

LINEAR PLUGGABLE OPTICAL MODULE AND METHOD FOR IMPLEMENTING HIGH STABILITY AND LOW POWER CONSUMPTION THEREFOR

CROSS-REFERENCE TO RELATED APPLICATION

[001] This application is the national phase entry of International Application No. PCT/CN2025/091819, filed on April 28, 2025, which is based upon and claims priority to Chinese Patent Application No. 202410530499.0, filed on April 29, 2024, entitled “LINEAR PLUGGABLE OPTICAL MODULE AND METHOD FOR IMPLEMENTING HIGH STABILITY AND LOW POWER CONSUMPTION THEREFOR”, the entire contents of which are incorporated herein by reference.

TECHNICAL FIELD

[002] The present disclosure relates to the technical field of linear pluggable optical modules, and in particular to a linear pluggable optical module and a method for implementing high stability and low power consumption for the linear pluggable optical module.

BACKGROUND ART

[003] High-speed linear pluggable optical modules (LPOs) are widely used in large data centers. The emergence of supercomputing and artificial intelligence applications has driven the demand for bandwidth, prompting large data center operators to explore high-density, low-latency, and low-power consumption solutions. Since LPOs do not include digital signal processor (DSP) components, compared to conventional pluggable optical transceivers, LPOs naturally have low power consumption, low cost, and low latency, and can be widely used in AI and hyperscale data centers.

[004] In a large data center or large AI application scenario, the number of high-speed transceivers used may be as high as hundreds of thousands. In such a scenario, the transceivers interact with each other, which may affect the power supply of a system, leading to noise in the power supply of the system. In addition, changes in some external environmental factors, such as temperature, humidity, lightning, etc., may also cause noise in the power supply of the system. Conventional high-speed optical modules use DC-DC converters to isolate various power supplies when employing DSP chips. Since LPO modules do not have DSP chips, they cannot isolate power supply noise. Therefore, system noise is directly applied to the power supply of the LPO module, affecting its performance, and in severe cases, may cause the entire system to malfunction.

SUMMARY

[005] The objective of the present disclosure is to provide a linear pluggable optical module and a method for implementing high stability and low power consumption for the linear pluggable optical module, which can save energy, reduce noise, and improve stability.

[006] The embodiments of the present disclosure are implemented through the following technical solutions.

[007] In one aspect, an embodiment of the present disclosure provides a method for implementing high stability and low power consumption for a linear pluggable optical module, including: arranging a Buck-Boost DC-DC conversion module at a power supply input port of the linear pluggable optical module, wherein the Buck-Boost DC-DC conversion module isolates a system power supply on a Host side from a power supply of the linear pluggable optical module; and arranging at least one DC-DC conversion module at an output end of the Buck-Boost DC-DC conversion module, wherein the DC-DC conversion module supplies power to the high-power laser.

[008] Optionally, three DC-DC conversion modules are arranged at the output end of the Buck-Boost DC-DC conversion module, and the three DC-DC conversion modules supply power to a silicon optical MZ modulator, a photoelectric conversion module, and the high-power laser, respectively.

[009] Optionally, a power output end of a golden finger module of the linear pluggable optical module is connected to an input end of a soft-start module, an output end of the soft-start module is connected to a power end of a main control module and an input end of the Buck-Boost DC-DC conversion module, the output end of the Buck-Boost DC-DC conversion module is connected to an input end of a first DC-DC conversion module, an input end of a second DC-DC conversion module, an input end of a third DC-DC conversion module, a power end of a linear driver, and a power end of a linear TIA module; and an output end of the first DC-DC conversion module, an output end of the second DC-DC conversion module, an output end of the third DC-DC conversion module are respectively connected to power ends of the high-power laser, the silicon optical MZ modulator, and the photoelectric conversion module; an RF signal output end of the golden finger module of the linear pluggable optical module is connected to an RF signal input end of the linear driver, and an output end of the linear driver is connected to an RF signal input end of the silicon optical MZ modulator; an RF signal output end of the photoelectric conversion module is connected to an RF signal input end of the linear TIA module, and an RF signal output end of the linear TIA module is connected to an RF signal input end of the golden finger module of the linear pluggable optical module; and a low-frequency signal output end of the main control module is connected to a low-frequency signal input end of the Buck-Boost DC-DC conversion module and a low-frequency signal input end of the first DC-DC conversion module,

and a low-frequency signal output end of the high-power laser is connected to a low-frequency signal input end of the silicon optical MZ modulator.

[010] Optionally, the linear driver has a shutdown function, and the Buck-Boost DC-DC conversion module supplies power to the linear TIA module and the linear driver, respectively.

[011] Optionally, in the method for implementing high stability and low power consumption for a linear pluggable optical module of the embodiment of the present disclosure, a fourth DC-DC conversion module is further provided in the linear pluggable optical module, the output end of the Buck-Boost DC-DC conversion module is further connected to an input end of the fourth DC-DC conversion module, the output end of the Buck-Boost DC-DC conversion module is connected to the power end of the linear driver, the linear driver is connected to the power end of the linear TIA module through a first switch, and an output end of the fourth DC-DC conversion module is connected to the power end of the linear TIA module through a second switch; and the low-frequency signal output end of the main control module is further connected to a low-frequency signal input end of the fourth DC-DC conversion module.

[012] Optionally, the first switch and the second switch are not open or closed simultaneously; when the first switch is open and the second switch is closed, the linear TIA module is powered by the fourth DC-DC conversion module; or, when the first switch is closed and the second switch is open, the linear TIA module is powered by the Buck-Boost DC-DC conversion module.

