WHITE PAPER

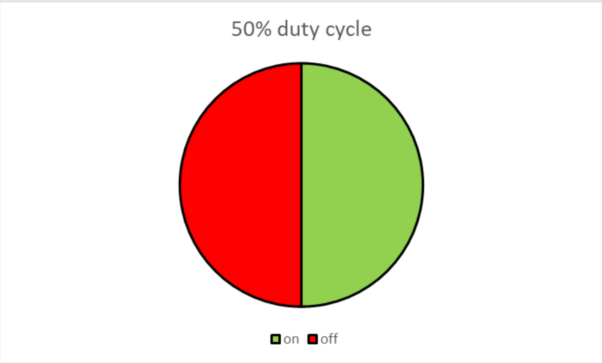
The ins and outs of Pulse Width Modulation (PWM) and why to prefer WEED-IT

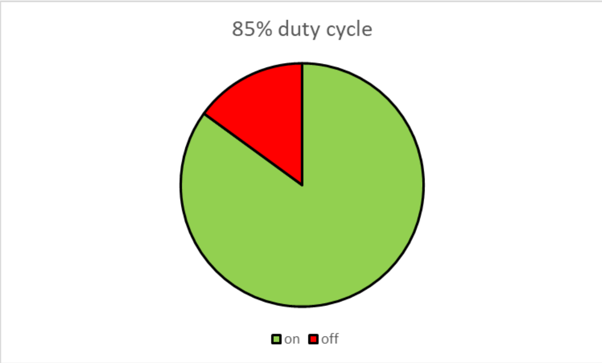
PWM stands for Pulse Width Modulation, a technology to regulate the power to a device by means of fast ON/OFF pulses. The foundation for the technology was laid in the 1960's. Today, PWM is widely used in all kinds of electronic applications.

For use on agricultural sprayers, PWM was invented in 1992 by Dr. Ken Giles of the University of California at Davis. PWM nozzle control was first made available commercially by Capstan on Case IH sprayers in 1998.

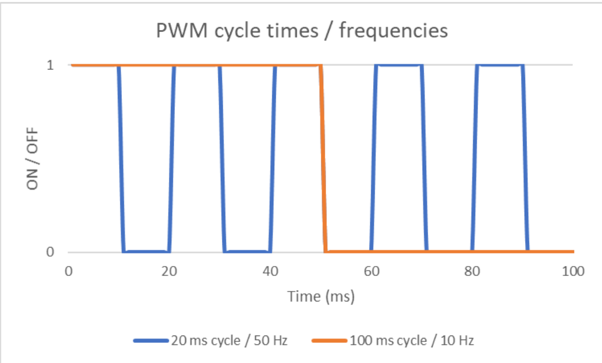
PWM terminology

PWM is used to vary the ON and OFF time within a cycle time. Imagine a circle, each round on this circle is one cycle. Within this cycle, the time that a nozzle is ON or OFF can be varied. The percentage of time that the nozzle is ON, is called the duty cycle (DC). Below are two examples; left a duty cycle of 50% and right a duty cycle of 85%.

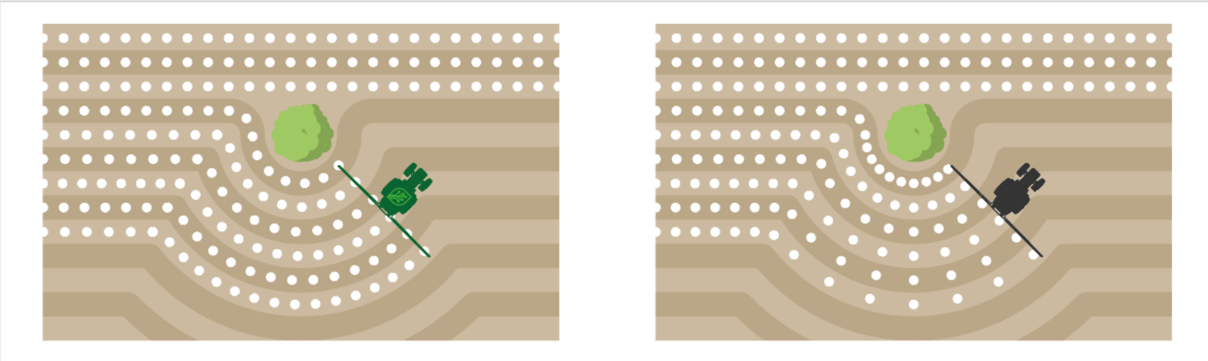




So far, only the ON/OFF proportions are described. However, there is another important factor in the circle. That is the time it takes to make one cycle. The first PWM systems used a fixed cycle time of 100 ms. Better expressed, they were able to run 10 cycles a second, 10 Hz. Today, available PWM systems use frequencies between 10 and 50 Hz in practice while 20 Hz is the most commonly used frequency today. The graph to the right compares a 100 ms cycle / 10 Hz system with a 20 ms / 50 Hz system, both running at a 50% duty cycle: the nozzle is open 50% of the time in a cycle. Referring to the circle diagrams above, the 50 Hz system runs 5x a cycle at the same time as the 10 Hz system does. Higher frequencies then 50 Hz can be made, but have no advantages in practice as it requires (much) more power and does not affect the spray quality any further.



