White Paper: Renesas' Zero Standby Power Applications

Using Digital Control Simplifies Design and Lowers Cost in Zero Standby Power Applications

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Vampire power, the power consumption of a power supply when no load is connected, is a significant contributor to wasted energy in households. As a result, just about anything that a consumer plugs into the wall and never unplugs is now subject to tightening power constraints. This includes home appliances and white goods such as dishwashers, refrigerators, freezers, washers and dryers, vacuum cleaners, electronics displays (e.g., televisions), phone chargers, and even USB wall outlets. Today, the EU commission requires most appliances to use less than 500mW in standby mode or 1W if they are displaying their status information while in standby mode. By 2027, this requirement is fine-tuned to use less than 0.5W in standby, 0.8W in standby while displaying status, and 0.3W in off mode. In the United States, ENERGY STAR® and new Department of Energy (DoE) regulations are following suit with regulations approaching the European standards. The main AC/DC converter is responsible for managing these off-mode and standby mode power levels and, with the right technology, can enable zero standby power (ZSP).

In typical always-connected applications, when the device is in off-mode or standby mode (in the case of an appliance or TV), power consumption in that system reduces to near zero, but voltage is still required to maintain bias on key circuits to provide quick response to inputs from the user. During this process, the AC/DC converter that provides the main voltage in the system generates most of the power consumption. AC/DC converters with zero standby power (ZSP) capability can reduce these power consumption levels well below the required limit of < 500mW.

However, the problem of achieving ZSP gets trickier the higher up the power spectrum you go. Traditional analog solutions tend to yield a bigger power supply with higher current consumption, making it much more difficult to accomplish ZSP and maintain a lower bill of materials (BOM) cost and small package size. Over a decade ago, Renesas pioneered the first ZSP solution with the iW1700 pulse width modulation (PWM) controller that uses digital control to accomplish < 5mW(1) of power consumption in standby mode for a 5W power supply. Since then,a strong portfolio of digital ZSP ICs have launched that support up to 140W. These solutions provide enhancements to the original ZSP solution to maintain <5mW standby power, or ZSP, within a small footprint by using digital control and minimizing BOM cost.

Higher power, same ZSP requirement

The issue of achieving ZSP becomes more challenging with higher power ratings. Most conventional USB chargers used between 5 to 15W of power supporting old "brick" phones, and now, these chargers can use up to 100W to support today's highly complex smartphones – still with lower power consumption expectations. AC receptacles with

USB ports are being increasingly deployed in homes, offices, coffee shops, airports, and hotels. These units will naturally require ZSP when there is nothing connected to them.

The same trend can be seen with home appliances: the control boards of these systems generally consume 15 to 20W of power; however, depending upon the motor used, the motor control can cause the application to run up to 75W in active mode. Electronic displays such as HDR 4K and 8K TVs and gaming monitors consume more than 100W in active mode and have requirements to reach zero power consumption in standby mode. Charging battery packs for portable power tools can also consume vampire power when the battery is fully charged and disconnected (but the charger is still plugged in). These chargers can range between 50 to 100W of power. Devices such as these will spend the vast majority of their time not being used while still connected to AC and therefore require ZSP solutions that are rated for these higher output powers.

The conventional approach to achieving ZSP in higher power applications

Several design challenges emerge as the power consumption of power supplies increases. Traditional analog converters **(Figure 1)** will have performance directly proportional to current consumption (i.e., quiescent current). The size of the components within the largely analog solution (e.g., references, error amplifiers, comparators, etc.) will therefore also grow with higher power applications. This increases complexity and yields much bulkier and more costly power supplies to achieve ZSP.

