Paladin Hot Water Diverter
User Guide

Contents

1. Important Safety Information

All safety warnings give specific details of the potential danger/warning present and indicate how to reduce risk of injury, damage and electric shock resulting from improper use of the device. Carefully observe the following instructions:

- Installation and maintenance must be carried out by a competent person, in compliance with the manufacturer's instructions, the relevant wiring regulations and local safety regulations. If in any doubt, consult a qualified electrician.
- The device must be disconnected from the power supply before carrying out any installation work.
- The device must have adequate ventilation.
- The device must be installed in a vertical position.
- Regulations require that the device is earthed.
- Do not remove the device cover while the power supply is connected.
- Do not operate the device with the cover removed.
- Do not attempt to repair or replace any part of the device.
- Do not touch the device with any wet part of the body.
- All maintenance operations must be carried out by a qualified technician.
- This appliance is not suitable for outdoor use.
- The manufacturer accepts no responsibility for any damage or injury caused by improper use or failure to comply with these instructions.

2. Warranty & Disclaimer

Paladin has made every effort to ensure the accuracy of the content of this manual. However, it is possible that it may contain technical inaccuracies or typographical or other errors. The manufacturer will assume no liability for any inaccuracy found in this publication, nor for damages, direct, indirect, incidental, consequential or otherwise, that may result from such an inaccuracy.

The information provided in this manual is subject to change without notice. The manufacturer reserves the right to alter product designs or specifications without notification.

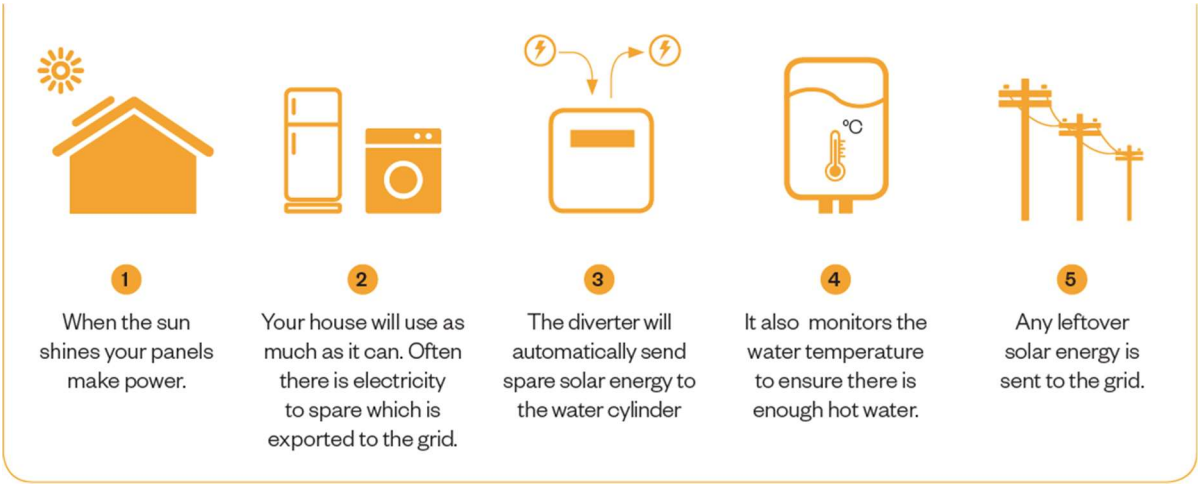
3. Document Purpose

This document is intended to provide you, the end user, with an overview of the hot water diverter basic functioning and display settings and to summarise basic steps for in-home troubleshooting.

4. Basic Functioning & Settings

4.1 What does the diverter do?

The hot water diverter is designed to maximise the value of your solar system by capturing any excess solar power and diverting it to heat your hot water instead of exporting back to the grid. The hot water tank is acting like a battery, re-directing unused power within your own system.



4.2 How does it do it?

The device constantly monitors the main power line on your home and the operation of the hot water cylinder (via a temperature probe fitted during installation of the diverter). It analyses this information to control the following functions:

- Should the hot water temperature drop below the pre-set minimum (see para. 6.1) the diverter will allow grid power to be used to bring the tank back to the minimum temperature. Once it has reached the pre-set minimum, the device will revert to watching for excess power generation.
- When the device detects excess solar power generation, if the hot water temperature is below the pre-set maximum (see para. 4.3), the diverter instantaneously sends the excess power to your tank, instead of exporting it.

