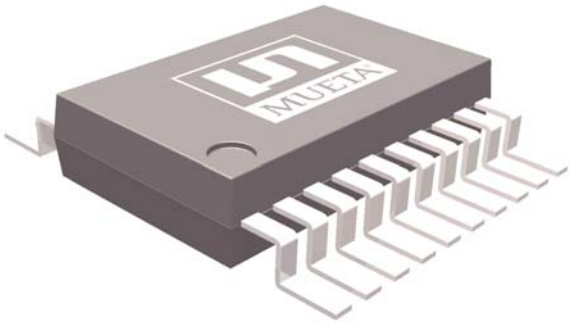
MUETA®

efficiency in amplification



# MUETA® CLASS-D

Efficiency in Amplification

## Contents

**Introducing MUETA®**

## A REVOLUTION IN HIGH–END AUDIO

MUETA® is the most significant development in class-D amplifier technology in decades, and a breakthrough for high-end audio. It not only combines the ultra-high efficiency of class-D with the awe-inspiring audio quality of high-end amplifiers, but it also enables cost-effective products to be built without compromising specifications.

## MUETA® CLASS-D

All class-D amplifiers are very efficient compared to the class-A and class-AB topologies generally used for audio amplifiers. However, "conventional" class-D technology has an inherently poor frequency response above 15kHz making it unsuitable for high-end applications. Various enhancements of class-D amplification do exist, but these tend to come with limitations of their own and are very costly. The MUETA® solution uses proven new techniques to overcome all the drawbacks of previous class-D amplifiers.

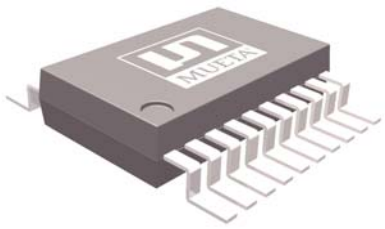
## PATENTED AUDIO TECHNOLOGY

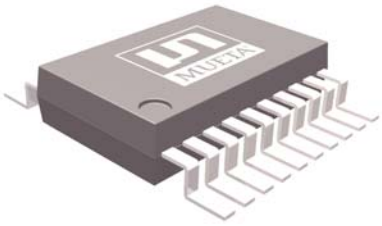
The MUETA® solution was developed and patented by the Eindhoven University of Technology (The Netherlands). MUETA® (Wijk en Aalburg, The Netherlands) has the worldwide rights to use the technology in audio applications, and has developed an integrated controller IC and audio power amplifier evaluation boards for delivering up to 1000W per channel. These amplifiers are a fraction of the size of conventional power amplifiers as virtually no heat sink is required. The Ics are suitable for home entertainment, in-car audio, professional sound reinforcement and public address applications.



During the past years, the global interest for the MUETA® audio technology has been overwhelming.

For this reason, the management of MUETA® has decided to develop an integrated circuit for the MUETA® technology. Using the years behind us to implement all improvements we encountered during the design phase, MUETA® now makes the MU201 available in Q1 2007.





THD + N = 0,002%
S/N = 130dB
Damping factor >1000
Output impedance 3mΩ
Frequency response 10Hz-20kHz (-1dB)
Variable switching frequency up to 350kHz
Will drive any load on the output
SSOP-20 Package

## MUETA® Key Features and Benefits

- Combines class-D amplifier efficiency with high-end audio quality and specifications
- Eliminates the need for large heatsinks thanks to Efficiency between 90 and 95%
- Enables extremely compact high-performance amplifiers to be built up to 1000W RMS
- Features good ripple and supply drop rejection for cost-effective power supply design
- Speeds up assembly and eliminates fine-tuning as all critical components are integrated in the IC
- Simplifies speaker matching as MUETA® Control-led amplifiers are unaffected by varying loads

The MUETA® integrated amplifier control IC is a break-through for high-end audio amplifiers. MUETA® enables highly efficient, high-performance power amplifiers to be built in compact, cost-effective enclosures.