[013] Optionally, the DC-DC conversion module supplies power to the high-power laser through a first operational amplifier, and the first operational amplifier adjusts the current flowing through the high-power laser according to a set voltage.

[014] In another aspect, an embodiment of the present disclosure provides a linear pluggable optical module, configured to operate according to any one of the aforementioned methods for implementing high stability and low power consumption for a linear pluggable optical module.

[015] In yet another aspect, an embodiment of the present disclosure provides another method for implementing high stability and low power consumption for a linear pluggable optical module, including: arranging a Buck-Boost DC-DC conversion module at a power supply input port of the linear pluggable optical module, wherein the Buck-Boost DC-DC conversion module isolates a system power supply on a Host side from a power supply of the linear pluggable optical module; and further arranging at least one DC-DC conversion module at the power supply input port of the linear pluggable optical module, wherein the DC-DC conversion module supplies power to a high-power laser.

[016] Optionally, three DC-DC conversion modules are included, and the three DC-DC conversion modules supply power to a silicon optical MZ modulator, a photoelectric conversion module, and the high-power laser, respectively.

[017] Optionally, a power output end of a golden finger module of the linear pluggable optical module is connected to an input end of a soft-start module, an output end of the soft-start module is connected to a power end of a main control module, an input end of the Buck-Boost DC-DC conversion module, an input end of a first DC-DC conversion module, an input end of a second DC-DC conversion module, and an input end of a third DC-DC conversion module, an output end of the Buck-Boost DC-DC conversion module is connected to a power end of a linear driver and is connected to a power end of a linear TIA module; and an output end of the first DC-DC conversion module, an output end of the second DC-DC conversion module, and an output end of the third DC-DC conversion module are respectively connected to power ends of the high-power laser, the silicon optical MZ modulator, and the photoelectric conversion module; an RF signal output end of the golden finger module of the linear pluggable optical module is connected to an RF signal input end of the linear driver, and an output end of the linear driver is connected to an RF signal input end of the silicon optical MZ modulator; an RF signal output end of the photoelectric conversion module is connected to an RF signal input end of the linear TIA module, and an RF signal output end of the linear TIA module is connected to an RF signal input end of the golden finger module of the linear pluggable optical module; and a low-frequency signal output end of the main control module is connected to a low-frequency signal input end of the Buck-Boost DC-DC conversion module and a low-frequency signal input end of the first DC-DC conversion module, and a low-frequency signal output end of the high-power laser is connected to a low-frequency signal input end of the silicon optical MZ modulator.

[018] Optionally, the linear driver has a shutdown function, and the Buck-Boost DC-DC conversion module supplies power to the linear TIA module and the linear driver, respectively.

[019] Optionally, in the method for implementing high stability and low power consumption for a linear pluggable optical module of the embodiment of the present disclosure, a fourth DC-DC conversion module is further provided in the linear pluggable optical module; the output end of the soft-start module is further connected to an input end of the fourth DC-DC conversion module, an output end of the Buck-Boost DC-DC conversion module is connected to the power end of the linear driver and is connected to a power end of the linear TIA module through a first switch, and an output end of the fourth DC-DC conversion module is connected to the power end of the linear TIA module through a second switch; and the low-frequency signal output end of the main control module is further connected to a low-frequency signal input end of the fourth DC-DC conversion module.

[020] Optionally, the first switch and the second switch are not open or closed simultaneously; when the first switch is open and the second switch is closed, the linear

TIA module is powered by the fourth DC-DC conversion module; or, when the first switch is closed and the second switch is open, the linear TIA module is powered by the Buck-Boost DC-DC conversion module.

[021] In still another aspect, an embodiment of the present disclosure provides another linear pluggable optical module, configured to operate according to any one of other aforementioned methods for implementing high stability and low power consumption for a linear pluggable optical module.

[022] The technical solutions of the embodiment of the present disclosure have at least the following advantages and beneficial effects.

[023] In the method for implementing high stability and low power consumption for a linear pluggable optical module of the embodiment of the present disclosure, by arranging a Buck-Boost DC-DC conversion module at the power supply input port of the linear pluggable optical module, the system power supply on the Host side and the power supply of the linear pluggable optical module can be isolated, achieving the effect of isolating power supply noise from the system side, thereby improving the application stability of the linear pluggable optical module. By directly supplying current to the high-power laser through the arranged DC-DC conversion module, the headroom of the current-mode digital-to-analog converter is eliminated, reducing the power consumption of the linear pluggable optical module. Through the micro-control work of the main control module, the MCU can operate normally only by ensuring that the digital low-level voltage is between 0 and 0.8 V and the digital high-level voltage is within the range of VCC-0.8 V to VCC. Therefore, the MCU is not affected by noise, further enhancing system stability.

BRIEF DESCRIPTION OF DRAWINGS

[024] FIG. 1 is a schematic diagram illustrating the principle of connecting a Buck-Boost DC-DC conversion module and a DC-DC conversion module to a linear pluggable optical module according to an embodiment of the present disclosure;

[025] FIG. 2 is another schematic diagram illustrating the principle of connecting the Buck-Boost DC-DC conversion module and the DC-DC conversion module to the linear pluggable optical module according to an embodiment of the present disclosure;

[026] FIG. 3 is another schematic diagram illustrating the principle of connecting the Buck-Boost DC-DC conversion module and the DC-DC conversion module to the linear pluggable optical module according to an embodiment of the present disclosure;

[027] FIG. 4 is another schematic diagram illustrating the principle of connecting the Buck-Boost DC-DC conversion module and the DC-DC conversion module to the linear pluggable optical module according to an embodiment of the present disclosure;

[028] FIG. 5 is a schematic diagram of a five-corner test TDECQ performance results provided by an embodiment of the present disclosure; and

[029] FIG. 6 is a schematic circuit diagram of a DC-DC conversion module supplying power to a high-power laser according to an embodiment of the present disclosure.

