Review on Darlington Transistor for Recent Modern Application

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ABSTRACT
Recently, the rising the demand of Darlington products for the high data rate communication system. Darlington transistors are used in applications where a high gain is needed at a low frequency. Recently Darlington cell and Darlington topology have been reported high gain and good bandwidth for modern application. In modern communication Darlington amplifier is versatile used in low noise amplifier, distributed amplifier, broadband mixer, power amplifier and active balunes. Today technology required high speed transmission efficiency with less power consumption and less circuitry to used, Darlington amplifier satisfy all parameters so that review and future advancement required. In these papers designing, application, issues and recent trends of Darlington amplifier is reviewed; we have surveyed almost all the Possible Work Done in Darlington transistors in Past Decades.

Keywords
Darlington cell, Hetero junction bipolar transistor (HBT), high electron-mobility transistor (HEMT), Analog period, RF period

1. INTRODUCTION
The two transistor put inside a single package is knows as a Darlington pair it acts like a single transistor that has high gain and high input impedance. In the circuit of the Darlington amplifier the output of the first transistor is connected with the input of the second transistor. The Darlington amplifier was invented by Darlington. It provides excellent characteristics with high input impedance and low output impedance. Darlington amplifier used, in Scientific, and Medical(ISM)bands for gigabit-per-second wireless network solutions wireless Sensor network (WSN), point-to-point communications (18–23 GHz) and short-range(22–29 GHz) automotive radars .Wideband and low-cost millimeter - wave(mm-wave)circuits. A Darlington amplifier has potential for high-speed applications due to its compact chip size and broadband performance .The Darlington amplifier was invented by Darlington, and it can be a two- or three-transistor cell. Many broadband circuits designed using the Darlington pairs have been reported, such as low noise amplifier. Basic Darlington amplifier shown in figure 1.

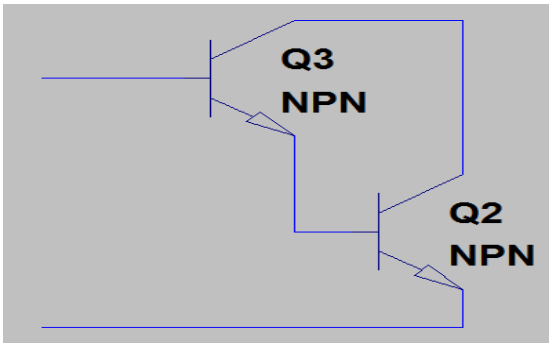

Figure 1 Basic Darlington amplifier

2. REVIEW OF PAPER
Darlington transistor pair, demonstration in the early 1950's. In the last decade silicon transistors suffered from low values of current gain, and large variations of current gain in similar manner transistor. Today technology wanted transistors with larger current gain with stability in operation so negative feedback could be employed, at the sacrifice of gain of system, to stabilize overall circuit performance against variations in operating conditions and transistor characteristics. Darlington pair transistor is a best solution to provide large current gain with large stability. In the past decade Darlington transistor reported high loading capacity with high input impedance and low out resistance. Reported unit voltage gain with high current gain and voltage gain. Darlington pair is versatile used due to all above features. For high-speed data Communications is increasing day by day. A few multi gigabits/second transceivers have been reported for advanced semiconductor technologies [5] [6]. A broadband amplifier is very important for transmitting system. A distributed amplifier gives broad bandwidth with very high speed [7]. However, the distributed amplifier has a few disadvantages, such as large chip size and high dc power consumption. A Darlington amplifier has potential for high-speed applications due to its compact chip size and broadband performance. The Darlington amplifier was invented by Darlington in 1950, and it can be a two- or three-transistor cell. Many broadband circuits designed using the Darlington cells have been reported, such as low noise amplifiers [9], [10], distributed amplifiers [11], broadband mixers [12], power amplifiers [13], and active baluns [14]. The bandwidth of the Darlington amplifier is mainly limited by the base resistor and the Miller multiplication of the transistors. A few techniques have been proposed to improve the performance of Darlington amplifier the hetero junction bipolar transistor (HBT), high electron mobility (HEMT) TRANSISTORS PAIR, Series inductance, pole zero compensation technique. The broad bandwidth fully- integrated power amplifier (PA) is discussed. The Darlington cell with cascode topology was adopted in 2013 as the power cell to elevate the maximum available gain of the transistors in standard 0.18 CMOS technology for being capable of operating at Ka band. Utilizing broadband and low-loss Guanella-type transmission-line transformers as the matching networks, this PA provided bandwidth from 17.8 to 34.6 GHz, and 3 dB bandwidths from 17 to 35.2 GHz.