## HONEST, PURE AND CLEAN SOUND

The MUETA® solution uses a patented feedback measurement technique with a special PWM modulator to build an ultra-efficient class-D amplifier with absolute high-end audio specifications. MUETA® controlled amplifiers display no audible harmonic distortion, deliver a linear flat response across the audio spectrum, and have an exceptionally high signal-to-noise ratio. They also have a very high damping factor for excellent bass clarity.

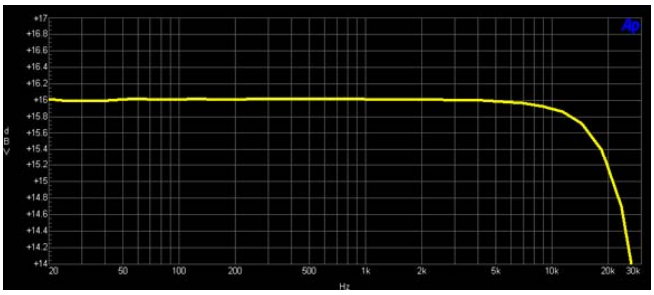
Efficiency of between 90 to 95% eliminates the need for large, costly heat sinks, while reduced supply voltage stability requirements allow for a much smaller and cheaper power supply. As a MUETA® controlled amplifier is close to a perfect voltage source, it ensures that the voltage at the speaker terminals is correct under all conditions, making the output insensitive to load or crossover filter characteristics.

The IC contains all the critical components, allowing a compact single-channel power amplifier to be designed and built without the need for special fine-tuning or component matching. The net result is a high-end power amplifier at an affordable price.

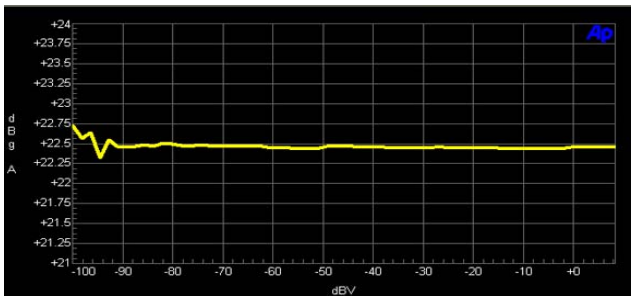
## HIGH-END CONSUMER AND PROFESSIONAL AUDIO

A MUETA® controlled amplifier with top quality, compact size, low weight, simplified power supply requirement and cool operation makes it ideal for high-end consumer audio such as multi-channel ‘surround sound’ amplifiers and in-car entertainment systems where space and power are limited. It is also suitable for price-sensitive professional PA, and for portable (lightweight) stage amplification.