Power diversion takes place using a solid-state relay. This allows power to be sent to the tank at any rate from 0-3500 watts, as opposed to the normal on/off tank operation, until the pre-set maximum is reached.

4.3 Maximum temperature settings

There are two maximum temperature pre-sets within your system:

- The diverter is pre-set to a maximum temperature of 73°C.
- Your tank has an adjustable thermostat. At the time of installation, your thermostat will have been set to your tank's maximum rated capacity (or some other temperature agreed between you and the installer).

The lower of these two settings will determine the maximum operating temperature of the tank.

4.4 The Health Protocol

The device is set up to run a Health Protocol every 72 hours to ensure a safe water supply, free of harmful bacteria which can flourish in a warm (but not hot!) environment. See para. 9.2 for an in-depth explanation.

5. Display Explanations

The display screen is for information only and is not necessary for correct operation of the device.

5.1 In general terms:

- When there is nothing interesting to show, the associated line will be blank.
- When there is no activity on that line, the line will show totals for the day so far if any.
- There is no rounding or smoothing of data. Even the 'noise' is interesting (see section 9).

5.2 Line by line

Line 1
To the left is the hot water tank temperature in degrees Celsius. The symbol immediately following the temperature reading is determined by the position of the toggle switch (see section 6).

On the right is the number of hours and minutes that excess power has been diverted to the cylinder so far today.

In the centre is a short description of the function currently being performed:

- The 'throttle' graphic' indicates that excess solar energy is currently being diverted and gives a sense of how hard the diverter is working.
- PALADIN indicates hot water temperature above the minimum and no excess PV.
- TOP UP indicates hot water temperature has dropped below the pre-set minimum (see para. 6.1) and grid power is heating the water.
- ELEMENT indicates an error with the temperature probe (see section 10).

Line 2
This is the Grid activity line. This line is always displayed and shows either IN or OUT and a number in Watts.

- If there is excess solar power (PV) this will bounce between IN and OUT.
- When there is no excess PV, it will always show IN.
- If your hot water is at maximum or you have PV in excess of your heater element's capacity, it will show OUT.

Remember these are snapshots of what is happening 3200 times a second internally and the gross values of the numbers while bouncing are not actually what is passing through your meter.

Line 3
This shows the diversion of PV to the hot water cylinder.

- While there is active PV diversion the line shows: 'DIVERT', diverted power in Watts and 'TOT', total diverted today in Watt Hours.
- When diversion stops the line changes to: 'X'FERED' and 'TOP' (both in Watt Hours), which shows the total diverted and topped up from the grid respectively.

Line 4
This line only shows if you have a second CT fitted to measure Solar production. Most diverters installed do not have this second CT and so this line will not display.

6. Toggle Switch Function

6.1 Toggle Switch positions

This switch has 3 positions. LEFT – CENTRE – RIGHT. This is what it does:

CENTRE

Minimum temperature is set to 40°C. This is the position recommended for normal operation, especially in the summer months when there is plenty of excess solar.

With the switch in the CENTRE position, the temperature reading in the top left of the display will be appended by the symbol '°'.

LEFT

With the switch in the LEFT position the diverter will boost the water temperature to 60°C in the small hours of the morning, at the time of the daily reset (see para. 11.1). Depending upon the quality of your hot water cylinder insulation this will leave your water temperature at around 58°C for morning showers etc, to avoid topping up on peak grid power. If the water is already above 60°C when the daily reset occurs, then nothing happens.

With the switch in the LEFT position the symbol appending the displayed water temperature changes to '+'.

RIGHT

Putting the switch RIGHT changes the minimum temperature setting to 50°C (from 40°C). If the water temperature falls below 50°C then you will start heating.

With the switch in the RIGHT position the symbol appending the displayed water temperature changes to '^'.

6.2 Which position to use

The CENTRE position maximises transfer and therefore allows the diverter to do what it is designed to do – i.e. minimise grid electricity use to heat hot water. Be sure to keep the toggle switch position to the centre when the below conditions do not apply.