[030] Reference numerals: R1 - first resistor, R2 - second resistor, R3 - third resistor, R4 - fourth resistor, R5 - fifth resistor, R6 - sixth resistor, R7 - seventh resistor, R8 - eighth resistor, C1 - first capacitor, C2 - second capacitor, C3 - third capacitor, C4 - fourth capacitor, C5 - fifth capacitor, A1 - first operational amplifier, L1 - first inductor, U1 - DC-DC conversion module.

DETAILED DESCRIPTION OF EMBODIMENTS

[031] To make the objectives, technical solutions, and advantages of the embodiments of the present disclosure clearer, the technical solutions in the embodiments of the present disclosure will be described clearly and completely below with reference to the drawings in the embodiments of the present disclosure. It is to be understood that the described embodiments are only some, but not all, embodiments of the present disclosure. The components of the embodiments of the present disclosure generally described and illustrated in the drawings herein may be arranged and designed in various different configurations.

[032] An embodiment of the present disclosure provides a method for implementing high stability and low power consumption for a linear pluggable optical module, including arranging a Buck-Boost DC-DC conversion module at the power supply input port of the linear pluggable optical module. The Buck-Boost DC-DC conversion module isolates the system power supply on the Host side from the power supply of the linear pluggable optical module. The power supply output by the golden finger module of the linear pluggable optical module achieves soft power-on modulation through soft-start, and is then transmitted to the corresponding optical devices at the transmitting end or receiving end respectively after passing through the Buck-Boost DC-DC conversion module. On one hand, the power supply voltage is stabilized after passing through the Buck-Boost DC-DC conversion module; on the other hand, due to the isolation of the Buck-Boost DC-DC conversion module, the system noise caused by the power supply of the golden finger module is isolated on one side, which reduces the interference of noise caused by power supply and enhances the system stability. At least one DC-DC conversion module is arranged at an output end of the Buck-Boost DC-DC conversion module, and the DC-DC conversion module supplies power to the high-power laser. Using the DC-DC conversion module to supply power to the high-power laser can eliminate the headroom of the current-mode digital-to-analog converter (IDAC) and reduce power consumption.

[033] In some implementations, for example, three DC-DC conversion modules can be arranged on the power supply input side of the linear pluggable optical module of the embodiment of the present disclosure, and the three DC-DC conversion modules supply power to a silicon optical MZ modulator, a photoelectric conversion module, and a high-power laser, respectively. The DC-DC conversion module can be a buck DC-DC conversion module or a boost DC-DC conversion module, etc., selected according to the functional requirements of the device connected to the DC-DC conversion module.

[034] In this example, the DC-DC conversion module that supplies power to the photoelectric conversion module at the receiving end is a boost DC-DC conversion module, which can provide better performance support for the photoelectric conversion module. The DC-DC conversion modules that supply power to the silicon optical MZ modulator and the high-power laser at the transmitting end are buck DC-DC conversion modules. Since the voltage required for powering the silicon optical MZ modulator and the high-power laser is relatively low, and since the system power supply voltage for the pluggable optical module is relatively high and remains high even after passing through the Buck-Boost DC-DC conversion module, the system power supply is stepped down by buck DC-DC conversion modules and then supplied to the silicon optical MZ modulator and the high-power laser respectively, thereby reducing power consumption and loss and ensuring the stable operation of the silicon optical MZ modulator and the high-power laser.

[035] Specifically, the specific wiring and functional implementation process of the system is further explained below.

[036] Referring to FIG. 1, a power output end of a golden finger module of the linear pluggable optical module is connected to an input end of a soft-start module, an output end of the soft-start module is connected to a power end of a main control module and an input end of the Buck-Boost DC-DC conversion module, the output end of the Buck-Boost DC-DC conversion module is connected to an input end of a first DC-DC conversion module, an input end of a second DC-DC conversion module, an input end of a third DC-DC conversion module, a power end of a linear driver, and a power end of a linear TIA module; and an output end of the first DC-DC conversion module, an output end of the second DC-DC conversion module, an output end of the third DC-DC conversion module are respectively connected to power ends of the high-power laser, the silicon optical MZ modulator, and the photoelectric conversion module.

[037] An RF signal output end of the golden finger module of the linear pluggable optical module is connected to an RF signal input end of the linear driver, and an output end of the linear driver is connected to an RF signal input end of the silicon optical MZ modulator.

[038] An RF signal output end of the photoelectric conversion module is connected to an RF signal input end of the linear TIA module, and an RF signal output end of the

linear TIA module is connected to an RF signal input end of the golden finger module of the linear pluggable optical module.

[039] The low-frequency signal output end of the main control module is connected to the low-frequency signal input end of the Buck-Boost DC-DC conversion module and the low-frequency signal input end of the DC-DC conversion module, and the low-frequency signal output end of the high-power laser is connected to the low-frequency signal input end of the silicon optical MZ modulator.

