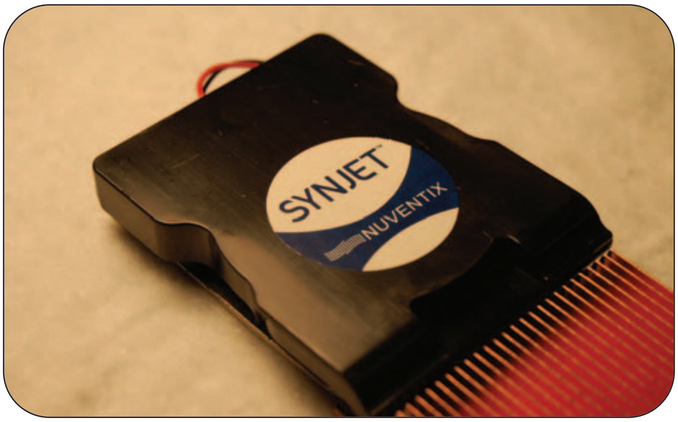
Synthetic Jet Cooling Technology Makes LED Lighting a Viable Option in the Automotive Market

By Brandon Noska, Thermal Application Engineer and Mick Wilcox, Director of Marketing, Nuventix

Driving down the highway at night, yellow colored light comes at you from almost every car you see. But coming around the bend every once in a while, a car's headlights beam ahead a perfect white light, perfectly shaped to the driver's viewing angle, as they approach. This car's manufacturer used LED lighting in the headlamps, thus saving the owner time and money on replacing bulbs throughout the life of the car. Why aren't more automotive manufacturers taking this approach?



According to industry analyst firms, they will. LED lighting is poised to make a significant impact on the automotive market as exterior lighting demands drive major growth opportunity. Industry analyst firm Strategy Analytics predicts the LED automotive market will be worth $1 billion by 2014. However, while automotive makers see the benefits of incorporating LEDs into headlamps, the issue of reliable cooling needs to be resolved.

Traditional cooling options like fans are likely not to provide viable options because of the required form factors for exterior lighting designs and especially the reliability required for such an application. Instead, an alternative active LED cooling option, synthetic jets, can provide efficient cooling in a small space and with reliability expectations longer than the typical life of the car. This technology, called SynJet, will enable LED product designers for the automotive industry to take full advantage of the expected market growth.

What are Synjets:

A synthetic jet flow, or synjet, is a type of jet flow. A synthetic jet flow synthesizes the flow from the surrounding or ambient fluid or air. Normally, producing a jet requires an external source of fluid, such as piped-in compressed air or plumbing for water. A synthetic jet flow can be developed in a number of ways, such as with an electromagnetic driver, a piezoelectric driver or even a mechanical driver such as a piston. Each moves a diaphragm up and down hundreds of times per second, sucking the surrounding fluid into a chamber and then expelling it. Although the mechanism is fairly simple, extremely fast cycling requires high-level engineering to produce a device that will last in industrial applications.

For hot spot thermal management, the SynJet was patented in 2000 by engineers at Georgia Tech and is offered commercially today by Nuventix. The tiny SynJet module creates jets that can be directed to precise locations for industrial spot cooling. Traditionally, metallic heat sinks conduct heat away from electronic components and into the air, and then a fan blows the hot air out. SynJet modules replace or augment cooling fans for many small, but hot, devices across the LED lighting, telecommunications, consumer electronics and automotive industries. SynJet high reliability cooling modules enable new electronic designs by allowing designers to focus on functionality, not thermals.

The vortex-dominated SynJet flow enhances small-scale mixing near the heated surfaces to yield higher effective heat transfer at low-volume flow rates compared to conventional air movers. The SynJet flow is created using patented actuator technology and proprietary fluidic packaging expertise.

The system-wide heat removal takes advantage of the jet ejector effect inherent to high-momentum jet flows. As it operates, the SynJet module expels high momentum pulses of air. Each pulse of air "entrains" or pulls nearby ambient air behind it in its wake. The diagram below shows the velocity vectors of the SynJet flow as the jet is ejected.

Figure 1a shows the pulse of air emerging from the nozzle. In Figure 1b the pulse has moved away from the nozzle. Note the large velocity vectors associated with the vortices accompanying the SynJet formation. In Figure 1c the pulse has moved further away, and the entrained air can be seen behind it in the form of the large velocity vectors all pointing in the direction of the pulse. In Figure 1d the tail of the pulse is seen. Finally in Figure 1e the pulse has almost fully left the frame, and the air can be seen recharging the nozzle in preparation for the next pulse. The result is highly turbulent, high-heat transfer-coefficient air flows located directly where they are needed inside a product providing system level heat removal.

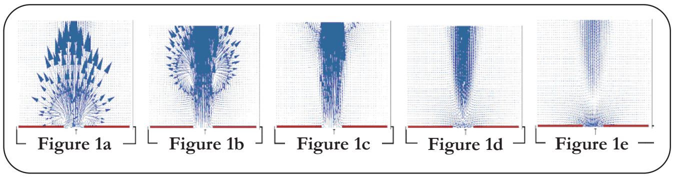


Figure 1a - 1e.

Benefits of Synjet Technology:

Increased Thermal Efficiency

Several intrinsic qualities of SynJet modules result in much more thermally efficient air flow than that created with conventional air movers. The turbulence of the flow results in more efficient heat transfer from the heat source to the air. The pulsating nature of a SynJet airflow increases mixing between the boundary layer and mean flow. Finally the self-induced entrained flow results in the ability to move the heated air out of the system.