Either the LEFT or RIGHT positions may be used when the user is not getting enough hot water. This may occur when:

- There are high losses from the system overnight (poor cylinder insulation).
- There is high morning hot water demand.
- A small solar system is installed.
- During winter months when solar generation is lower.

7. Auto/Manual Changeover switch

The diverter is installed with a 3-way changeover switch. This allows you to bypass the diverter in case the unit fails, needs to be turned off, or malfunctions.

AUTO
Hot water diversion device controls the temperature in the hot water tank. The switch should be left in this position for normal operation.

OFF
The diversion device and the hot water tank will be completely off with no electricity passing through to either.

MANUAL
The diverter device is entirely bypassed, and grid power will feed the hot water cylinder. This will return control of the hot water cylinder to the internally installed thermostat, as it was before the installation of the device.

When the switch in is the MANUAL position the display may flash periodically. This is normal and will not impede performance. If it is problematic due to positioning of the device in your home, please discuss this with your supplier as an alternative wiring method is available.

8. Basic Specifications

There are some practical and basic limitations to hot water cylinder set-ups that can take best advantage of the diverter's abilities:

- A hot water cylinder of at least 180 litres and a thermostat set above 73°C.
  - Paladin's normal top temperature is set at 73°C, the practical maximum for a generic water tank. If your thermostat is tripping before 73°C (most standard ones do), you are not only exporting PV that could go into the tank, but the dwell between the thermostat ON and OFF could be stopping you finishing the solar day with an optimally heated water tank.
  - Talk to your installer about an 85°C thermostat. If suitable for your system, it is inexpensive and very easy to fit. Set that at about 78°C as a backstop and let Paladin do its best for you.
  - If your thermostat does not allow at least 60°C in the tank, the Paladin device will not be able to perform its Health Protocol (see para. 9.2) and will be continuously topping up from the grid.
- A tempering valve that will enable the cylinder thermostat to be set at more than 60°C. The hotter the water the more power it can store, and the better the buffer for cloudy days.
- Normal use of hot water. If you are not regularly drawing off hot water then the best that the diverter can manage is about 1.6 KWh of solar power diversion per day, as that is the magnitude of normal thermal losses (see para. 9.1 for an in-depth explanation).

9. The Really Technical Stuff

9.1 Thermal losses within your system

The average household consumes 8 to 12 kWh of electricity a day for hot water. Individual mileage may vary but, in general, 180-litre hot water tank uses 3.15kWh of electricity to raise the water temperature by 15 degrees Celsius. A normally insulated 180L tank uses around 1.6kWh of energy per day in lost heat.

If you have a 1:1 FIT you really don't care when your hot water cylinder 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. Without a large battery, the only practical power storage you have in the average home is the hot water cylinder.

9.2 Health Protocol & Legionnaire's Disease

There is a health problem associated with accumulated 'nasties' that breed in water systems that run at temperatures below 50°C or so for prolonged periods. The effective recommended prevention technique is to ensure that the water temperature reaches 60°C at least every 72 hours. The diverter does exactly that. Whenever the water temperature reaches 60°C it resets an internal counter to zero (the Health Timer). Every hour that the temperature stays below 60°C is counted and if the Health Timer reaches 72 hours the hot water is boosted to 60°C, at which point the whole cycle starts again.

If you have excess PV then this activity will be rare, but there will be times when it happens, particularly in winter. Internally the diverter tries to anticipate this, and if it anticipates a potential 'health top up' occurring during day-time peak hours it will forward-schedule the temperature boost to 60°C in the early hours of the day, just after the totals reset (see para. 11.1).

With regard to water temperatures, if your hot water cylinder main thermostat is defective, not set to maximum or in some other way not able to allow a temperature of at least 60°C then the Health Protocol sequence will force the diverter to top up continuously and be totally ineffective.

Likewise, if the temperature probe is incorrectly positioned a similar situation will occur (see section 10).