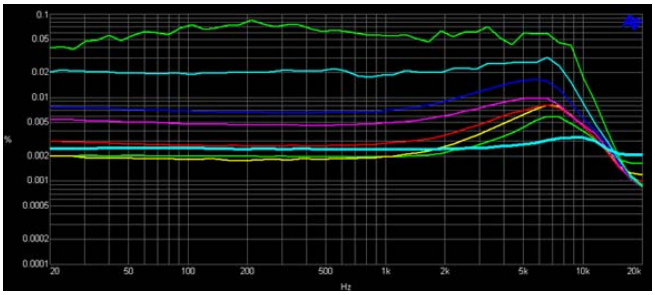
Frequency response from 20 to 20kHz



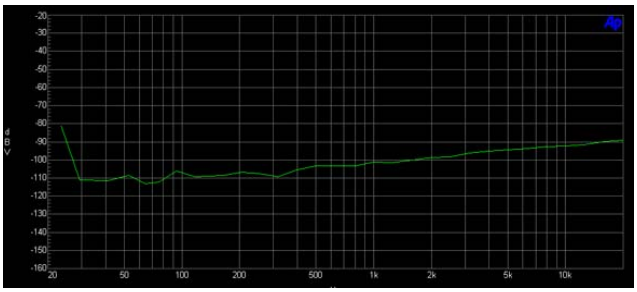
Input Output linearity from 20 to 20kHz



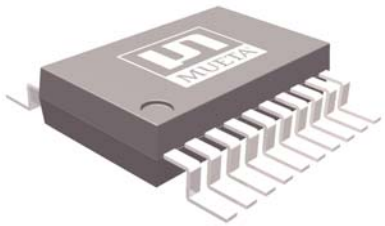
THD + noise vs Frequency



Multi tone noise



Output power: CY-5W, G-10W, YL-25W, R-50W,
MG-100W, B-150W, CY-200W, G-250W



## Why class-D?

### HIGHLY EFFICIENT AMPLIFICATION

Class-A and class-AB audio power amplifiers are characterized by large heat sinks and heavy power supplies. With maximum efficiency around 50 percent, a 100-watt class-A amplifier needs 200 watts to power it, and continues to consume this power even with a low output level or when idling. So for just one watt of audio power (typical for music), 199 watts are dissipated as heat! Such inherently low efficiency is inevitable because the output transistors are constantly in a state somewhere between on and off, meaning they are resistive and dissipating power. In contrast, a class-D amplifier has an output stage comprising transistors (usually MOSFETs) that are either fully on or off; never in between. Consequently, efficiency is high and dissipation is low even with a very low output level. With efficiency over 90 percent, little heat is generated. It also consumes very little power when idling.

### PULSE WIDTH MODULATION

Class-D amplifiers generally use Pulse Width Modulation (PWM) in which an analog audio input signal is modulated with a carrier frequency of several hundred kilohertz. This results in a series of pulses with varying widths which switch the output devices on and off at the carrier frequency. A passive analog low-pass filter on the output of the amplifier takes out the high-frequency pulses, delivering audio to the speaker.

### THE CHALLENGES OF CLASS–D AMPLIFIER DESIGN

Although class-D amplifier topology is very efficient, there are design challenges to overcome. For example, the low-pass filter's performance deteriorates at higher frequencies and higher output power. Modulating an input signal at a high carrier frequency can also cause distortion. Depending on the timing and level of the input, and the tolerance of components used in practice, distortion, noise and instability occur at certain higher audio frequencies (typically above 1kHz). This limits the audio applications of non-MUETA® class-D amplifiers to sub-woofer power amplifiers, public address systems and low-power integrated amplifiers for portable devices where audio quality is less critical (such as laptop PCs).

### IMPROVING CLASS–D PERFORMANCE

The performance of non-MUETA® class-D amplifiers can be increased. For example, very careful circuit layout and accurate component matching do yield improvements. And by applying bridge-output feedback, dead-time-, timing- and power supply related errors can be reduced. However, errors in the low-pass filter are not reduced with this type of feedback. In practice, the enhancements are either inadequate or too expensive to be competitive with quality class-AB audio amplifiers.

## The MUETA® solution

### HONEST, PURE AND CLEAN SOUND

The MUETA® class-D amplifier redefines the standard for high-end audio. In contrast to non-MUETA® class-D amplifiers, the MUETA® solution involves a patented measurement method that guarantees the correct voltage at the speaker terminals under all conditions. The output voltage is totally insensitive to the actual load, irrespective of the type of speaker used. The results are no audible distortion, a flat linear response, and sound as pure as you can get.

### CONTROLLING THE SIGNAL AT THE OUTPUT

Output control techniques used in non-MUETA® class-D amplifiers overlook the combination of the low-pass output filter in the amplifier and the crossover filter in the speaker, leading to an unwanted detuning of the crossover filter. Since MUETA® controls the final signal at the output behind the low-pass filter, whatever load is connected will not influence the output signal or change the speaker's crossover filter performance.

### CLOSE TO A PERFECT VOLTAGE SOURCE

MUETA® measures both current and voltage behind the analog low-pass filter. The current through the capacitor in the output low-pass filter is measured, which is an effective way of looking at the trend/slope of the output voltage (since current leads voltage by 90° in a capacitor). Via this form of feedback, MUETA® tackles problems before they happen, thus realizing a close to perfect voltage source. Together with the unique PWM modulator topology, MUETA® prevents deviation in the output voltage, thus eliminating any effects of supply variation, dead-time, output filter non-linearity, load dependencies, and so on.

### LOWER COST POWER SUPPLY

Due to the unique PWM modulation method used for MUETA®, the power supply rejection is very high. This means the signal is virtually independent of voltage ripple or supply drop due to high load, allowing a lower cost, simpler power supply circuit to be used without compromising performance.

