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III-Vs start propelling cable services to a new level

GaAs and GaN technologies can spur high-quality delivery of advanced video, data and telephony services to the home, says **TriQuint's Chris Day.**

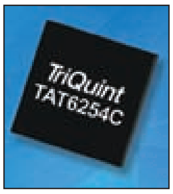
Like all consumer-driven services, the cable industry always needs to find new ways to generate cash. Higher sales can come from existing services, but long-term success hinges on investment in the new technologies that are starting to appear, such as high-definition channels, new services, "3-D TV", and video on demand.

Each of these adds a layer of complexity, and demands better performance from distribution resources alongside greater bandwidth and superior use of the bandwidth that exists today.

At TriQuint we believe that compound semiconductor technologies, principally those utilizing GaAs and GaN, will be essential ingredients in products that can meet these challenges. These III-Vs combine higher efficiency with greater linearity and a broader bandwidth, attributes that cable system designers crave, and deployment of these superior technologies will have a positive impact throughout cable systems, from headends to customer premises.

One way to understand where technology stands today is to see where we've come from. There's no doubt that the

Semiconductor technologies like GaAs and GaN are enabling CATV system operators to offer competitive 'triple play' services like high-definition TV (HDTV), Video on Demand (VOD) as well as voice and broadband data communications



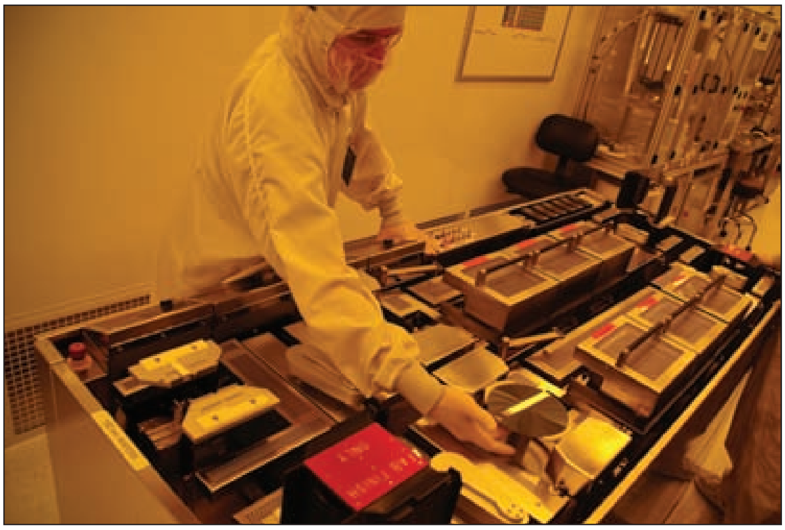
TAT6254C: FTTH / RFoG low noise amplifier for CATV receivers / triplexers. AGC to maintain +19 dBmV/ch output (+23 dBmV / high output mode). Ensures video quality / ease of design

early days of television were wondrous for some, but for many the experience was marred by poor reception. Areas that were not in a line-of-sight path to the transmitting antenna had to make do with weak, snowy pictures. Viewers resorted to erecting tall towers and adding preamplifiers, which usually helped, but often not all that much.

To address this weakness television pioneers, whose names have been lost to all but fervent followers of broadcast technology, created the first community antenna television (CATV) systems. The acronym CATV was apt as these systems allowed a community to achieve reliable reception of local stations on at least a few channels. Often these included major network channels and perhaps a public broadcast station.

CATV was enabled by finding the highest point in or around the community, erecting high-gain directional antennas, and pointing them at broadcast towers many miles away. Channels were aggregated at this "head-end", and distributed via coaxial cable to the community's residents. Although results varied, they were invariably better than those achieved by individual viewers. To maintain an adequate signal throughout the system, distribution amplifiers were periodically spaced along the path of the cable "plant". They initially employed vacuum tubes that degraded the signal with high levels of second-order distortion, but this was remedied with the bipolar transistors introduced in the 1960s.

The tremendous benefits provided by CATV systems resulted in explosive growth, and the "community" antenna television concept expanded to cover entire metropolitan areas, states, regions, and ultimately into today's Multiple System Operators (MSOs) that provide standard- and high-definition television services throughout North America. Similar models were followed across the globe, although there was a notable difference. Residents of Europe and many other countries were initially restricted to broadcasts by state-operated monopolies that inaugurated television service, and these viewers had to wait to embrace the competitive service offerings that they enjoy today.