9.3 DELTA_T Operation

The diverter introduces a novel concept (for a device like this) of DELTA_T - that is rate of change of temperature over time. This is largely transparent in operation, but the more eagle-eyed may see its effects. If the water temperature is dropping quickly towards minimum (40°C normally) the DELTA_T mechanism will see this well before the water actually reaches 40°C and will start a top-up sequence earlier than would be possible by just waiting for 40°C to be registered. This allows the diverter to head off most cold shower situations, subject to water use and heater size etc. Conversely, when topping up, if there are only a few degrees of temperature to change then DELTA_T will not activate the heater at full power.

The device will monitor the DELTA_T value and use that as an inverse analogue of your hot water use. Simply put, by watching DELTA_T the device can anticipate if the tank temperature could fall below the minimum set-point in the near future. This ensures that your tank maintains the minimum set-point in a range of conditions.

The software then uses DELTA_T to anticipate the tank heater turn on point by changing the minimum water temperature value every 12 seconds to adjust it

for a decreasing or increasingly negative DELTA_T. If the tank temperature is above 50°C this creates a minimum tank temperature increase equal to the negative DELTA_T. Below 50°C the DELTA_T influence is doubled. If you are watching your MAX | MIN values, you will see this happening. To avoid over doing this function, if there is active Solar this effect will be moderated if more than 500W of Solar activity is perceived. This will ensure that grid power is not wasted heating water that will be heated later by solar.

9.4 The true nuts & bolts of it

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

Happily, everyone now has a smart meter installed. All smart meters work in essentially the same way. They have (conceptually) a 1Wh or 3600-joule 'power bucket' that keeps track of the energy flow. When the 'bucket' fills, for either 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 model the state of that 'bucket' and we can leverage that data to switch the hot water cylinder 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 crossing phase of the mains 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 just another, larger number. However, think about a 1kW heater running for 1 hour. In that time, it uses 1kWh (1000Wh) of energy, give or take. What about each minute? That would be 1000/60 = 16.6Wh. What about every second? That will be 1000/3600 = 0.278Wh.

There might be a couple "Aha!" moments happening at this point? One will be for the 3600, which is, not by 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 a fraction of the 1Wh of the 'bucket'. Even a large 3kW hot water cylinder element uses less than 1 Watt per second. How convenient is that?

The diverter can control your element on and off up to 50 times per second (Hz), at the mains frequency. Additionally, it is monitoring the mains flow, over 60 times per mains cycle - which is >3000 times per second.

A simple metaphor for the diverter's operation would be a reservoir, filled by your solar at a variable rate dependant on the panel output, and emptied by the amount of power use in the home. At the bottom of the reservoir is an outlet that represents your hot water cylinder element. The diverter watches, calculates and waits until the reservoir is half full, it then opens the outlet to the element. Depending upon the rate of input flow, the reservoir either begins to empty or continues to fill. If the reservoir starts to empty, then the outlet is closed off. Otherwise, it stays open for another cycle. If the solar input exceeds the reservoir capacity and the flow to the element then it will eventually fill, and you will have to export that Watt of power, and the cycle starts again.

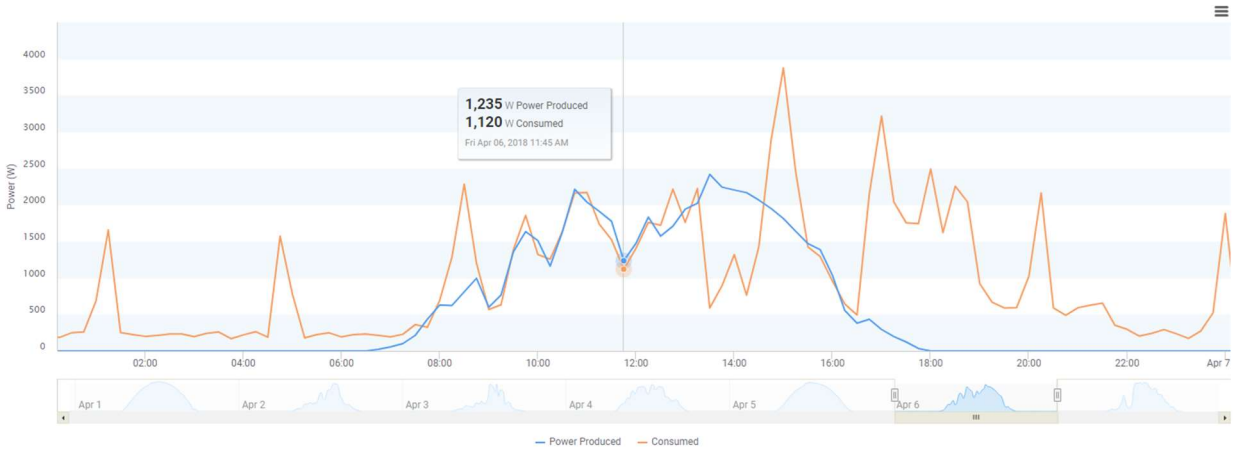
In practice, if you have a solar array that is significantly larger than your heater and not much power use in the house in the middle of a summer's day, you are going to export power. But only the remainder, and it is unavoidable. The good news is that this doesn't happen that often because of the shape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

