



## PALADIN - A guardian of Solar Values

### Display Decode

The display for **PALADIN** is not at all important for its' correct operation, but there is a host of information there which can be useful. There are no buttons, touch pads / screens or areas to play with at all. Once installed it just works. You want to turn it off to reset it – fine.

The display is provided for the user to monitor and be informed as to what is happening, in real time, with the house and solar power use. Consequently there is a lot of data in a small space, but it is for reference, not entertainment. Below is a picture and a decode of each element of the display.

An explanation of the why and the how for **Paladin** is pertinent, but if you don't want to read this rather nerdy stuff, just read the display section directly below. But then why not read it all - you might find something of interest. Or indeed, do not read any of this - **PALADIN** will work just as well, but you may miss out on a unique understanding of how your house uses power.

### The Display

The only interface is the display screen. This is a busy and superficially confusing display as there is so much that Paladin can tell us about the state of our PV and household system.

Here is a simple diagram and decode of the display elements.



The order of interest and importance is top to bottom, left to right.

**Web:** [paladinsolarcontroller.com.au](http://paladinsolarcontroller.com.au) **Email:** [sales@paladinsolarcontroller.com.au](mailto:sales@paladinsolarcontroller.com.au)

**Facebook:** Paladin Solar Australia Pty Ltd

For basic data, only the left hand column is of interest. To avoid cluttering the screen, if there is no data to display (the value is zero) it will be a blank field. So using that left to right, top to bottom order here is an expansion of the data fields and significance:

### **Hot Water Temp:** *(updated every second)*

Hot Water Temperature is updated as it changes and is displayed to 1/100th of a degree Celsius. The **Paladin** temperature probe is a self contained computer module and is very accurate within the limitations of thermal inertia.

### **GRID I/O:** *(updated every second)*

Is the actual flow of electrical power in and out of the house in Watts. A positive number means you are exporting and a negative means you are consuming. You might see this as backwards, but think of it in money terms.

When **Paladin** is transferring (you have excess PV over the household use), this will be near zero. It will never be perfectly zero, since the displayed value is a 1 second aggregation of what is being measured some 3600 times and acted on 50 times in that second. The movement of this display element is essentially **Paladin's** heartbeat. The 'bounce' on this reading is subtle and is discussed further in the Technical discussion below.

### **TRANSFER:** *(updated every second)*

Is the Energy, in Watts, being transferred to the hot water cylinder in that second. This is either from excess PV, or, if the water temperature is below minimum, from the grid. **PALADIN** maintains a temperature of 40C as a minimum, but read the DeltaT explanation below.

### **SOLAR:** *(updated every 4 seconds)*

Is the Energy, in Watts, being transferred to the hot water cylinder in that second. The PV connection to **Paladin-4** is optional and is not required for correct operation. The Solar data is for information only. If there is no solar activity or then solar sensor is not installed then this field will be blank.

### **Transfer Graphic:** *(updated every second)*

The heavy lifting of controlling flow of energy to the hot water heater is performed by the Solid State Relay attached to the large heat sink on the front of the box. (Read the discussion of SSRs in Technical below). This Bar Display is a visual indication of how much this 'throttle' is open. Closed when there is no transfer, fully open when the hot water heater is absorbing maximum.

### **Total Grid IN:** *(updated every 4 seconds)*

Is the accumulation of all inbound energy since the last reset, in Watts. One of the key reasons for **Paladin's** accuracy is that it does not function in absolute values as it continually adjusts to suit current conditions. Therefore this and the other Total fields are sometimes not perfectly accurate. They are an overall guide. The final accurate figures are from the electricity meter and the PV inverter.

### **Total TRANSFER:** *(updated every 4 seconds)*

Is the accumulation of all excess PV transferred to the hot water heater since the last reset.

### **Total SOLAR:** *(updated every 4 seconds)*

Is the accumulation of all PV recorded since the last reset (if used).

**Web:** [paladinsolarcontroller.com.au](http://paladinsolarcontroller.com.au) **Email:** [sales@paladinsolarcontroller.com.au](mailto:sales@paladinsolarcontroller.com.au)

**Facebook:** Paladin Solar Australia Pty Ltd

### **TRANSFER TIME:** *(updated every minute)*

Is a display, in a HH:MM format, of the total time that PV transfer has taken place since the last reset. (See Technical for more details).