[040] In this embodiment, when the system power supply is disturbed, noise will travel along the system power line to the golden finger of the LPO. The soft-start module is a MOS chip configured to achieve a soft power-on effect for subsequent devices. The soft-start module itself cannot isolate noise, so the noise will reach the input stage of the Buck-Boost DC-DC conversion module along with the soft-start module. The main control module part performs micro-control work. The main control module can operate normally provided that the digital low-level voltage is between 0 and 0.8 V and the digital high-level voltage is within the range of $V_{CC}-0.8\text{ V}$ to V_{CC} . Therefore, the main control module is not affected by noise and can directly use the power supply after the soft-start module. Since the working principle of the DC/DC conversion module is mainly based on the energy storage and release principle of the inductor and the switching control of the switching tube, and sufficient filter capacitors are provided at the output stage, the input stage noise is also converted into energy and stored during the charging phase, at which point the noise disappears. When the switching tube is in the off state, the input voltage and the inductor jointly charge the output capacitor, and the inductor releases the energy absorbed previously, thereby maintaining the stability of the output voltage. Based on this working principle, the output end of the DC-DC conversion module is unaffected by the noise from the input end. This means the DC-DC conversion module effectively isolates the input noise. Therefore, all components powered by the output of the DC-DC conversion module have clean power supplies. The power supply noise from the system side cannot affect the working state of various components within the LPO, thereby improving the stability of the LPO operation and enhancing the performance of the LPO.

[041] Since the power supply voltage required by many components in the LPO module is 3.3 V, if a Buck DC-DC conversion module is used, the input power supply may be lower than or equal to 3.3 V, at which point the Buck DC-DC conversion module cannot work normally. Therefore, to ensure that the LPO still has noise isolation capability and can work normally when the input voltage is lower than or equal to 3.3 V, a Buck-Boost DC-DC conversion module is used in this embodiment.

[042] On the other hand, the modulator used in this embodiment is a silicon optical MZ modulator, also known as a silicon optical Mach-Zehnder modulator, because for LPOs, the linearity of the module is an important indicator for evaluating its overall performance. Currently, electro-absorption modulators (EMLs) are still widely used in the market. Their linear range is greatly affected by negative voltage, and changes in

ambient temperature also affect the linearity of EML modulators. In comparison, the silicon optical MZ modulator has very good linearity throughout its entire operating range. Therefore, using a silicon optical MZ modulator can significantly improve module performance.

[043] In addition, this embodiment uses a high-power laser to provide a light source for the silicon optical MZ modulator, enabling the silicon optical MZ modulator to convert RF electrical signals into optical signals. The high-power laser needs to provide sufficient current to ensure that the output optical power meets the requirements. The conventional method of providing current is to use dedicated IDAC devices, but IDAC devices have headroom, which causes part of the energy to be consumed by the IDAC device. For example, an IDAC device commonly used in the prior art has a headroom of 0.3 V when outputting a current of 150 mA, which is equivalent to 0.18 W of power consumption of the LPO module being wasted on the IDAC device ($4 \times 0.3 \times 0.15 = 0.18$ W). When the module operates in a high-temperature environment, the required current is larger, and the power consumption due to headroom is greater. Therefore, in this embodiment, the output of the DC-DC conversion module is directly configured to supply current to the high-power laser. The output of the DC-DC conversion module is directly and fully applied to the high-power laser, which can completely eliminate headroom and reduce power consumption.

[044] In a feasible implementation of the present disclosure, referring to FIG. 2, a fourth DC-DC conversion module is further provided in the pluggable optical module, and the linear TIA module is powered by the fourth DC-DC conversion module or the Buck-Boost DC-DC conversion module. Because if all components are powered through the Buck-Boost DC-DC converter, the overall power consumption of the LPO may increase. Because the DC-DC conversion module itself has a certain conversion efficiency, all components supplied by the output of the DC-DC conversion module will be affected by this conversion efficiency, and the reduced power consumption may not be significant. Therefore, optimization can be performed based on the goal of further reducing power consumption.

[045] For example, when the linear driver has a shutdown function, the linear TIA module is powered by the Buck-Boost DC-DC conversion module; if the linear driver does not have a shutdown function, the linear TIA module is powered by the fourth DC-DC conversion module.

[046] Referring to FIG. 2, when a fourth DC-DC conversion module is provided in the pluggable optical module of the embodiment of the present disclosure, the power output end of the golden finger module of the linear pluggable optical module is connected to the input end of the soft-start module, the output end of the soft-start module is connected to the input end of the Buck-Boost DC-DC conversion module and the power end of the main control module, the output end of the Buck-Boost DC-DC conversion module is connected to the input end of the first DC-DC conversion module, the input end of the second DC-DC conversion module, the input end of the third DC-DC

conversion module, the input end of the fourth DC-DC conversion module, and the power end of the linear driver. The output end of the Buck-Boost DC-DC conversion module is further connected to the power end of the linear TIA module through a first switch, the output end of the fourth DC-DC conversion module is connected to the power end of the linear TIA module through a second switch. The output end of the first DC-DC conversion module, the output end of the second DC-DC conversion module, and the output end of the third DC-DC conversion module are respectively connected to the power ends of the high-power laser, the silicon optical MZ modulator, and the photoelectric conversion module. An RF signal output end of the golden finger module of the linear pluggable optical module is connected to an RF signal input end of the linear driver, and an output end of the linear driver is connected to an RF signal input end of the silicon optical MZ modulator. An RF signal output end of the photoelectric conversion module is connected to an RF signal input end of the linear TIA module, and an RF signal output end of the linear TIA module is connected to an RF signal input end of the golden finger module of the linear pluggable optical module. The low-frequency signal output end of the main control module is connected to the low-frequency signal input end of the Buck-Boost DC-DC conversion module, the low-frequency signal input end of the fourth DC-DC conversion module, and the low-frequency signal input end of the first DC-DC conversion module, and the low-frequency signal output end of the high-power laser is connected to the low-frequency signal input end of the silicon optical MZ modulator.