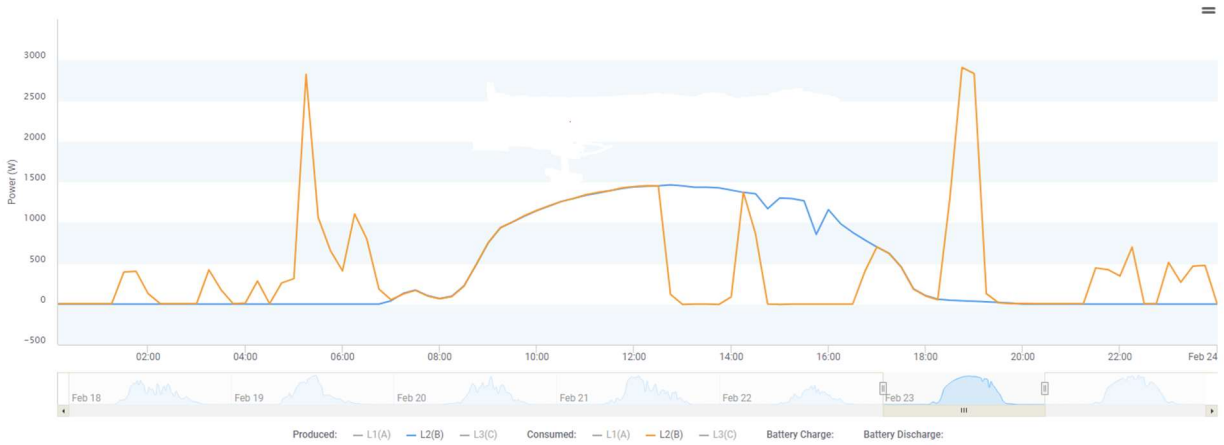
At this point, just to stay a little nerdy, it is well to mention that the diverter is not perfect. Despite a very high sampling rate and high-quality sensors, the vagaries of inductive loads, such as the motors / compressors on refrigerators and freezers, power tools and heat exchangers etc, do cause the diverter to miss the odd Watt here and there. In practice, this can be around 5% of excess PV per day in unintended export, it depends on your household use, the variability of the sunshine and the quality of your house wiring.

But to put that in perspective, on the same day you will have diverted all the rest to your hot water cylinder element.

9.5 A final word on thermostats

Below are two diagrams showing power generated and consumed over a 24-hour period. They are from the same house but the first is without Paladin and the second is with the device installed.





It is clear from the second diagram that the system with Paladin is doing a much better job of managing that excess solar.

However, look at Paladin's problem about 12:30. The thermostat tripped and Paladin had to wait until that thermostat reset until it could get back to diverting again. Then after a short while, the thermostat tripped again. This example highlights the need for an appropriate thermostat to be installed and set correctly in order to maximise the diverter's impact.