### **Total Grid OUT:** *(updated every 4 seconds)*

Is the accumulation of all Exported energy since the last reset, in Watts. **Paladin's** main purpose is to keep this number as low as possible. See Technical for more details.

### **Total TOPUP:** *(updated every 4 seconds)*

Is the accumulation of all energy used to maintain the minimum hot water temperature from the grid since the last reset, in Watts.

## **Technical Details**

### **DeltaT/MinT/Perf:**

This field displays a great deal of interesting, but definitely not essential, information.

[1] The time of day. This is a battery backed clock that looks after; the time. PALADIN needs the time of day to manage hot water top ups over night, to make sure the water goes to at least 55C every 3 days for health reasons, to turn off its' backlight at night, etc . Accuracy is not important give or take an hour or so.

[2] This is just a graphical whimsy that shows the state of the 'bucket'. The more you are diverting, the more ^s there will be.

[3] The temperature of your hot water in the HWC. It is very accurate and will read to decimals of a degree.

[4] This is how much, in Watts, you are diverting to the HWC literally, this second. Even though you may have a 3Kw immersion heater (3000W), because of the time slicing of the heater power this is variable down to less than a single Watt.

[5] The power used, in Watts, to top up the water temperature from the mains supply if needed. This can occur at any time of the day when the water temperature drops to less than 40C. **PALADIN** maintains 40C as a minimum.

[6] This the actual flow of power in and out of the house in Watts. A positive number means you are exporting and a negative means you are consuming. You might see this as backwards, but think of it in money terms.

[7] This is the perceived accumulated export from the house to the grid since midnight. All counters are reset to zero at midnight. Understand that the only really accurate value for this export amount is your Power Company meter. This value will always be positive.

[8] This is a message line to give you a sense of what **PALADIN** is up to in plain English.

[9] This is the perceived accumulated import to the house from the grid since midnight. All counters are reset to zero at midnight. Understand that the only really accurate value for this import amount is your Power Company meter. This value will always be negative.

[10] This is the perceived total accumulated diverted power to your immersion heater. This is just the total value of [4] above integrated over time. The total amount of power put into your HWC would be the sum of [4] and [5].

So there you have it. I am sure you will be delighted, if not mesmerized, by the display. The values change every 4 seconds, in a rolling cycle. Originally they were all set to change every second, but this was just too much information. Did you know that a vacuum cleaner uses more power on the forward stroke than the backwards? Yes it is that accurate.

This is the slightly nerdy stuff that is definitely just 'nice to know', not 'need to know'.

## Why

The why is simply that the power companies have decided, because they can, to drop the Feed- In Tariff (FIT) to totally unrealistic levels. **PALADIN** is a push back and protection from this and a solution that works very well in almost all situations. There are some practical and basic limitations to HWC setups that can take vest advantage of **PALADIN's** abilities:

1. A HWC of at least 180 liters (a standard tank in NZ).
2. A tempering valve that will enable the HWC water temperature thermostat to be set at more than 70C. (The hotter the water the more power it can store, and the better the buffer for cloudy days).
3. A normal use of hot water. If you are not drawing off hot water then the best that **PALADIN** can manage is about 1.6kWh of solar power diversion per day, as that is the magnitude of normal thermal losses. (See below).
4. A 'Smart Meter'. **PALADIN** will work on any meter, but it works best on the 'Smarties'. If you have the old style 'spinning wheel' then, you don't need this anyway since, to mangle a metaphor, that wheel spins both ways.

The average household consumes 10 to 12 kWh of electricity a day for hot water. The numbers are: (and individual mileage may vary)

A 180 liter hot water tank uses 3.15kWh of electricity to raise the water temperature by 15 degrees Celsius. A normally insulated 180L tank uses 1.6kWh of energy per day in lost heat.

**The situation is this:** If you have a 1:1 FIT you really don't care when your immersion heater runs. You produce the power, you use the power - the time frame is not important. However, if you are buying power at 4 times the rate you can sell it for, then it makes perfect sense to use as much of your own power as possible at the exact moment you produce it. If the Grid doesn't want your power, then the Grid doesn't get it. Absent a large battery, the only practical power storage you have in the average home is the hot water cylinder (HWC).