Gallium Arsenide (GaAs) wafer processing in TriQuint's Hillsboro, Oregon 150mm facility

Growth of the cable TV service was achieved through exponential advances in every key technology, from RF devices through to the introduction of delivery via fiber optic cables, which now form the latest generation of hybrid fiber coax (HFC) networks. Significant additional contributions include signal-processing technology and improved devices, better software, advanced modulation schemes, and linearization techniques. Today, cable systems are flexible enough to provide over 80 channels of legacy analog television programming alongside digital and high-definition services, video-on-demand services, high-speed data service, and packetized telephony…and more is on the way.

Mixing old and new

From a technical perspective, cable systems are incredibly diverse. The plant of a typical system contains decades-old semiconductor technology sitting alongside its leading-edge brethren. However, it is possible to combine analog, digital, RF, microwave, and lightwave technologies, and make them all work together more or less seamlessly to provide today's high quality of service.

This approach is employed in cable hybrid amplifiers, the long-established staple of every cable distribution system. This device can be seen on utility poles everywhere, boosting signal levels throughout the system while maintaining high levels of linearity. While older silicon bipolar transistor amplifiers are still in service, the cable networks they support simultaneously employ fiber optic technology, advanced digital modulation schemes, and assorted other technologies that are at or near the state of the art. Not surprisingly, streamlining this technological alphabet soup is essential if the cable industry is to address three key objectives: meeting expectations set out by shareholders and investors; fending off competing network technologies; and wooing legions of consumers hankering after novelties such as 3-D TV.

In a larger context, the MSOs primary challenge is to deliver the greatest variety of entertainment choices with the highest performance, at the lowest cost, to the

The holy grail for lightwave is Fiber-to-the-Home (FTTH). This high-cost approach eliminates coaxial cable and all content is delivered directly to the customer through fiber optic cables. In the US, this fiber-based approach has been championed principally by Verizon, through its FiOS network that competes directly with traditional cable systems in terms of content. It has been very well received, and its limited success has spurred an increase in the speed of entrenched cable MSOs

greatest number of subscribers. The most effective way to do this is to reduce or eliminate components in the system. A classic example of implementing this advice was the introduction of the so-called "power doubler" in the mid 1980s. The power doubler reduced the need for many trunk and 'bridger' amplifiers and line extender amplifiers.

The most pervasive mixed technology in the network is employed in fiber optic distribution, which was introduced in the 1980s against a backdrop of a coax-only domain. The appeal of this lightwave technology is its far lower distribution losses compared to coaxial cables, coupled with near immunity to interference. And as this technology has evolved, the number of amplifiers required to cover a given area has diminished.

The upshot has been the removal of costly components from the distribution system, leading to improved signal quality and access to the immense bandwidth required by "triple-play" networks that offer voice, video, and data. In short, the end user is getting closer and closer to realizing the benefits provided by fiber optic technology.

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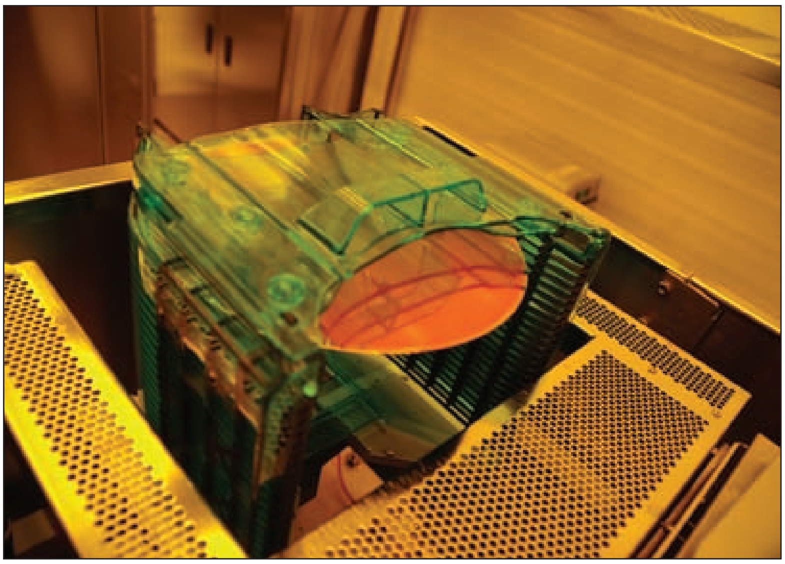
In the US, this fiber-based approach has been championed principally by Verizon, through its FiOS network that competes directly with traditional cable systems in terms of content. It has been very well received, and its success has spurred an increase in the speed of new service standards and deployments by entrenched cable MSOs. They responded with a third generation of the Data Over Cable Service Interface specification (DOCSIS), which has been developed by Cable Labs. This not only provides support for IPv6 and IPTV – it also allows customers to tap into data at up to 160 Mb/s in the downstream and 120 Mb/s in the upstream, making it competitive with VDSL and FTTH.