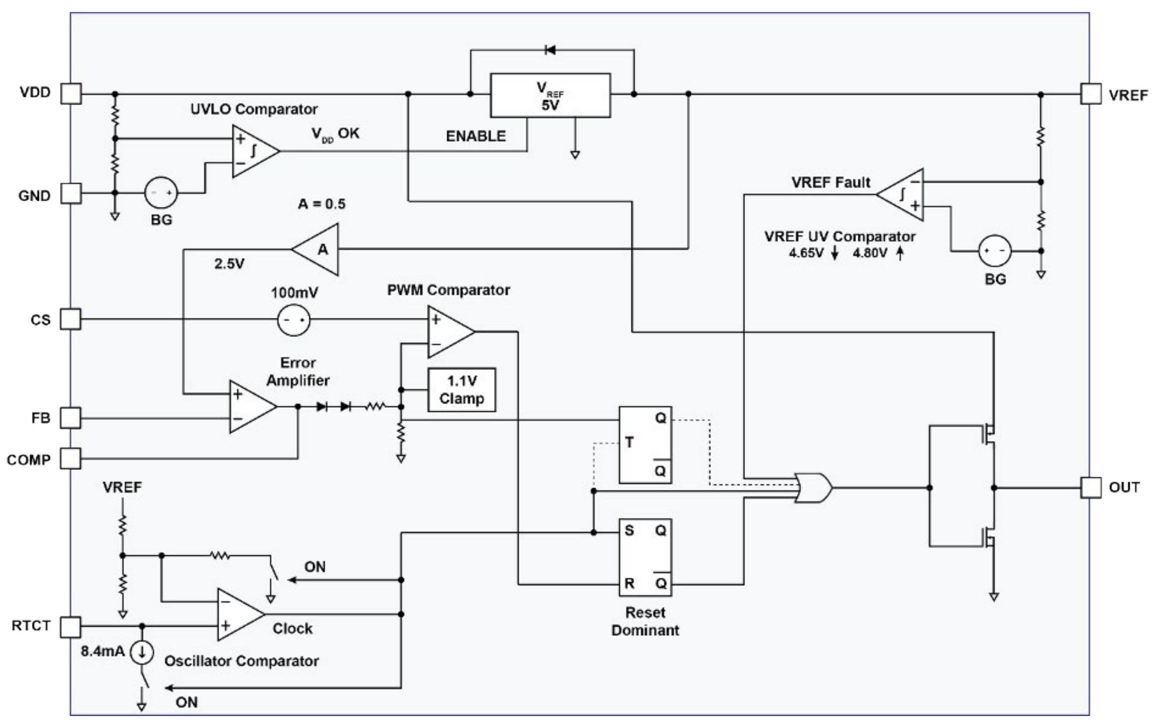

***Figure1**: Performance of traditional analog converters is typically directly proportional to current consumption the size of the solution to grow as power increases.*

Renesas ZSP solution: use digital control to simplify design, reduce size, lower cost

The complexity/size/cost scaling that comes with analog ZSP solutions can seem less and less viable with the trend to higher rated power supplies. This is where digital control becomes a much more effective solution. Renesas' first ZSP solution was the iW1700 and addressed 5W chargers using a proportional–integral–derivative controller (PID) control block to enable a degree of freedom over analog circuitry, where the current consumption can be increased or decreased as a function of the output current (Figure 2).

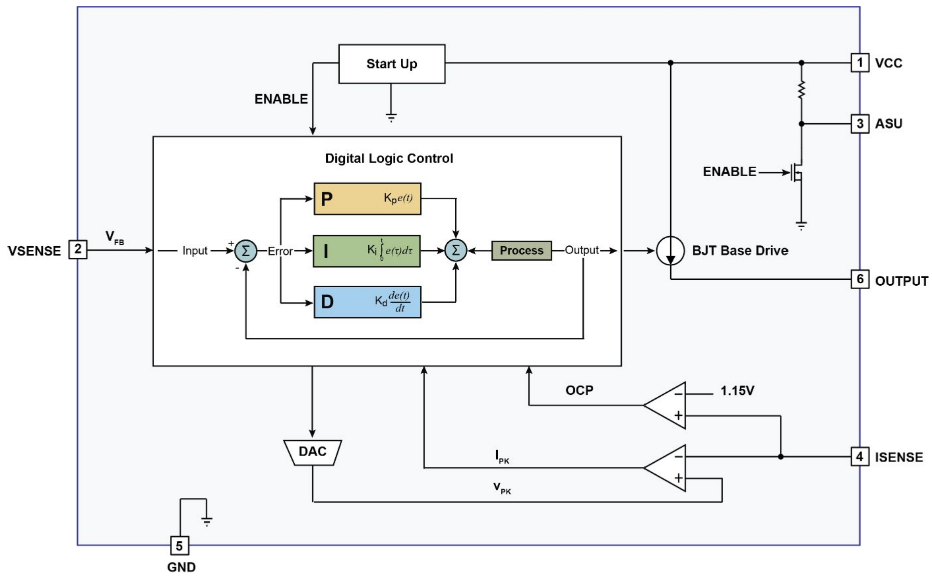

***Figure2**: PID digital control technology is used in the Renesas **iW1700** to accomplish the constant frequency quasi-resonant PWM control. Note: PID control is used in all Renesas ZSP solutions.*