[047] In some feasible implementations, as shown in FIG. 3, an embodiment of the present disclosure can further provide a method for implementing high stability and low power consumption for a linear pluggable optical module, including: arranging a Buck-Boost DC-DC conversion module at a power supply input port of the linear pluggable optical module, wherein the Buck-Boost DC-DC conversion module isolates a system power supply on a Host side from a power supply of the linear pluggable optical module; and further arranging at least one DC-DC conversion module at the power supply input port of the linear pluggable optical module, wherein the DC-DC conversion module supplies power to a high-power laser. The power supply output by the golden finger module of the linear pluggable optical module achieves soft power-on modulation through soft-start, and is then transmitted to the linear driver at the transmitting end and the linear TIA module at the receiving end for power supply after passing through the Buck-Boost DC-DC conversion module. The power supply for the high-power laser at the transmitting end or the devices at the receiving end is output through the DC-DC conversion module. On one hand, the power supply voltage is stabilized after passing through the Buck-Boost DC-DC conversion module; on the other hand, due to the isolation of the Buck-Boost DC-DC conversion module, the system noise introduced by the power supply from the golden finger module is isolated on one side, reducing the interference from power supply noise and enhancing system stability. At least one DC-DC conversion module is further arranged at the power supply input port of the linear pluggable optical module after soft-start to supply power to the high-power laser. Using a DC-DC conversion module to supply power to the high-power laser can

stabilize the voltage and eliminate the headroom required when using a current-mode digital-to-analog converter (IDAC), reducing power consumption.

[048] In some implementations, for example, the at least one DC-DC conversion module further arranged at the power supply input port of the linear pluggable optical module after soft-start specifically includes three DC-DC conversion modules, and the three DC-DC conversion modules supply power to a silicon optical MZ modulator, a photoelectric conversion module, and a high-power laser, respectively.

[049] Specifically, the specific wiring and functional implementation process of the system is further explained below.

[050] Referring to FIG. 3, the power output end of the golden finger module of the linear pluggable optical module is connected to the input end of the soft-start module, the output end of the soft-start module is connected to the power end of the main control module, the input end of the Buck-Boost DC-DC conversion module, the input end of the first DC-DC conversion module, the input end of the second DC-DC conversion module, and the input end of the third DC-DC conversion module, and the output end of the Buck-Boost DC-DC conversion module is connected to the power end of the linear driver and the power end of the linear TIA module. The output end of the first DC-DC conversion module, the output end of the second DC-DC conversion module, and the output end of the third DC-DC conversion module are respectively connected to the power ends of the high-power laser, the silicon optical MZ modulator, and the photoelectric conversion module.

[051] An RF signal output end of the golden finger module of the linear pluggable optical module is connected to an RF signal input end of the linear driver, and an output end of the linear driver is connected to an RF signal input end of the silicon optical MZ modulator. An RF signal output end of the photoelectric conversion module is connected to an RF signal input end of the linear TIA module, and an RF signal output end of the linear TIA module is connected to an RF signal input end of the golden finger module of the linear pluggable optical module.

[052] A low-frequency signal output end of the main control module is connected to a low-frequency signal input end of the Buck-Boost DC-DC conversion module and a low-frequency signal input end of the first DC-DC conversion module, and a low-frequency signal output end of the high-power laser is connected to a low-frequency signal input end of the silicon optical MZ modulator.

[053] When the system power supply is disturbed, noise will travel along the system power line to the golden finger of the LPO, and the noise will reach the input stage of the Buck-Boost DC-DC conversion module along with the soft-start module. Since the working principle of the DC/DC conversion module is mainly based on the energy storage and release principle of the inductor and the switching control of the switching tube, and sufficient filter capacitors are provided at the output stage, the input stage noise is also converted into energy and stored during the charging phase, at which point

the noise disappears. When the switching tube is in the off state, the input voltage and the inductor jointly charge the output capacitor, and the inductor releases the energy absorbed previously, thereby maintaining the stability of the output voltage. Based on this working principle, the output end of the DC-DC conversion module is unaffected by the noise from the input end. This means the DC-DC conversion module effectively isolates the input noise. Therefore, all components powered by the output of the DC-DC conversion module have clean power supplies. The power supply noise from the system side cannot affect the working state of various components within the LPO, thereby improving the stability of the LPO operation and enhancing the performance of the LPO. It can be seen that devices connected to the output end of the Buck-Boost DC-DC conversion module can effectively isolate noise through the Buck-Boost DC-DC conversion module, and the DC-DC conversion module can also stabilize the voltage for the transmitting end or receiving end devices connected to its output.

[054] Referring to FIG. 4, in a feasible implementation of the present disclosure, a fourth DC-DC conversion module is further provided in the pluggable optical module, and the linear TIA module is powered by the fourth DC-DC conversion module or the Buck-Boost DC-DC conversion module.

[055] For example, when the linear driver has a shutdown function, the linear TIA module is powered by the Buck-Boost DC-DC conversion module; if the linear driver does not have a shutdown function, the linear TIA module is powered by the fourth DC-DC conversion module.