## The MUETA® benefits

### COMPACT AND EFFICIENT

A MUETA® amplifier capable of delivering several hundred watts fits in an enclosure about the size of a cigarette box, thanks to efficiency in the order of 90 to 95 percent and the absence of a bulky heatsink. The reduced supply voltage stability requirements mean the power supply can be much smaller, simpler and more cost effective. This reduces the overall size, a huge benefit in automotive applications where space and power are severely limited, and in home cinema systems where up to seven high-quality amplifiers are squeezed into a 'standard' width housing.

### HIGH-END AUDIO PERFORMANCE

MUETA® amplifiers are totally 'honest'. What comes out is the same as what goes in, only LOUDER! The frequency range spans the entire audio spectrum (from 20Hz to 20kHz), and is completely load independent (see figure 1). There is almost no harmonic distortion. Measured results (see figure 2) show THD at around 0.002%. A high-end class-AB amplifier costing as much as $15,000 rarely gets better than 0.005%, while a good-quality amplifier achieves 0.01%. A very expensive non-MUETA® class-D, however, struggles to reach 0.02%. The measured signal-to-noise ratio (S/N) is better than 130dB compared to 90dB for an 'average' audio amplifier (see figure 3). Considering a difference of 40dB would imply S/N performance 100 times better, this highlights just how accurate the MUETA® really is – just 5µV of noise on the output. This is over 50 times less than the theoretical S/N ratio of CD!

### INSENSITIVITY TO OUTPUT LOAD

Thanks to the MUETA® control method, it doesn't matter what is connected to the output. Speaker amplifier matching is usually a weak link in an audio chain, and even many of the highest quality speakers do not represent a consistent load across all audio frequencies. Most high-end amplifiers, particularly non-MUETA® class-D, are unable to deal with this. The sound fidelity of the MUETA® solution, on the other hand, is unaffected by varying loads.

### EXCELLENT BASS CLARITY AND NO CHANGE IN CROSSOVER PERFORMANCE

A critical aspect in reproducing clear bass is the damping factor of an amplifier, and the output impedance determines this. Because a speaker is an inductive device, coil movement also creates a signal that can cause a 'muddy' sound if the amplifier has a low damping factor. The MUETA® amplifier has a damping factor of over 1000 at 10kHz, and in the critical bass region below 1kHz, it is greater than an astonishing 4000. A good quality class-AB amplifier achieves around 200 in this region, and a non-MUETA® class-D amplifier just 40! The output of MUETA® amplifiers is short-circuit protected without compromising output impedance.

## Typical MUETA® application areas

### HOME ENTERTAINMENT

The specifications of MUETA® amplifiers are better than those of many of the very best high-end products, bringing unparalleled levels of fidelity within economic reach of a much wider group of consumers. The trend towards home cinema, with multi-channel ‘surround sound’ systems, is another area where the compact size is a major advantage. Five to seven amplifiers will easily fit into the standard width housing.

### AUTOMOTIVE AUDIO SYSTEMS

The low voltage (12V or 42V) and limited space available in automotive applications makes MUETA® particularly attractive for in-car entertainment systems. The cool operation is another important benefit. Conventional power amplifiers are power supply sensitive, which results in distortion, even when not clipping. MUETA® amplifiers are much less critical to supply voltage and delivers true hi-fi up to the clipping point.

### PUBLIC ADDRESS AND STAGE AMPLIFICATION

Public address systems do not demand such high fidelity as consumer audio, but are very price sensitive and must be able to deliver high power. MUETA® provides an excellent solution on all counts. Driving audio transformers in 100V transmission systems is also no problem for MUETA®. In sound reinforcement applications, such as stage amplification for live music, there is a general trend towards loudspeaker cabinets with built-in power amplifiers. The MUETA® solution, with its compact size, low weight, low power supply requirement and cool operation, is an ideal solution.