This iW1700 quasi-resonant PWM controller was the first IC on the market to use PID control and could do the following:

- Minimize switching/conduction losses by reducing switching frequency at no-load,
- Reduce internal current consumption during off-time – optimizing it for no-load power consumption and,
- Quickly increase current consumption to respond to load change during on-time.

Design challenge: the more power, the more capacitance needed

The iW1700 solution is viable for power supplies up to 5W. At higher powers, however, another technical challenge becomes prominent: the overall performance of the control loop when transitioning from ZSP mode to active mode determines the amount of capacitance needed in the system **(Figure 3)**, which in turn determines the size and cost of those components.

***Figure3**: Image of output capacitors used in a power supply with ZSP. The size of the capacitors at higher powers is key to keeping the BOM cost and solution size low.*

How Renesas enables ZSP with minimum BOM cost

As shown in Table 1, there is a large portfolio of ZSP solutions for output power ratings up to 140W, depending on the combination of primary-side and secondary-side ICs used.

Table1. AC/DC Power Management ICs for ZSP

Primary Side	Secondary Side	Synchronous Rectifier (SR) >90%efficiency	Output Power	No-Load Standby Power	Primary-Side Driver Type
Max output power < 12 W					
iW1700	-	-	5W	< 5mW	BJT
Max output power > 63 W					
iW9860	iW760	IntegratediniW760	63W	< 5mW	FET
iW9860	iW765	IntegratediniW765	100W	< 5mW	FET
iW9860	iW690	IntegratediniW690	140W	< 5mW	FET
iW9870	iW760	IntegratediniW760	63W	< 5mW	GaN
iW9870	iW765	IntegratediniW765	100W	< 5mW	GaN
iW9870	iW690	IntegratediniW690	140W	< 5mW	GaN

So how did Renesas manage to reach maximum output powers beyond 60W without increasing the BOM count (and therefore the size and cost) of the ZSP solution? In short, this is accomplished through unique dynamics between the primary and secondary ICs. First, the proprietary digital control technology was improved to bring the no-load switching frequency down to 20Hz. However, it is critical to optimize the response time from no-load to active mode to minimize the output capacitance.

This is achieved by employing dynamic power management of the IC’s internal circuitry, where additional Deep Sleep modes are introduced. In normal/active mode, both the primary and secondary ICs will operate at their nominal current consumption to, for example, supply 50W of power on the output of the power supply. When the load is detached, or when the load enters a low power state, the converter itself goes into a standby mode. This mode simply detects that the load has “gone away,” so that it may enter an even lower power consumption mode.

However, the switch from active to the lowest switching frequency state (Deep Sleep mode) is not immediate: there is a delay to confirm that the device will, in fact, stay in a very-light-load mode. These ZSP solutions will also cycle back into the intermediate state (Standby Mode) to ensure the system remains in a no-load state. If current is actually being drawn when the solution has switched back to this intermediate state, then it can very rapidly go back into Normal mode, reducing the response time and the amount of capacitance required to achieve the same regulation performance **(Figure 4)**.