Although FTTH may be the ultimate data delivery technology, the edge that it has over the latest variant of DOCSIS is not a big concern for today's cable operators.

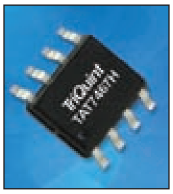
Verizon's aggressive deployment of FiOS has created the only real competitor to cable for state-of-the-art performance. An intensive marketing war has ensued between the two entities, with each side scrambling to expose chinks in the armor of the other. While they battle it out, the differences between the two are increasingly narrowing as the cable industry enhances its product offerings.

Linearization

RF linearization techniques at the circuit level have held the key to enabling optical transmitters to attain their optimum performance and arguably cement their usefulness in cable distribution. Regardless of the technique employed to amplitude-modulate light, significant distortion arises that hampers the transmission



150mm Gallium Arsenide wafer with photo resist applied in the TriQuint Hillsboro, Oregon high-volume facility



TAT7467H: Edge QAM / DOCSIS 3.0 amplifier for CATV headend applications. A true differential amplifier for medium power applications with excellent 3rd order distortion performance. 350-380mA power usage that is up to 50% better than other solutions

of information through the network. If this distortion were not reduced, it would impair the effectiveness of lightwave systems for cable applications. Even early systems required extremely high linearity, and this demand became even more stringent over the years as bandwidth and channel counts increased.

Linearization of RF and optical systems over wide CATV bandwidths is far from trivial. When performed using external discrete circuits, this goal is complicated by parasitic effects that are difficult to compensate out of the linearizer. However, if these circuits can be integrated directly on-chip, adjacent to the amplifying device, then the parasitic problem is largely eliminated. Thanks in part to the use of techniques developed by TriAccess Technologies, a company that we acquired last year, we can now linearize amplifiers for DOCSIS 3.0 and cable infrastructure using on-chip techniques.

Substantial cost savings have already resulted from linearization, because it has enabled the construction of fiber optic modulators with the necessary distortion characteristics for transmitting analog content. Looking forward, linearization is poised once again to enable cost savings, this time to benefit RF amplification needs. Integrated linearization techniques are available to enable mature GaAs technologies to compete with more expensive semiconductor options without paying the penalty of a substantial sacrifice in performance. Linearization can also enhance the already excellent performance of newer device technologies, providing an even higher level of power efficiency to the operator.

GaAs, GaN, and cable

It is safe to say that compound semiconductor technology along with advanced linearization techniques will be two key enablers for allowing all types of future cable systems to fulfill the cost, service quality and competitive challenges lying around the corner. The RF, microwave and lightwave portions of the system are already relying extensively on compound semiconductor technologies, and will increasingly do so in the coming years.

Quality check on a wafer being fabricated at TriQuint's Hillsboro, Oregon facility

On the RF side, the hybrid amplifier that has employed silicon bipolar transistors for decades to deliver the high RF output power and linearity required for Class A operation is on its way out. The performance of silicon-based hybrids has reached its limit by failing to keep up with increases in bandwidth made available to cable MSOs, which have grown from 300 MHz to 550, 870, and now 1000 MHz. In its place will be GaAs devices delivering greater performance in every key metric, combining greater bandwidth with much lower multi-carrier distortion, superior RF output power, lower noise and greater efficiency. Spurring the switch to the superior technology is a shrinking price gap between GaAs-based hybrids and their silicon rivals. The insurgent often benefits from a single RFIC that leads to improved push-pull amplifier matching and fewer distortion-induced problems such as composite carrier noise ratio.

One of the big questions hanging over cable hybrid amplifiers is this: how long will they be needed, as fiber continues its march deeper into the network? Industry prophets have long predicted the demise of this class of amplifier. However, to paraphrase Mark Twain, rumors of their death have been greatly exaggerated. The global market for cable hybrid amplifiers, while very cyclical, shows only small signs of diminishing. What's more, it is rapidly being enhanced by widespread deployment of GaAs devices. While some regions of the world are significantly built-out with cable service networks, others are just beginning. In developing nations with growing economies citizens are just starting to enjoy the luxury of discretional income, and there's no doubt that some of this will be used for entertainment, including cable TV.

