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Wideband low noise Darlington amplifier: A review

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Abstract- *At present, one of the most important requirements of daily life is high speed data transfer communications systems. It has a revolutionary role in the development of a developing country like India and in reaching various schemes on the ground. An amplifier plays a very sensitive and important role in building a high-speed communication system. Darlington pair has been very important in the use of high-speed amplifiers available till now. The important reason behind this pair being first choice of electronics industries for high-speed data transfer in modern communications system is wideband bandwidth, low noise, high current gain, sufficient frequency response at higher and lower frequency etc. Another advantage of this pair is its easy to design low noise amplifier, broadband mixer, distributed amplifier, power amplifier etc.*
Key word- *Darlington pair, wideband, high speed, low noise, current gain, voltage gain.*

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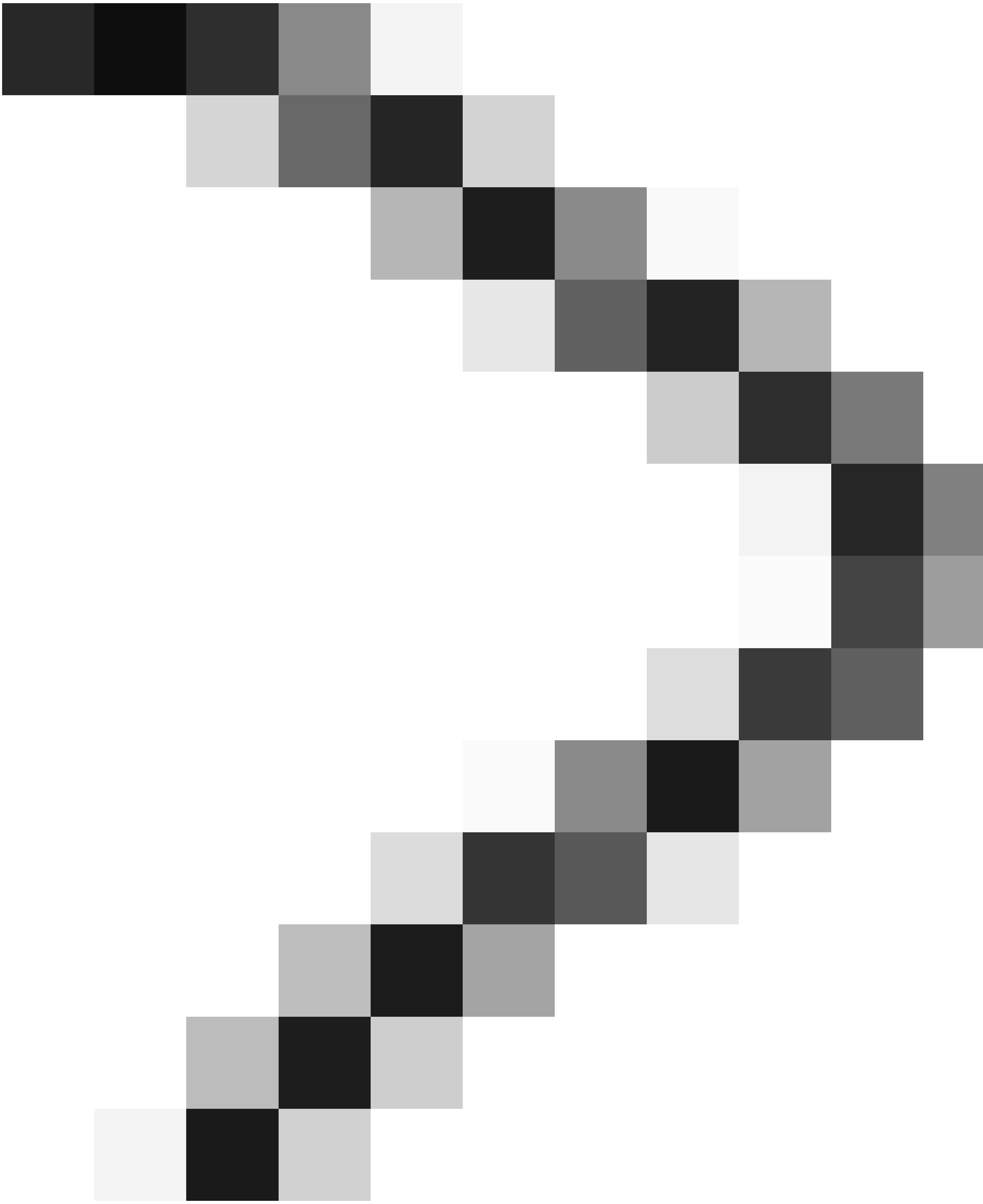
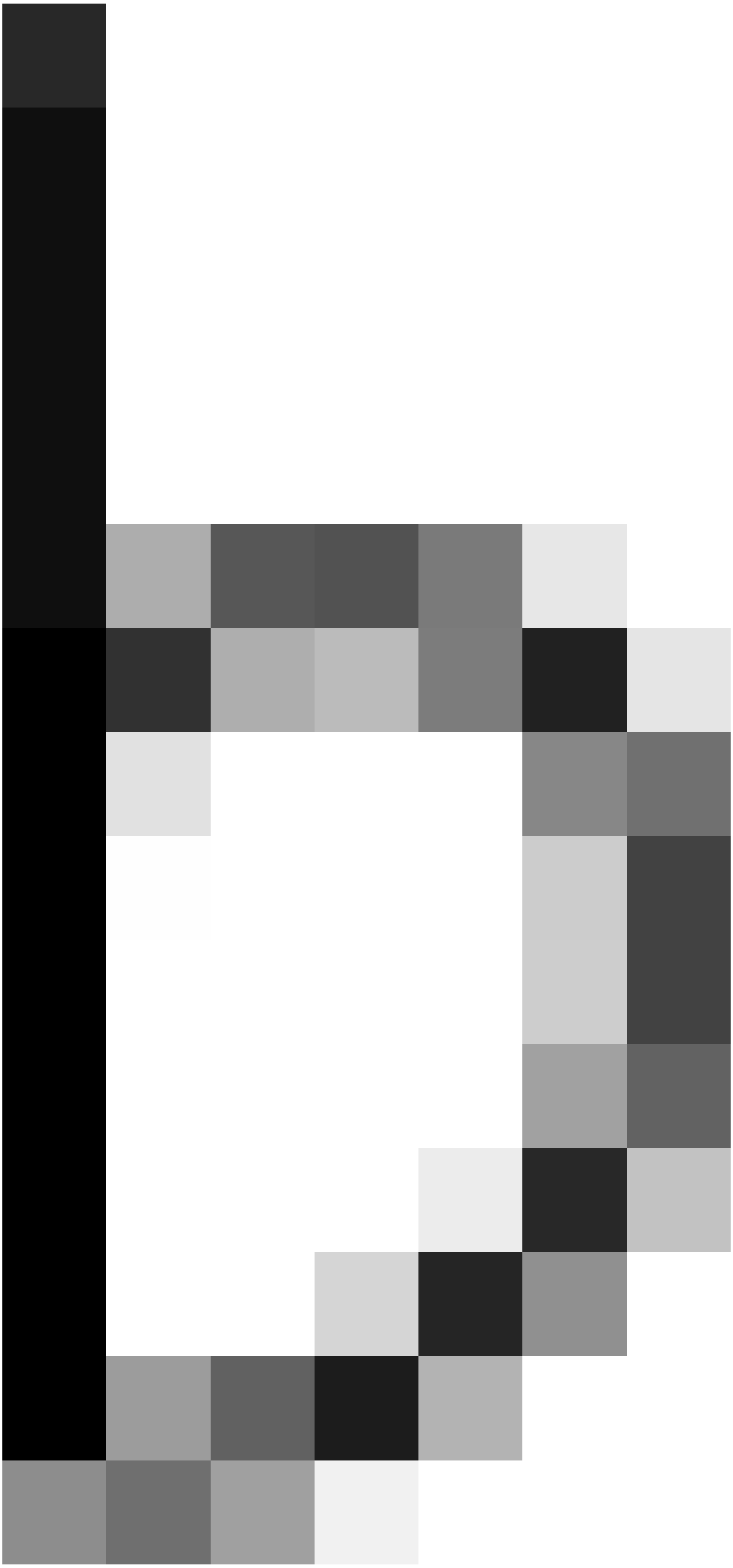
I. Introduction