[056] Referring to FIG. 4. When a fourth DC-DC conversion module is provided in the pluggable optical module of the embodiment of the present disclosure, the output end of the soft-start module is connected to the input end of the fourth DC-DC conversion module, the output end of the Buck-Boost DC-DC conversion module is connected to the linear driver, and is further connected to the power end of the linear TIA module through a first switch, and the output end of the fourth DC-DC conversion module is connected to the power end of the linear TIA module through a second switch. The low-frequency signal output end of the main control module is further connected to a low-frequency signal input end of the fourth DC-DC conversion module. In this way, it is also possible to selectively power the linear TIA module through the Buck-Boost DC-DC conversion module or through the fourth DC-DC conversion module.

[057] The difference between the connection method shown in FIG. 1 and the connection method shown in FIG. 3 is that in the case of the connection method shown in FIG. 1, all components except the main control module have DC-DC conversion modules to isolate their power supply, and the third DC-DC conversion module used for powering the photoelectric conversion module is a boost converter (step-up converter). The fourth DC-DC conversion module for powering the linear TIA module has two types of converters to choose from: Buck type and Buck-Boost type, which correspond to the following two situations respectively:

[058] 1. When the employed linear driver features a shutdown function, the Buck-Boost DC-DC conversion module is selected to power the linear TIA module, i.e., the first switch A is closed and the second switch B is open. Since the main energy-consuming parts of the LPO module are the linear driver and the linear TIA module, the energy consumption of these two components accounts for 70% of the total power consumption of the LPO. In this case, the method to reduce the overall power consumption of the LPO is to lower the output voltage of the Buck-Boost DC-DC conversion module to the limit where both the linear driver and the linear TIA module can operate normally.

[059] The data of the linear driver and linear TIA module in Table 1 show the voltage range in which they can operate normally as recorded in the manuals of commonly used linear drivers and linear TIA modules in practical applications.

[060] Table 1 Data of Linear Driver and Linear TIA Module

Type	Minimum operating voltage	Typical operating voltage	Maximum operating voltage	Unit
Driver	3.135	3.3	3.465	V
TIA	2.9	3.3	3.5	V

[061] As can be seen from the above table, the voltage output of the Buck-Boost DC-DC conversion module can be set to at least 3.135 V. However, chip manufacturers generally leave margins when formulating data sheets. To explore their working capability, the output voltage of the DC-DC conversion module can be selected through experimentation. For example, in the LPO module shown in Table 1, the selected operating voltage of the DC-DC conversion module is 2.97 V. Compared to the normal power supply voltage, this method can reduce the overall power consumption of the LPO by 10%.

[062] 2. When the linear driver used does not have a shutdown function, the Buck DC-DC conversion module should be selected to power the linear TIA module, i.e., the first switch A is open and the second switch B is closed. The objective of this is to improve responsivity and reduce reflection during package coupling production. Because when coupling the photoelectric conversion module, the temperature of the PCB cannot be effectively dissipated. If the linear TIA module and the linear driver work simultaneously, the temperature of the PCB will rise rapidly, leading to slight deformation of the PCB and the optical components placed on it. The optimal optical position obtained by coupling under conditions with physical deformation is not the optimal optical position during normal operation, which will lead to changes in the responsivity of the RX end, increased reflection, and other issues. The only solution is to reduce the overall power consumption during the coupling process of the photoelectric conversion module and lower the temperature of the PCB. Therefore, in this case, it is necessary to separate the power supply of the linear TIA module and the

linear driver. When coupling the photoelectric conversion module, the power supply of the linear driver is turned off, so that it does not work, thereby reducing power consumption and the temperature of the PCB. In addition, in other specific working scenarios, the minimum operating voltage of the linear TIA module and the linear driver can also be found experimentally according to requirements to reduce the overall power consumption.

[063] Using the connection method shown in FIG. 3 can make the system connection method more flexible. If not all components are powered through the Buck-Boost DC-DC converter, some devices at the transmitting end or receiving end may still need to be powered sequentially through the Buck-Boost DC-DC converter and then a DC-DC converter, resulting in a certain increase in the overall power consumption of the LPO. This method allows devices to be flexibly connected to the Buck-Boost DC-DC converter or the DC-DC converter as needed, further reducing system power consumption. In addition, the connection methods of the embodiments of the present disclosure are not limited to the above examples. In fact, other reasonable variations made by those skilled in the art based on the aforementioned working ideas according to actual needs are within the scope of the present disclosure.

[064] In addition to the advantages of isolating system-side noise and reducing the overall power consumption of the LPO, the pluggable optical module of the embodiment of the present disclosure has another important advantage: the LPO module operates very stably, and there is no situation where performance changes due to changes in the system-side power supply voltage. If the power supply method of this embodiment is not configured to power the LPO module, the following situation may occur during application: the system power supply of Manufacturer A's equipment is 3.3 V, and at this time, the operating points of various components of the LPO module are adjusted to the optimum according to 3.3 V; however, the system power supply of Manufacturer B's equipment is 3.15 V, and at this time, the optimal operating points of some components of the LPO module change, resulting in affected LPO performance. For example, when the LPO module uses a silicon optical solution, 3.3 V and 3.15 V power supplies will cause the heater point of the modulator to be at different operating points. The manifested phenomenon is that the linearity of the eye diagram changes, and the transmitter dispersion eye closure for quaternary (TDECQ) changes, thereby affecting the performance of the LPO.

[065] However, when using the method in the embodiments of the present disclosure, since the operating voltages of all key components are constant and do not change with variations in the system power supply voltage, the stability of the LPO module operation can be greatly improved. FIG. 5 shows the TDECQ performance results of the five-corner test after adopting this optimized embodiment, demonstrating the TDECQ performance of the LPO module in the five-corner test. It can be seen that it is very stable and almost unaffected by the power supply voltage.