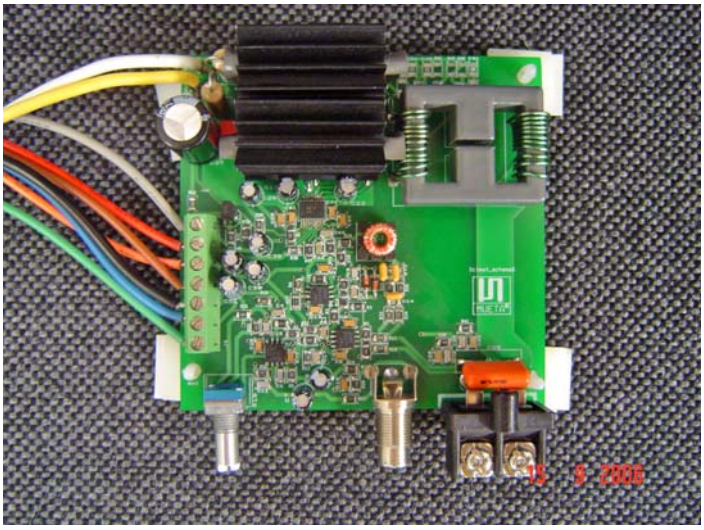
## MUETA® products

### EVALUATION BOARDS

A one-channel (mono) MUETA® amplifier can be built using the integrated MUETA® IC, which contains all critical components in a 20-pin SSOP housing. One of the many unique aspects of the MUETA® technology is that the basic amplifier circuit configuration does not change for different output power ratings. This means MUETA® amplifiers with rated output power from 50W to 1000W can be produced using the same basic PCB layout and enclosure. Simply changing a few components and adding an appropriate powerful supply can produce a whole range of products very cost effectively.

## PRODUCT AVAILABILITY

A number of 200W full bridge Reference Design boards will be available in Q1 2007.



## The MUETA® background

### THE 'MUETA' NAME

The MUETA® name is derived from a combination of the Greek symbols Mu (μ, commonly used to designate amplification factor) and Eta (η, commonly used to designate efficiency).

### DEVELOPMENT HISTORY

The MUETA® breakthrough was actually inspired by America's desire for air-conditioning! Engineers were looking at ways to control generators to meet the unpredictable demand for power for air conditioners, and a class-D amplifier is, after all, nothing more than a 'voltage-controlled voltage source'. The circuit they designed was so strong, it stalled the combustion engine when being overloaded! Armed with ideas from this non-audio discipline, the Eindhoven University of Technology closely studied the classic shortcomings of class-D from a radically different angle. After designing, verifying and patenting the solution, the University licensed MUETA® to develop it into a commercially viable product for audio applications. By applying its experience in designing, manufacturing and marketing high-quality audio products, and by using fast new components, many of which became available thanks to the explosive growth in mobile telephony, this company has succeeded in producing the range of MUETA® products.

# MUETA® CLASS-D

**Efficiency in Amplification**

## AMPLIFIER TOPOLOGIES

The letter designation for amplifier topologies indicates recognition by the Institute of Electrical and Electronic Engineers (IEEE). A was the first type recognised, B the second, C third, and so on.

Class-A amplifiers use output transistors that are turned ‘on’ all the time, generating considerable heat. Consequently, class-A amplifiers are very inefficient (in the range 25 to 50%). Consumed power is constant, as power flows either to the load or to the heat sink.

Class-B amplifiers are more common, using two output transistors, one for the positive and one for the negative part of the cycle. However, at the point when one transistor stops amplifying and the other takes over, there is always a small distortion on the signal called ‘crossover distortion’. Since each transistor is ‘on’ only half of the time, it does not get as hot as a class-A, yielding a smaller size and better efficiency (typically 50 to 78%).

Class-AB amplifiers are a combination of the two types described above. Transistors conduct a little more than half a cycle. At lower volume levels, the amplifier works in class-A, at higher levels, it operates in class-B mode.

Class-C amplifiers are not applicable for audio amplifiers and used mainly in radio-frequency (RF) applications. Transistors conduct for less than half a cycle usually in combination with a tuned load.

Class-D amplifiers operate in a similar manner to a 1-bit digital-to-analog converter. The input signal is sampled at high rates, and then reconstructed at higher power. It produces almost no heat and is very small in size. These amplifiers are easily capable of delivering over 1000 watts, and efficiency is greater than 90%.