For gain enhancement of Darlington amplifier gate-pumped down-conversion mixer is realized in a standard 90-nm CMOS process in 2013 [2]. The mixer consists of Darlington cell and a microstrip-line Lange coupler to yield wide 3-dB bandwidth. the measured performance demonstrates a conversion gain (CG) of 6 dB at 4.2-mW power consumption. The 3-dB RF bandwidth is 14 GHz. In this technique, the authors present a simple circuit topology for a gate-pumped mixer that includes a Darlington cell and a microstrip-line Lange coupler to fulfill the requirements of low power consumption, high bandwidth and gain. For Wideband

receiver (RX) and transmitter (TX) for wireless universal radio applications, feedback and shunt peaking techniques is used [3]. Broad bandwidth Darlington amplifiers in recent years GaAs heterojunction bipolar transistor (HBT) high electron-mobility transistor (HEMT) is versatile preferred for high gain and broad bandwidth application.

3. DARLINGTON EVALUTION

The invention and development in Darlington transistor technology started from 1953, the period started from analog period 1953-1980, Origin Darlington transistor invention in 1953, and IT-doubler Darlington amplifier invented in 1980, after 1980 RF period is started, from 1981 to till now Darlington transistor is developed for RF Technology application. Si-BJT Darlington transistor developed in 1981, 1981 to 1983 Si-BJT Darlington pair products was used in mostly application, in Darlington history first demo of GaAs Darlington pair performed in 1989 and first GaAs Darlington transistor product used in application at 1995, from 1999 Si-Ge Darlington transistor developed and used in versatile application from 1999 to 2000, the gallium transistor leap in technology application up to 1980, current gain and high loading capacity is less in Si-Ge product so that after 1980 gallium transistor came in consideration, gallium transistor provide high current gain, high data speed and more stability for versatile application, The first demo of Gallium nitride is performed in 1995,GaP Product used from 2000, In 2005 Self-Biased Darlington invented , E-mode PHEMT Darlington's (2006),

Linearized Darlington Cascode (2006), Dynamic Feedback Linearized Darlington (2007) Dynamic Feedback Linearized Darlington (2007) First GaN HEMT MMIC (2007) Darlington-Cascode - P1dB >1Watt,

In RF application evaluate that Linearization Techniques, Adv. Semiconductors technology, Future GaN E-mode 3.3V Infrastructure is consider. In recently years high mobility and hetro junction transistor is preferred, many number of impedance matching techniques like pole-zero compensation technique, miller compensation, post –pre distortion compensation technique, variable inductor etc is used in many research for improvement in performance of Darlington transistor product, the Darlington amplifier versatile used in many RF and analog modern application, continuously demand required for how to enhance compactness and performance of Darlington amplifier. Summary of RF Darlington Linear efficiency [8] is shown in figure 2. Review of four recent techniques is shown in table 1.

Summary of RF Darlington Linear Efficiency

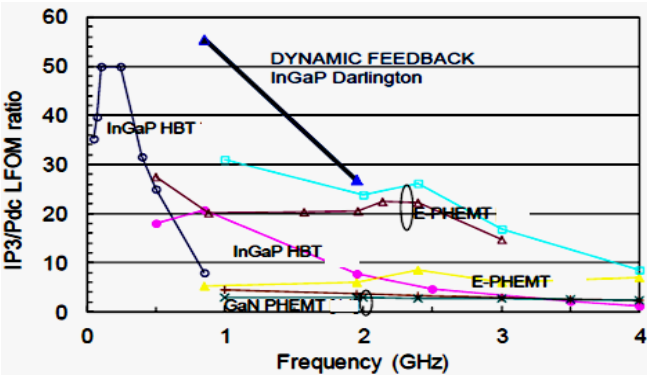

Figure 2 Summary of RF Darlington Linear Efficiency

Table 1 Comparison of Techniques

Topology Used	Chip area (mm2)	Gain (dB)	Operating bandwidth	Noise Figure (dB)
0.18 CMOS technology [1]	0.86	15.2	17.8-34.GHz	-
Gate pumped mixer[2]	0.14	6.5	36 GHz	7.1
Wide band RX& TX[3]	0.67	10	9Ghz	6
HBT-HEMT process[4]	1*1	11	1.8-26 GHz	8.6

This table shows the comparison between all four recent techniques

4. CONCLUSION

From the review of Darlington transistor from 1953 to 2013, Darlington product is versatile used in modern application. First Darlington transistor used in 1953, Darlington transistor provided high current gain and high input impedance in a single package, two transistor configure in single package, many number of development reported in Darlington products like HEMT, HEBT ,Impedance matching network, GaAs and GaP Transistor used in application, post –pre distortion techniques etc, all techniques used to improve gain and bandwidth of Darlington products but technology required more gain, bandwidth with fast transmission of data so that more discussion and research demanded for Darlington product. We compare and discuss four recent techniques in table-1, the highest gain 15.2 dB and highest bandwidth 17.8 to 34 GHz with the small chip area 0.86mm^2 reported in [1]. This technique uses the 1.8 CMOS technology. Efficiency 10.2% is achieved at 26 GHz under the power consumption of 711 mW. We have reviewed Darlington transistor from origin and discuss development and find Different technologies are used for implementing the different designs in the global Foundries.

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