## How

Happily, everyone now has a smart meter installed. All smart meters work in essentially the same way. They have (conceptually), a 1Wh 'power bucket' that keeps track of the power flow. When the 'bucket' fills, for import or export, the light flashes and the appropriate power counter goes up by 1 unit - usually 1000 units to the kWh.

If we monitor the mains feed to the house and collect data fast enough, we can accurately access the state of that 'bucket' and we can leverage that data to switch the immersion heater on and off just enough to stop the bucket filling, and consequently ticking over the meter. The key here is speed, and you can only practically switch the heater on and off on the phase cycle, which is 50 times a second.

The 1Wh 'bucket' capacity is a real bonus in this sense. 1Wh doesn't sound a lot, but in other units it is 3600 Joules. This is probably just another, larger number. However, think about a 1kW heater running for 1 hour. In that time it uses 1kWh (1000Wh) of power, give or take. What about each minute? That would be  $1000/60 = 16.6\text{Wh}$ . What about every second? That will be  $1000/3600 = 0.278\text{Wh}$ . There might be 2 light bulbs above your head at this point? One will be for the 3600, which is, not by

**Web:** [paladinsolarcontroller.com.au](http://paladinsolarcontroller.com.au) **Email:** [sales@paladinsolarcontroller.com.au](mailto:sales@paladinsolarcontroller.com.au)

**Facebook:** Paladin Solar Australia Pty Ltd

coincidence, the number of seconds in an hour and also the number of Joules in a Watt. The second, and most important, is that the power use on a 1kW heater every second is much less than the 1Wh of the 'bucket'. Even a large 3kW immersion heater uses less than 1 Watt per second. How convenient is that?

**PALADIN** can control your heater on and off up to 50 times per second, which is the mains frequency. Additionally it is monitoring the mains power flow, around 40 times per mains cycle - which is 2000 times per second. Practically this is way in excess of the accuracy of the support circuitry such as the current clamps, but why not?

So the metaphor for **PALADIN's** operation would be a water tank, being filled by your solar at a variable rate dependant on the panel output and the amount of power use in the home. At the bottom of the tank is a large tap that represents your immersion heater. **PALADIN** watches, calculates and waits until the tank is half full, it then opens the tap. Depending upon the rate of input flow, the tank either begins to empty or continues to fill. If the tank starts to empty then the tap gets turned off. Otherwise it stays on for another cycle. If the solar input exceeds the tank capacity then it will eventually fill and you will just have to export that Watt of power, and the cycle starts again.

In practice, if you have a solar array that is significantly larger than your heater and not much power use in the house in the middle of a summer's day, you are going to export power. But not a lot and it is unavoidable. The good news is that this doesn't happen that often. You will also be forced to export if your tank temperature reaches maximum, obviously.

At this point, just to stay a little nerdy, it is well to mention that **PALADIN** is not perfect. Despite a very high sampling rate and high quality sensors, the vagaries of inductive loads such as the motors / compressors on refrigerators and freezers, power tools and heat exchangers etc, do cause **PALADIN** to miss the odd Watt. In practice this can be between 100W and 200W per day in unintended export, it depends on your household appliances. But to put that in perspective on the same day you will have diverted over 7kW to your immersion heater. One finger in the air to the power company.

## Enjoy and save money

### Paladin 4's Hardware & Software changes:

Improved Motherboard and Power Supply (Red 5A)

Arduino MEGA computer (2 x speed on paper - slight improvement in response and accuracy in practice)

Dynamic PWM SSR control and slow start Top Up (Ramps to full power over 2-3 minutes on top-up rather than starting at full 'noise') and only small wattages used for small top up amounts.

Sockets for 4 CT's - MAINS / TRANSFER (as now) + SOLAR (optional) + BATTERY (Under commercial trial).

Improved screen display + SSR rate display moving bar graphic top center.

Fully up-gradable to Paladin 6 with simple daughter board change in future.

The code and documentation is still a work in progress, but all new Paladins will be delivered with Paladin-4 software.

Paladin-2's are not field up-gradable. But the Paladin-4 is functionally identical to Paladin-2 except for the (optional) Solar CT and display.

The software automatically self-configures on startup.

**Web:** [paladinsolarcontroller.com.au](http://paladinsolarcontroller.com.au) **Email:** [sales@paladinsolarcontroller.com.au](mailto:sales@paladinsolarcontroller.com.au)

**Facebook:** Paladin Solar Australia Pty Ltd