The last 10 years, interest in PWM technology for agricultural sprayers has increased for several reasons. One of these is the ability to regulate the application rate independently of the pressure. This is a big advantage as the pressure determines the droplet size. The droplet size is a key factor in the spray effectiveness. With a constant pressure, the droplet size can be kept constant, while the PWM regulates the flow of each individual nozzle. Another advantage of PWM is the ability to apply crop protection products evenly in corners. Worldwide, lots of fields have irregular shapes making corners inevitable. While turning corners, the outer parts of the spray boom are gaining speed, whereas the inner and centre parts of the spray boom are standing still or even moving backwards. On normal sprayers, this results in an overapplication in the centre of the spray boom and an underapplication on the outer boom parts. PWM solves this issue by adjusting the flow for each nozzle to match the desired application rate. When turning a corner with a 36-metres sprayer, you'll be amazed by the speed the outer parts of the boom are gaining! Sometimes, the speed is that high, that the end of the boom is applying too less. In this case, the WEED-IT system triggers a 'Too Fast' warning, asking the driver to slow down.



WEED-IT PWM technology that can compensate for the driving speed (left image) and other PWM technology (right image) that can't and resulting in outer boom parts applying too less spray liquid.

When using higher frequencies in PWM, the robustness and reliability of opening and closing times become more important as they become a bigger proportion of the cycle time. With more than 20 years' experience in PWM, the Rometron solenoid valves together with the controllers are optimised. The whole PWM control package comes standard with WEED-IT! Guaranteed fast opening and closing times optimise the droplet size and distribution from the spray nozzle, at any speed up to 25 km/h.

As the droplets from the pulses blend in (because of the overlap in the spray pattern) when blanket spraying if all nozzles are controlled, high frequencies seem not to be necessary. However, for spot spraying applications, it is important that a single nozzle can always open and apply spray liquid when a weed plant is detected. As it is never sure that neighbouring nozzles are activated during spot spraying, the reliability of each individual PWM nozzle is very important for an optimal effect. **WEED-IT** PWM technology can control all PWM cycles of the nozzles asynchronously, opening when needed. On top of that, the higher frequencies of up to 50 Hz, enable multiple cycles and thus bursts on the same weed. This results into the right amount and distribution on the weed, independent of the driving speed. The biggest challenge of using PWM technology are the skips that may occur. Skips are the result of longer OFF times in a cycle and means that the spray distribution is uneven, resulting in poor effectiveness of the spray job. Skips can simply be calculated by multiplying the OFF time (ms) in a cycle by the driving speed (km/h).

Some examples:

- With **50 Hz** and a 75% duty cycle, the OFF time is 5 ms. At a driving speed of 25 km/h, this is 6,9 m/s = 6,9 mm/ms * 5 ms = **34,5 mm**
- With **20 Hz** (the most commonly used frequency today) and a 75% duty cycle, the OFF time is 12,5 ms. At a speed of 25 km/h, this is 6,9 mm/s * 12,5 ms = **86,3 mm**
- With **10 Hz** and a 75% duty cycle, the OFF time is 25 ms. At a speed of 25 km/h, this is 6,9 mm/ms * 25 ms = **172,2 mm**

When the duty cycle increases, the skips become smaller. When the duty cycle decreases, the skip becomes larger. The same goes for the driving speed. To reduce the skip, **WEED-IT** uses a 50 Hz frequency at medium to high driving speeds if low to medium duty cycles are used. Skips are more likely to occur at low duty cycles with low frequencies and high driving speeds. Some PWM systems have intended to prevent this by controlling neighbouring nozzles in an opposite pattern (180 degrees out of phase). However, as the sprayer is moving forward, the opposite nozzle control brings the risk of an amplification of the uneven spray distribution instead of improving it.

In PWM technology, the used frequency (Hz), is an often-used argument, stating that a higher frequency is better. In practice, it is not the frequency itself, but the way the manufacturer is using the right frequency in combination with the duty cycle to reach the best spray result. Manufacturers of more advanced PWM systems like Rometron **WEED-IT** and Agrifac use a variable frequency, depending on the driving speed. This way, they are minimising the skip risks and increasing the spray distribution and effectiveness of the spray job.

An interesting read in this perspective is this article about independent, on-farm research on the benefits of PWM technology by independent spray applications specialist Tom Robinson and the New Farm Technologies Team from Syngenta.

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About this white paper

This white paper is offered by Rometron, the Dutch manufacturer of WEED-IT precision spraying technology. The author, Albert Bosscha, graduated on PWM distribution and optimisation from Dutch Wageningen University and Research (WUR) and is now working on product support and research & development at Rometron.

WEED-IT - works!

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