damage the device. Further, a user of the portable electronic device has to physically connect the charging cable to the receptacle connector in order to charge the battery.

[0005] To avoid such shortcomings, wireless charging technologies have been developed that exploit electromagnetic induction to charge portable electronic devices without the need for a charging cord. For example, some portable electronic devices can be recharged by merely resting the device on a charging surface of a wireless charger device. A transmitter coil disposed below the charging surface is driven with an alternating current that produces a time-varying magnetic flux that induces a current in a corresponding receiver coil in the portable electronic device. The induced current can be used by the portable electronic device to charge its internal battery. Some portable electronic devices have been designed to not only receive power wirelessly but also to transmit power wirelessly to other portable electronic devices, such as accessory devices.

SUMMARY

[0006] Among other factors, the efficiency of wireless power transfer depends on the alignment between the transmitter and receiver coils. For instance, a transmitter coil and receiver coil may perform best when they are aligned coaxially. Where a portable electronic device has a flat surface with no guiding features, finding the proper alignment can be difficult. Often, alignment is achieved by trial and error, with the user shifting the relative positions of the device and charger and observing the effect on charging performance. Establishing optimal alignment in this manner can be time-consuming. Further, the absence of surface features can make it difficult to maintain optimal alignment. For example, if the portable electronic device and/or charger are jostled during charging, they may be shifted out of alignment. For these and other reasons, improved techniques for establishing and maintaining alignment between electronic devices would be desirable.

[0007] According to embodiments described herein, a portable electronic device and an accessory device can include complementary magnetic alignment components that facilitate alignment of the accessory device with the portable electronic device and/or attachment of the accessory device to the portable electronic device. The magnetic alignment components can include annular magnetic alignment components that, in some embodiments, can surround inductive charging transmitter and receiver coils. In the nomenclature used herein, a "primary" annular magnetic alignment component refers to an annular magnetic alignment component used in a wireless charger device or other terminal accessory. A "secondary" annular magnetic alignment component refers to an annular magnetic alignment component used in a portable electronic device. An "auxiliary" annular magnetic alignment component refers to an annular magnetic alignment component used in a charge-through accessory.

[0008] In some embodiments, a magnetic alignment system can also include a rotational magnetic alignment component that facilitates aligning two devices in a preferred rotational orientation. A rotational magnetic alignment component can include, for example, one or more magnets disposed outboard of an annular alignment component. It should be understood that any device that has an annular alignment component might or might not also have a rotational alignment component, and rotational alignment components may be categorized as primary, secondary, or auxiliary depending on the type of device.

[0009] In some embodiments, magnetic alignment components can be fixed in position within a device housing. Alternatively, any or all of the magnetic alignment components in a device (including annular and/or rotational alignment components) can be made movable in the axial and/or lateral direction. A movable magnetic alignment component can allow the magnets to be moved (e.g., axially) into closer proximity to increase magnetic forces holding the devices in