In addition, suppliers of GaN-based RF power amplifiers have recently introduced their first products. Although in many respects GaN is still an emerging technology, it is still a very attractive contender, offering tremendous performance in several key figures of merit. Cost is a major concern – it is three to eight times that of GaAs devices – and this restricts GaN to use in situations demanding the highest possible performance. The higher price of GaN devices is mitigated to some degree by greater power output and other attributes, which can extend the reach from the fiber node to the customer (where the transition is made from fiber to coax) while maintaining low levels of distortion and power consumption. But it remains to be seen whether the market embraces GaN, and is willing to shell out for the greater performance that it offers.

In the aggregate of systems throughout the world, cost factors rather than leading-edge specifications are of paramount importance. This is particularly true in high-population, emerging economies such as China, India, and Eastern Europe. In these regions the monthly subscription cost, and by extension the capital cost of building new networks, governs the decision over whether to build out new networks. Silicon bipolar hybrids still dominate those markets, but the GaAs performance value is starting to take hold. The high cost of GaN-based hybrids will likely restrict their success in these desirable high-growth markets.

Other important sub-markets within cable TV are those for headend high-efficiency amplifiers and customer premise distribution. While the RF output level of the headend application is 5 to 10 dB lower than that of line extenders in coaxial distribution networks, the high density of equipment in headends makes high efficiency a sought-after premium.

Our DOCSIS 3.0 amplifiers address this issue, cutting power consumption by up to 50 percent and slashing the circuit board "real estate" required to employ these devices by up to 80 percent. These GaAs-based amplifiers are designed for use in customer premises equipment to support multi-room deployment as well as advanced in-home distribution architectures such as Ethernet over coax, the Multimedia over Coax Alliance (MOCA) standard, and for FTTH receivers. When these are used in cable hybrid amplifiers and line extender amplifiers they provide lower distortion than ever before, plus very high efficiency and low power consumption.

Taken together, these attributes benefit cable MSOs in terms of reduced operating cost and system complexity. They allow amplifiers to be smaller and more frugal with power. The latter benefit must not be underestimated, given the large numbers of hybrid amplifiers used throughout a system, and the consequent opportunity for considerable annual savings associated with operating costs. The benefit of greater efficiency also makes a difference to amplifiers at the headend, where it translates into reduced cooling requirements.

In short, the hegemony of silicon bipolar devices in hybrid amplifiers is drawing to a close. That's because this venerable technology that has played an enormous role in the growth of cable since the 1960s is no longer viable in the higher-frequency, higher-performance cable systems that will drive the industry into the future. In its place will be GaAs devices that are already enjoying rapid deployment, which combine low-cost with high performance, making them well suited to both current and future cable systems.

GaN, which has inherent characteristics that are highly desirable in cable hybrid amplifiers, is currently too expensive for use in most systems. Nevertheless, its role will continue to expand in years to come. It is destined to make an impact, because the combination of process evolution and economies of scale will enable the price reductions necessary for historically frugal-minded cable system manufacturers and operators to begin to adopt this compelling technology.

What's on tomorrow?

There are many variables that will determine the exact path of entertainment distribution to the home, including the possible entry of wireless technologies. However, there are some facets of the industry that will not change. First, the deployment of FTTH has altered the face of TV, data, and voice delivery to the home, giving traditional cable MSOs a true competitor for the first time. Distribution via satellite remains a key player, but it struggles to provide voice and data services, and its future is uncertain in those areas where established cable providers are highly competitive in terms of price and service.

In a competitive environment, the cable industry has little choice but to do whatever is necessary to retain its premier position. FTTH, from Verizon in the US and a growing number of operators in world-wide markets, will continue to gain market share as it is deployed in new regions. Together these two fierce competitors will rely on GaAs and GaN to deliver the highest levels of performance at the lowest cost.

As a result, the market for GaAs- and GaN-based cable hybrid amplifiers will continue to grow. Finally, fiber will inch its way closer and closer to the customer location in HFC systems, driving the growth of optical receivers and other system elements that also rely on III-Vs.

For consumers all of this is great news, since competition drives innovation, and innovation tends to lead to better, more varied services. From any vantage point, the home entertainment industry will be theater at its technological finest – and compound semiconductor technologies are a shoe-in for the leading roles.

TGA2807-SM: Edge QAM / DOCSIS 3.0 RF amplifier for CATV headend applications. ACPR ~2 dB better than previous generations. Standard 5x5mm QFN offers high-efficiency performance

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