[066] In the foregoing description of the method for implementing high stability and low power consumption for a linear pluggable optical module the embodiment of the present disclosure, the related circuit of the DC-DC conversion module that supplies power to the high-power laser is mainly further explained.

[067] In some feasible implementations, the DC-DC conversion module supplies power to the high-power laser through a first operational amplifier. The first operational amplifier adjusts the current flowing through the high-power laser according to a set voltage.

[068] As a specific implementation case, in this embodiment, referring to FIG. 6, the circuit used by the DC-DC conversion module to supply power to the high-power laser includes an output voltage adjustment module, a plurality of resistors, a plurality of capacitors, an inductor, and a first operational amplifier A1.

[069] One end of the first capacitor C1, one end of the first resistor R1, the PVIN end and the AVIN end of the DC-DC conversion module U1 are connected to a DC source. The other end of the first resistor R1 is connected to the MODE/PG end of the DC-DC conversion module U1, one end of the second resistor R2 is connected to the EN end of the DC-DC conversion module U1, and the other end of the second resistor R2, the other end of the first capacitor C1, and the GND end, AGNG end, and PGND end of the DC-DC conversion module U1 are grounded.

[070] The SW end of the DC-DC conversion module is connected to one end of the first inductor L1, and the other end of the first inductor L1 is connected to one end of the fifth resistor R5. One end of the second capacitor C2, one end of the third capacitor C3, one end of the fourth capacitor C4, one end of the sixth resistor R6, one end of the seventh resistor R7, and the inverting input end of the first operational amplifier A1. The other end of the fifth resistor R5, the other end of the second capacitor C2, one end of the third resistor R3, and one end of the fourth resistor R4 are connected to the FB end of the DC-DC conversion module. The other end of the fourth resistor R4 is connected to the output voltage adjustment module. The other end of the third capacitor C3, the other end of the fourth capacitor C4, and the other end of the third resistor R3 are grounded. One end of the fifth capacitor C5, the other end of the sixth resistor R6, and the other end of the seventh resistor R7 are connected to the non-inverting input end of the DC-DC module U1, and the other end of the fifth capacitor C5 is grounded.

[071] The output end of the first operational amplifier A1 outputs a voltage through the eighth resistor R8 and is connected to the high-power laser.

[072] For example, the model of the DC-DC conversion module U1 can be TPS62065.

[073] In a feasible implementation of the present disclosure, the voltage output by the DC-DC conversion module U1 is directly supplied to the anode of the high-power laser, and the cathode of the laser is grounded. The sixth resistor R6 and the seventh resistor R7 are connected to the first operational amplifier A1 together, and the voltage

difference between the two ends of the sixth resistor R6 and the seventh resistor R7 is amplified by 50 times through the first operational amplifier A1. The microcontroller can detect the current flowing through the high-power laser by collecting the amplified voltage and performing a certain operation. The current flowing through the high-power laser can be adjusted by setting different output voltages through the voltage adjustment module DAC_SET.

[074] The above are only the preferred embodiments of the present disclosure, and are not intended to limit the present disclosure. For those skilled in the art, the present disclosure may be modified and varied. Any modification, equivalent substitution, improvement, etc. made within the spirit and principles of the present disclosure shall fall within the protection scope of the present disclosure.

What is claimed is:

1. A method for implementing high stability and low power consumption for a linear pluggable optical module, comprising:

arranging a Buck-Boost DC-DC conversion module at a power supply input port of the linear pluggable optical module, wherein the Buck-Boost DC-DC conversion module isolates a system power supply on a Host side from a power supply of the linear pluggable optical module; and

arranging at least one DC-DC conversion module at an output end of the Buck-Boost DC-DC conversion module, wherein the DC-DC conversion module supplies power to the high-power laser.

2. The method for implementing high stability and low power consumption for a linear pluggable optical module according to claim 1, wherein three DC-DC conversion modules are arranged at the output end of the Buck-Boost DC-DC conversion module, and the three DC-DC conversion modules supply power to a silicon optical MZ modulator, a photoelectric conversion module, and the high-power laser, respectively.

3. The method for implementing high stability and low power consumption for a linear pluggable optical module according to claim 1 or 2, wherein a power output end of a golden finger module of the linear pluggable optical module is connected to an input end of a soft-start module, an output end of the soft-start module is connected to a power end of a main control module and an input end of the Buck-Boost DC-DC conversion module, the output end of the Buck-Boost DC-DC conversion module is connected to an input end of a first DC-DC conversion module, an input end of a second DC-DC conversion module, an input end of a third DC-DC conversion module, a power end of a linear driver, and a power end of a linear TIA module; and an output end of the first DC-DC conversion module, an output end of the second DC-DC conversion module, an output end of the third DC-DC conversion module are respectively connected to power ends of the high-power laser, the silicon optical MZ modulator, and the photoelectric conversion module;

an RF signal output end of the golden finger module of the linear pluggable optical module is connected to an RF signal input end of the linear driver, and an output end of the linear driver is connected to an RF signal input end of the silicon optical MZ modulator;

an RF signal output end of the photoelectric conversion module is connected to an RF signal input end of the linear TIA module, and an RF signal output end of the

linear TIA module is connected to an RF signal input end of the golden finger module of the linear pluggable optical module; and

a low-frequency signal output end of the main control module is connected to a low-frequency signal input end of the Buck-Boost DC-DC conversion module and a low-frequency signal input end of the first DC-DC conversion module, and a low-frequency signal output end of the high-power laser is connected to a low-frequency signal input end of the silicon optical MZ modulator.