10. Troubleshooting

Issue / Error	What this means / What to do
No hot water	➢ Check the Display ➢ If it is not displaying correctly or is blank, reset by switching the Changeover Switch (see section 7) to OFF and then back to AUTO. ➢ If the Display remains off or unreadable then move the Changeover Switch to MANUAL, to bypass the diverter, and contact your supplier.
Display showing only '>>>' on start-up	➢ Indicates a temperature probe error. ➢ Probe may be damaged, incorrectly wired or not fitted. ➢ Device is safe to operate but will not perform optimally. ➢ Please contact your supplier
NO TEMP is displayed in the centre top line	➢ Indicates a temperature probe error. ➢ Probe may be damaged, incorrectly wired or not fitted. ➢ Device is safe to operate but will not perform optimally. ➢ Please contact your supplier
ELEMENT is displayed in the centre top line	➢ Indicates a thermostat or temperature probe error. ➢ Temperature probe has not registered at or above 60°C within the last 72 hours. ➢ Either tank thermostat is set too low, or temperature probe is badly positioned. ➢ Reset Paladin by switching the Changeover Switch (see section 7) to OFF and then back to AUTO. ➢ If error remains, either replace the thermostat or reposition the temperature probe.

11. FAQ

11.1 When do the Totals reset?

The diverter's internal clock is linked to solar activity, or more specifically to PV transfer. An hour is still an hour, but the day's start-time is internally 8 hours since the last PV transfer activity to the hot water cylinder. Nominally this will be around or just after midnight, but in the summer, may be as late as 4am. Since this only affects the Totals (displayed on Line 3 of the Display), it is of no consequence to the diverter's performance, just the displayed totals. Since the totals are about transfer, using 'sun' time is the most practical option.

11.2 Why do the numbers 'bounce' and the PV Totals not match the Inverter?

The diverter is not designed to be a meter as its core task is to figure out what is happening at the grid entry point and divert every possible Watt of excess PV to the hot water cylinder. The dynamics of the electricity flow to and from a house are complex and chaotic and, depending upon the observation time frame, the relationship between PV and house activity is either serene or very variable.

The diverter reads that electron stream as fast as possible to get an accurate sense of what is happening every mains cycle (one fiftieth of a second) and acts on that information in the same time scale. It also continuously changes internal values to cater for varying conditions. The diverter's short-term accuracy is high; long term 'metering', not so much - by design.

With that in mind you will see the Grid values 'bouncing' since that number is updated once a second and it represents a snapshot of 1 second's worth of averaged activity. Hidden inside that 1 second number is another 50 cycles worth of activity and 3200+ grid reads.

Likewise, any totals are just an approximation of what has happened since the last reset. These numbers are not absolutes and are provided for the user to get a sense of the day's progress, not as a substitute for a meter reading. Your electricity meter and PV inverter data are the correct place to look for absolute values. That said, there should not be a huge difference and any large deviations should be investigated as it could indicate a badly placed or defective CT clamp, or even some problem with the diverter itself. But again, the diverter is extremely sensitive and often 'sees' effects that are not directly associated with pure household current flow, such as minute induced changes in the house and CT wiring caused by external influences. E.g., high values of solar radiation caused by Coronal Mass Ejections, induction from overhead power lines and such are typical suspects.