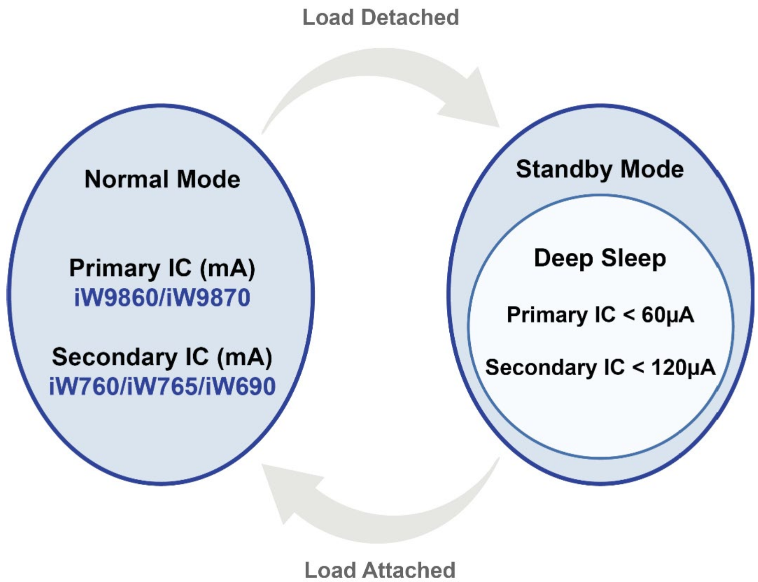

***Figure4**: The intelligent cycling between operating states for both the primary-side and secondary-side ICs allows for the end system to achieve a lower output capacitance and ZSP at higher power ratings.*

ZSP solution for 63 W USB PD 3.0 power supplies

Figure 5 shows the industry’s first ZSP solution for USB PD 3.0 applications up to 63W. While the target application is USB chargers and adapters, this can also be adopted in other applications such as USB ports in AC receptacles and even in small, battery-operated appliances to meet the new EU common charger specification. Renesas also offers ZSP chipsets for USB PD 3.0 power supplies up to 100W when the secondary IC is switched from the iW760 to the iW765 (the primary-side IC remains the same (iW9860).

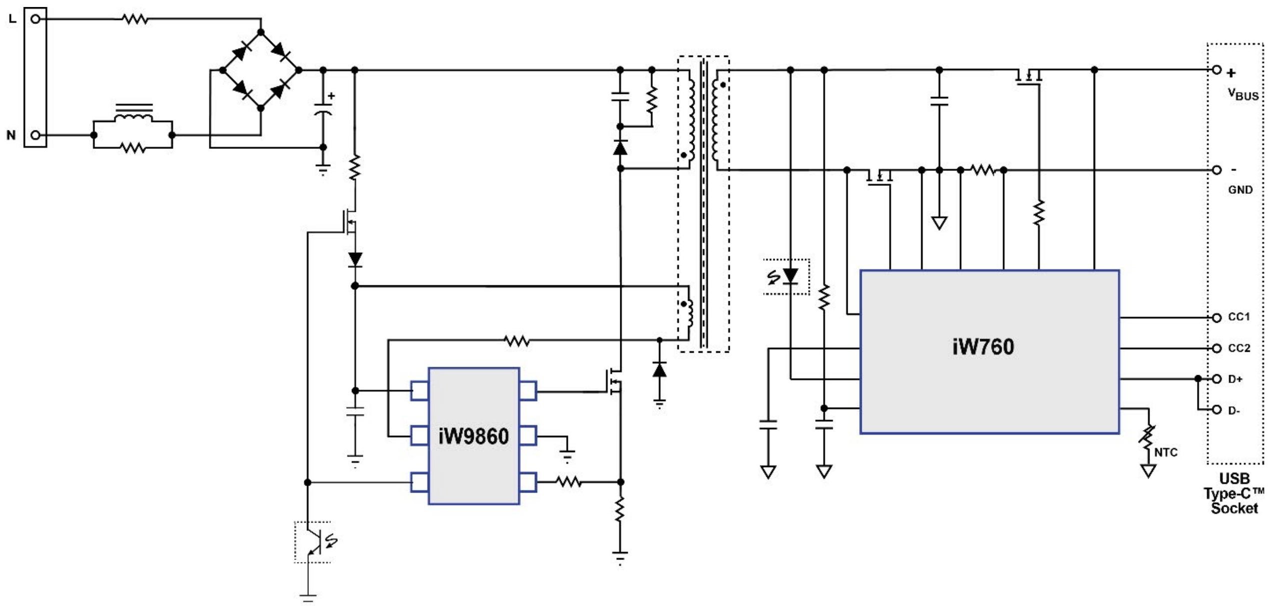

***Figure5**: The ZSP chipset for the 63W USB PD 3.0 power supply was the industry's first chipset to accomplish ZS Pat high power. 100W can be achieved by using the **iW765** in place of **iW760**.*

ZSP solution for 140W power supplies with Si MOSFET or GaN HEMT switching devices

Figure 6 illustrates the circuit for 140W power supplies. The primary-side device is the same iW9860 while the secondary side is now the iW690. In this application circuit, the support for the USB type-C connector is removed and the chipset is instead controlling a power supply with a fixed output voltage (e.g., 12 to 20V).