4. The method for implementing high stability and low power consumption for a linear pluggable optical module according to claim 2 or 3, wherein the linear driver has a shutdown function, and the Buck-Boost DC-DC conversion module supplies power to the linear TIA module and the linear driver, respectively.
5. The method for implementing high stability and low power consumption for a linear pluggable optical module according to claim 3 or 4, wherein a fourth DC-DC conversion module is further provided;

the output end of the Buck-Boost DC-DC conversion module is further connected to an input end of the fourth DC-DC conversion module, the output end of the Buck-Boost DC-DC conversion module is connected to the power end of the linear driver, the linear driver is connected to the power end of the linear TIA module through a first switch, and an output end of the fourth DC-DC conversion module is connected to the power end of the linear TIA module through a second switch; and

the low-frequency signal output end of the main control module is further connected to a low-frequency signal input end of the fourth DC-DC conversion module.

6. The method for implementing high stability and low power consumption for a linear pluggable optical module according to claim 5, wherein the first switch and the second switch are not open or closed simultaneously; when the first switch is open and the second switch is closed, the linear TIA module is powered by the fourth DC-DC conversion module; or, when the first switch is closed and the second switch is open, the linear TIA module is powered by the Buck-Boost DC-DC conversion module.

7. The method for implementing high stability and low power consumption for a linear pluggable optical module according to any one of claims 1 to 6, wherein the DC-DC conversion module supplies power to the high-power laser through a first operational amplifier, and the first operational amplifier adjusts the current flowing through the high-power laser according to a set voltage.
8. A linear pluggable optical module, configured to operate according to the method for implementing high stability and low power consumption for a linear pluggable optical module according to any one of claims 1 to 7.
9. A method for implementing high stability and low power consumption for a linear pluggable optical module, comprising:

arranging a Buck-Boost DC-DC conversion module at a power supply input port of the linear pluggable optical module, wherein the Buck-Boost DC-DC conversion module isolates a system power supply on a Host side from a power supply of the linear pluggable optical module; and

further arranging at least one DC-DC conversion module at the power supply input port of the linear pluggable optical module, wherein the DC-DC conversion module supplies power to a high-power laser.
10. The method for implementing high stability and low power consumption for a linear pluggable optical module according to claim 9, wherein three DC-DC conversion modules are provided, and the three DC-DC conversion modules supply power to a silicon optical MZ modulator, a photoelectric conversion module, and the high-power laser, respectively.
11. The method for implementing high stability and low power consumption for a linear pluggable optical module according to claim 9 or 10, wherein a power output end of a golden finger module of the linear pluggable optical module is connected to an input end of a soft-start module, an output end of the soft-start module is connected to a power end of a main control module, an input end of the Buck-Boost DC-DC conversion module, an input end of a first DC-DC conversion module, an input end of a second DC-DC conversion module, and an input end of a third DC-DC conversion module, an output end of the Buck-Boost DC-DC conversion module is connected to a power end of a linear driver and is connected to a power end of a linear TIA module; and an output end of the first DC-DC conversion module, an output end of the second DC-DC conversion module, and

an output end of the third DC-DC conversion module are respectively connected to power ends of the high-power laser, the silicon optical MZ modulator, and the photoelectric conversion module;

an RF signal output end of the golden finger module of the linear pluggable optical module is connected to an RF signal input end of the linear driver, and an output end of the linear driver is connected to an RF signal input end of the silicon optical MZ modulator;

an RF signal output end of the photoelectric conversion module is connected to an RF signal input end of the linear TIA module, and an RF signal output end of the linear TIA module is connected to an RF signal input end of the golden finger module of the linear pluggable optical module; and

a low-frequency signal output end of the main control module is connected to a low-frequency signal input end of the Buck-Boost DC-DC conversion module and a low-frequency signal input end of the first DC-DC conversion module, and a low-frequency signal output end of the high-power laser is connected to a low-frequency signal input end of the silicon optical MZ modulator.

12. The method for implementing high stability and low power consumption for a linear pluggable optical module according to claim 10 or 11, wherein the linear driver has a shutdown function, and the Buck-Boost DC-DC conversion module supplies power to the linear TIA module and the linear driver, respectively.

13. The method for implementing high stability and low power consumption for a linear pluggable optical module according to claim 11 or 12, wherein a fourth DC-DC conversion module is further provided, the output end of the soft-start module is further connected to an input end of the fourth DC-DC conversion module, an output end of the Buck-Boost DC-DC conversion module is connected to the power end of the linear driver and is connected to a power end of the linear TIA module through a first switch, and an output end of the fourth DC-DC conversion module is connected to the power end of the linear TIA module through a second switch; and

the low-frequency signal output end of the main control module is further connected to a low-frequency signal input end of the fourth DC-DC conversion module.

14. The method for implementing high stability and low power consumption for a linear pluggable optical module according to claim 13, wherein the first switch

and the second switch are not open or closed simultaneously; when the first switch is open and the second switch is closed, the linear TIA module is powered by the fourth DC-DC conversion module; or, when the first switch is closed and the second switch is open, the linear TIA module is powered by the Buck-Boost DC-DC conversion module.

15. A linear pluggable optical module, configured to operate according to the method for implementing high stability and low power consumption for a linear pluggable optical module according to any one of claims 9 to 14.