SynJet modules can be tailored to the air flow needs of any system. Multiple hot spots can be cooled as a SynJet module places the cooling directly where it is needed without complicated ducting. Heat sinks can be cooled much more effectively by providing uniform flow across the entire heat sink. The hub of a fan can often create problems and dead spots within a heat sink or chassis, but SynJet flow spans the entire heat sink and cools all channels equally. By the same count, the SynJet modules may be tailored to direct more flow across the center of the heat sink where the heat source is located. Heat sink flow bypass becomes a thing of the past as well, the low pressure created by a SynJet module at the heat sink inlet actually causes more air to be drawn through the flow channels causing entrainment of the ambient air. All in all, this means it is possible to remove more heat with less air.

Low Audible Noise

SynJet modules produce airflow that is much more thermally efficient, therefore the amount of air flow needed to cool the same heat load is reduced. Lower flow rates translate directly to lower acoustic emissions. In addition, by not having any bearings, brushes or other frictional parts, the SynJet module eliminates the acoustic problems associated with these interfaces.

Acousticians know that there is more to sound than just the DBA and SPL measurement. SynJet flow can often be tailored to accommodate psychoacoustic perceptions as well. Depending on the application, SynJet modules may be designed for effectively silent operation.

High Reliability Cooling Outpaces Even a High Reliability Fan

With the elimination of frictional parts common to fans and blowers, the potential failure modes are greatly reduced, the need to evaluate forced air vs. natural convection is eliminated, and the MTBF (mean-time-between-failures) of even the most reliable fan is exceeded by the SynJet.

For applications that operate in extreme environments, the device can be constructed out of robust materials. For applications previously requiring natural convection due to failure intolerance factors, the forced air versus natural convection tradeoffs with respect to reliability no longer apply. With SynJet modules, the air mover will no longer be the lowest reliability component in the system, as is the case with conventional air movers.

Low Power Consumption

Through the development of very efficient actuators, SynJet modules require very low power to operate. The modules can cool the same thermal load as a conventional fan with a fraction of the power needed.

Synjets in the LED Industry:

Product designers are under constant pressure to solve increasingly tougher thermal problems within smaller spaces and constrained budgets. Conventional cooling technology, like fans, doesn't offer the flexibility and effectiveness of a SynJet cooling module. SynJet technology is well suited for LED cooling because of its high reliability, low power consumption and quiet operation. Using the SynJet approach in the LED industry allows two to three times the light output compared to passive LED thermal management designs.

The LED market, stand-alone lighting as well as for use in LCDs, is proliferating at the rate of 15 to 20 percent per year and is expected to reach $7 billion in just three years. This growth will be attained through new uses of LEDs, many of which will require active cooling. SynJet modules are the only active cooling option for manufacturers of LEDs because their reliability matches, and exceeds, that of the LEDs themselves. SynJet modules also provide spot cooling and chip cooling in form factors which fit those of LEDs.

Synjets in the Automotive Industry:

While there are many benefits to SynJet cooling modules, the most beneficial to the automotive industry besides form factor must be that of reliability. The product life cycle of automotive manufacturers is quite lengthy (three to five years), thus making those manufacturers hesitant to try new approaches unless they are certain to only improve, not disrupt, a process already working fine. The old adage "if it ain't broke, don't fix it" applies here in spades.

Automotive manufacturers looking to incorporate LED lighting into their automotive designs can rest assured in the reliability of LEDs

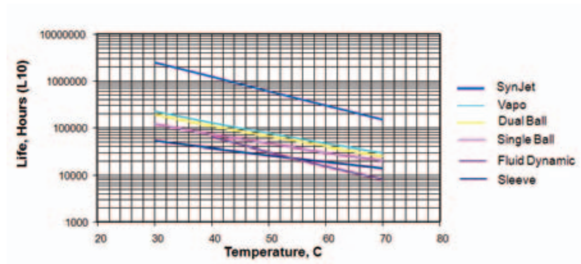


Figure 2. Comparison of SynJet L10 reliability to other leading air-movers

using SynJet technology. SynJet cooling offers increased system reliability in several ways. First, the SynJet cooler itself is highly reliable. Containing no frictional parts to rub or wear, it is inherently reliable when properly designed from carefully selected materials. When used as the sole air mover, system reliability is impressively high.

Figure 2 illustrates how SynJet cooler reliability compares to leading fans in the thermal management industry (note: all fan data provided was published by the fan manufacturer).

Despite decades of research and improvements, L10 reliability at 60°C for small fans still hovers around the 50,000 hour mark under normal circumstances, not taking into consideration the extreme environments of automotive applications. SynJets shatter this barrier and offer over 300,000 hours of L10 life at 60°C. The exceptionally high reliability cooling of SynJets makes them invaluable in applications such as industry automation, aerospace designs, premium consumer electronics and especially motor vehicles.

As more products are designed with SynJets, end users will reap the benefits of thermally efficient, very quiet and incredibly reliable forced convection cooling. To meet industry analyst predictions of significant growth of the LED automotive market, auto makers will benefit from incorporating LED lighting with SynJet cooling technology into their product lines.

Mick Wilcox received his MBA from Regis University in Denver Colorado and his undergraduate degree from the University of Wyoming in Mathematics. He has authored and co-authored numerous conference papers in the thermal and telecommunications fields and has patented work in both fields as well. Currently, he is the Director of Marketing for Nuventix's SynJet modules and is responsible for the marketing and business development for the product. He can be reached at mwilcox@nuventix.com.

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