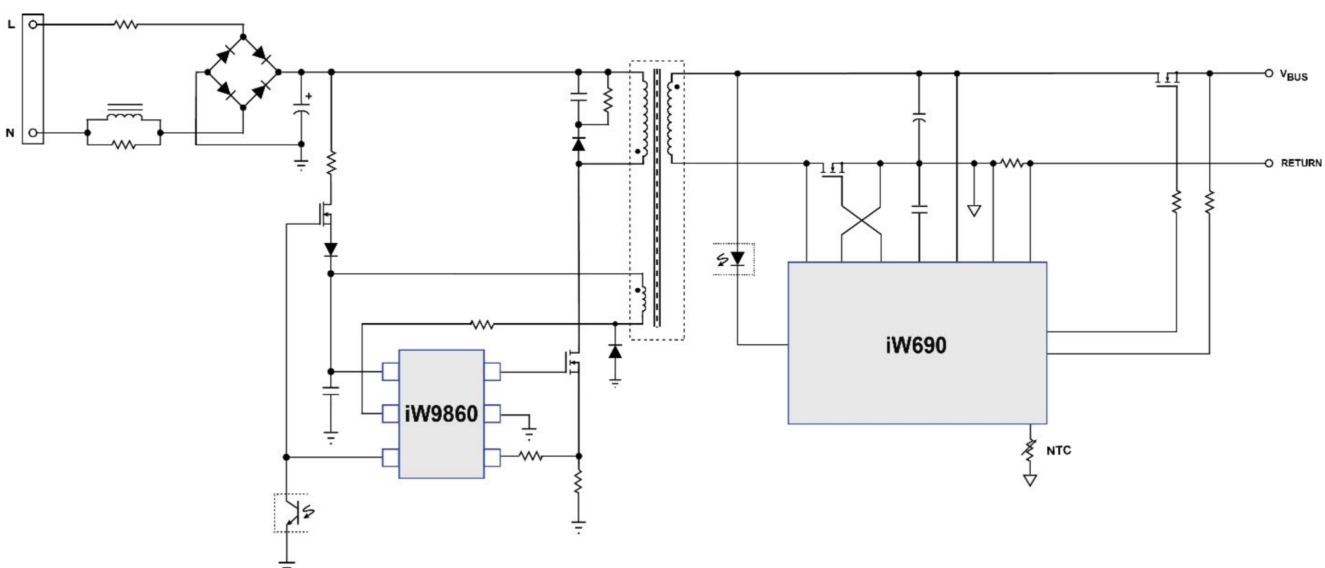

***Figure 6**: Application circuit for appliances and TVs with up to 140W power supplies using the **iW9860** primary-side IC and the **iW690** secondary-side IC, leveraging an Si MOSFET. Changing the primary-side IC to **iW9870** enables a GaN HEMT-compatible circuit.*

While **Figure 6** illustrates a solution that leverages an Si MOSFET, a GaN HEMT-compatible circuit can also be used with the 140W power supplies when the primary-side circuit IC is changed to the iW9870. This capability is important in next-generation appliances, power tools, and TVs that aim to both run more efficiently and decrease their system size through the use of GaN switching devices. The wide bandgap (WBG) semiconductor can run at higher switching frequencies and achieve a much higher power density than conventional Si technologies and, therefore, will be seen more often in commercial solutions.

Conclusion

Appliances and equipment will consume power when not performing their primary function, causing these "always on" circuits to waste electricity. "Always on" electricity, or vampire power, used by inactive consumer devices has been known to contribute to a significant percentage of household electricity consumption. This has driven standards organizations to revamp energy efficiency specifications in order to drive designers of consumer electronics to create more efficient ZSP power supplies.

The Renesas leadership in ZSP spans over a decade, where the iW1700 was a market first to use intelligent digital control to accomplish ZSP. This was followed by the iW9860 and iW760 combination as the industry's first to enable ZSP for power supplies up to 63W. Now, there is an entire portfolio of solutions available for power supplies up to 140W giving appliance, TV, power tools, and USB charger/adapter manufacturers the ability to rapidly implement a ZSP solution without adding massive cost or complexity. These power supply designs also allow designers to meet new EU EcoDesign and ENERGY STAR (USA) regulations with ease.

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