## Frequently-Asked Questions (FAQs)

### Q. Why is MUETA® better than other class-D amplifiers?

A. MUETA® uses both voltage and current measurements of the output capacitor. Combined with the special modulator, this eliminates any output deviations. Good quality 'non-MUETA®' class-D amplifiers do not use capacitor current feedback hence errors on their output, originating in the output filter, cannot be fully compensated thus causing distortion.

### Q. Why is MUETA® so insensitive to output load?

A. Unlike non-MUETA® class-D amplifiers, MUETA® measures both voltage and current through the output capacitor. By controlling the capacitor current, MUETA® controls the slope of the output rather than the output voltage. This is a form of predictive control. MUETA® amplifiers are therefore very fast in detecting and eliminating output disturbances.

### Q. Will an output short-circuit damage a MUETA® amplifier?

A. No, a MUETA® amplifier is over-current protected, including shorting to ground.

### Q. Can MUETA® amplifiers drive electrostatic speakers?

A. Yes, the MUETA® amplifier can drive any load, no matter how inductive or capacitive. Electrostatic speakers are therefore no problem at all for MUETA® amplifiers.

### Q. MUETA® amplifiers use output/global feedback. Isn't global feedback bad?

A. The global feedback loop is not an error-correction loop as such, but is an integral part of the PWM modulator. The truth is, all switching amplifiers apply feedback loops of some sort somewhere, even the ones that say they don't! In a MUETA® amplifier, the output filter is an integral part of the PWM modulator. Our global feedback loop thus includes the output filter but is only as short as other amplifiers' local (noise shaping) feedback loops. Our complete amplifier compares to others' local feedback, thus there is no problem.

### Q. What is so special about MUETA®'s modulator?

A. The hysteresis modulator in the MUETA® amplifiers works on zero-input. Together with the controller, which regulates the error to zero, this is an ideal combination because in case of a non-zero error on its input, the modulator reacts immediately to correct this. On the other hand, because conventional modulators make a direct translation from signal to duty-cycle, they require a non-zero input.

To generate a correct filter output, an additional non-zero correction signal is required at the modulator input. This is fundamentally imperfect since the generation of this correction signal requires the error to be non-zero! To make things worse, the amount of correction required increases for higher frequencies when there is less time to generate it. This is why filter output feedback will not work on switching amplifiers with a conventional modulator.
MUETA® controls the slope of the output rather than the output voltage. This is a form of predictive control. MUETA® amplifiers are therefore very fast. Under this condition, application of feedback is no problem, and in fact enables the correction of all filter effects and bridge switching errors within the audio frequency band.

## Q. What is a hysteresis modulator anyway?

A. A hysteresis modulator is an analog relative of SD modulation. Digital SD modulation is used in 1-bit DA converters and SACD audio. The analog equivalent has no clock and therefore doesn't quantize the signal; the modulator switches whenever necessary, without having to wait for the next clock pulse. MUETA® therefore gives high performance while switching at a rather low frequency, without the need for noise shaping.

## Q. Why is the DC voltage supply so cost-effective?

A. The MUETA® amplifier shows superb supply rejection, hence DC supply quality is much less important. Consequently, less critical (cheaper) components and simpler power supply design can be used.

## Q. Why is the power stage so cost-effective?

A. Thanks to the excellent control characteristics of MUETA®, it is no big problem to make small timing errors in the power stage. Thus slower switching is preferred for the benefit of reduced electromagnetic radiation. This alleviates shielding requirements and thus lowers consumer price.

## Q. What are the potential financial advantages for MUETA® amplifiers?

A. The excellent specifications of a MUETA® amplifier put it in the high-end of audio technology in terms of performance but not in terms of cost price. Without the need for a heavy (and expensive) heat sink, and the use of a much more economic power supply (using less critical components), it is considerably more cost effective to build than an equivalent specification conventional amplifier. In addition, the critical components are included in a MUETA® IC circuit that requires no adjustment or setting up and lends itself to faster assembly.

## Q. What does a MUETA® amplifier IC or evaluation board cost?

A. IC prices can only be discussed on an individual basis, and depend on the order quantities, etc. E-mail: sales@mueta.com or fax (+31(0)416 699004) for more information. Evaluation boards are available on special request.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