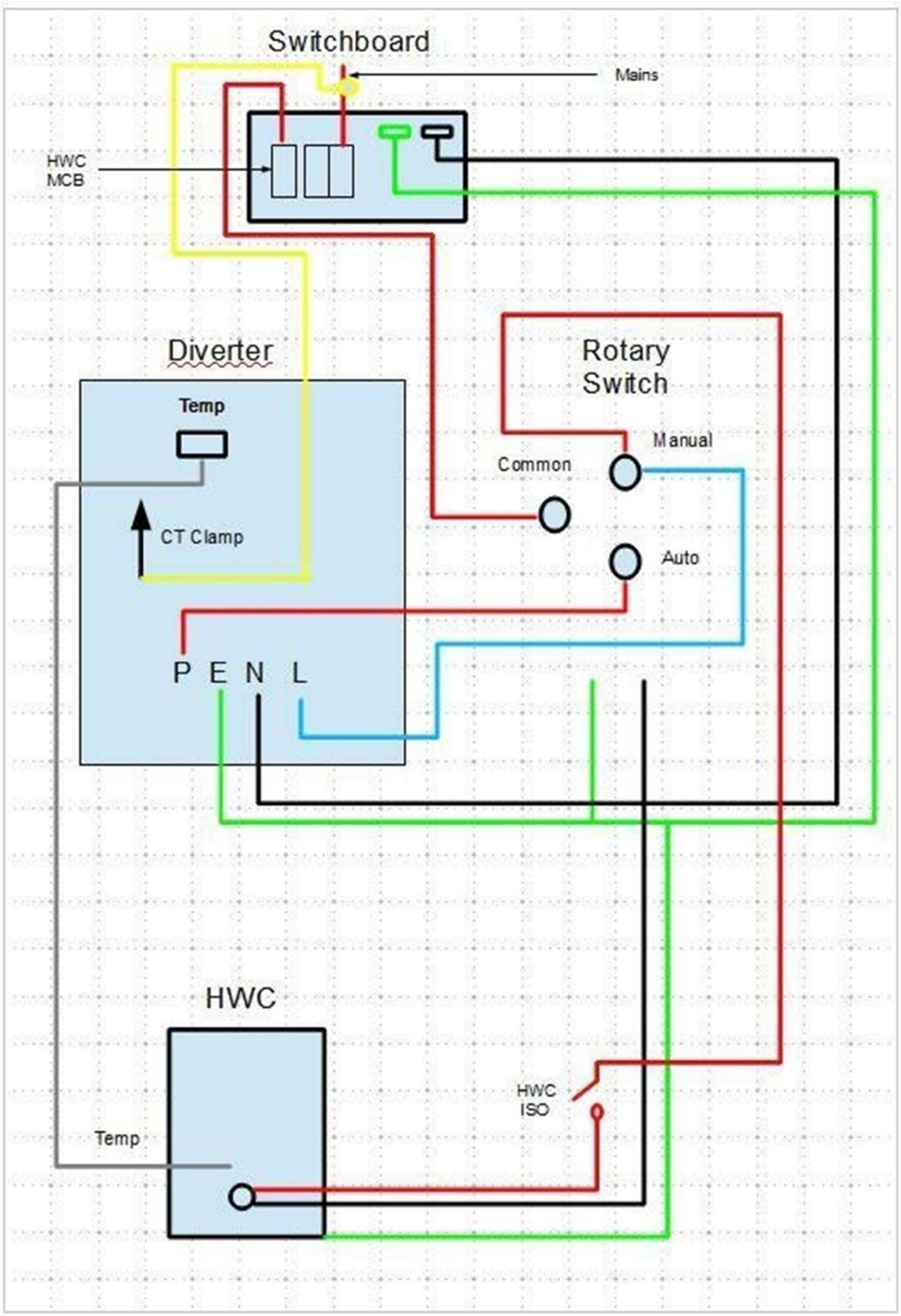
An aside on the subject of accuracy – a vacuum cleaner uses more power on the forward than on the backwards stroke. The diverter is so fast and accurate that it sees that and reacts accordingly. The reason is fairly obvious once you think about it. Pushing forward, there is a downward component to the applied force, which in turn presses the cleaning head harder onto the floor, thereby increasing the seal, and the effort required to spin the motor.

11.3 How accurately does the diverter transfer excess PV?

There are a couple of 'ifs' associated with the answer. If your excess PV never exceeds your hot water heating element rating and you never reach either 73°C water temperature or your tank thermostat limit then you can expect 90%, often 95% or sometimes even better. The 'even better' bit depends very much on the type of loads that occur in the house and the gross variability of the PV output itself. Typical 'difficult' loads for the diverter to manage are high wattage irons and induction cookers. The diverter does manage these rather well, but the very rapid surges in load that they produce can cause small amounts of 'spillage'.

Once you produce excess PV over and above what your cylinder element can absorb, or you hit maximum temperature, excess PV will, of course, be exported.

12. Installation Wiring Diagram



13. Technical Specifications

Diversion Current | 20 Amps (40 Amp SSR)
Rated AC Voltage | 230 VAC
Frequency AC | 50/60 Hz
Max Continuous Power | 4 kW
Power Source | Single Phase
Weight | 920 Grams (2.12lbs)
Temperature Probe Cable | 3 Meters
Display | 4-Line Backlight
Enclosure (cm) | 20 x 12 x 12
Enclosure IP Rating | None
Warranty | 2 Years
Environment Temp Range | 0-50oC
Environment Humidity | 95%
Environment Pollution Class | 2
Protection | Internal Resettable Fuse
Cooling | Passive External Heatsink
Standards: AS/NZS 4417.2

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