Due to the use of single transistor having its own limit, the limit of use of radio frequency device made by its use was also determined, under this, voltage gain, bandwidth power consumption noise etc. were also determined. Therefore, amplifiers made of single transit seem unable to meet the demands of today's time. Filling this gap has become a challenge for those working in the electronics sector. Keeping this goal in mind, in 1953, Sidney Darlington[1],[23][24] first prepared such a combination of two transistors that even after being made up of two identical transistors[25][26][27], it would work in exactly the same way as a single transistor, with the same type of transistors its construction is done[28][29].
The presented pair can be easily understood through the diagram shown below.





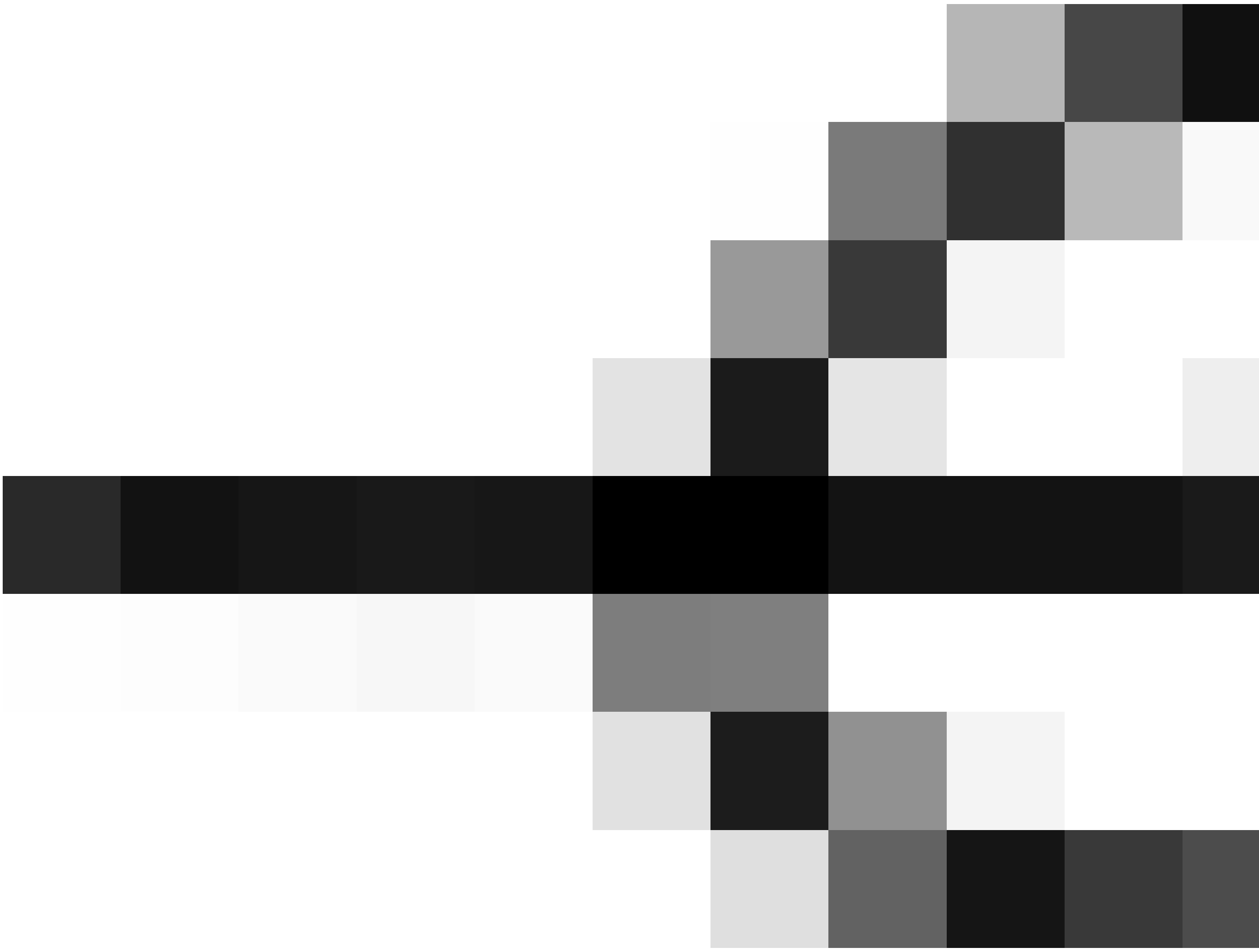


Figure-1 simple transistor and model of Darlington pair

The design of the presented pair can be easily understood in such a way that the emitter terminal of the first transistor is connected to the base terminal of the second transistor and the collector [30] terminal of the second transistor is connected to the collector terminal of the first. The pair thus formed behaves like a single transistor where the base terminal of the first is used as the collector and emitter terminal of the second.[31][32][33][34] In short, we can say that double transistor is single. Main advantage of this pair is high current gain (if both transistors are designed same materials, then current gain of hole pair is square of current gain of single transistor), very high input impedance in comparison of single transistor and very low output impedances.[35][36][37]

According to the first pair shown in figure first,

$$I_c^R = I_c^1 + I_c^2 \ldots\ldots\ldots.. \quad 1$$

Where, I_c^R = resultant current of whole pair

I_c^1 = first transistor collector current

I_c^2 = Second transistor collector current

But, $I_c^1 = \beta_1 I_b^1$ (where I_c^1&I_b^1 are collector and base current of transistor second)

$I_c^2 = \beta_2 I_b^2$ (where I_c^1&I_b^1 are collector and base current of transistor second)

$$I_c^R = \beta_1 I_b^1 + \beta_2 I_b^2 \ldots\ldots\ldots\ldots \quad 2$$

Since $I_b^2 = I_e^1 = I_c^1 + I_b^1 = (\beta_1+1) I_b^1$

$$I_c^R = \beta_1 I_b^1 + (\beta_1+1)\beta_2 I_b^1$$

$$I_c^R = (\beta_1 + \beta_2 + \beta_1 \beta_2) I_b^1 \ldots\ldots\ldots\ldots\ldots\ldots\ldots 3$$

From above equation it is clear that current gain is just square of gain of transistor or double.

In the presented review article, a brief description of the technique and technology used by author in the form of Darlington pair as wideband and designed pair has been presented.

Technique use to design Darlington pair- keeping in mind its special usefulness in the field of communications sectors, Darlington pair has been manufactured by the designers working in the electronics sector's using various techniques. By using these techniques, efforts have been made to increase bandwidth, gain, temperature stability reduces power consumptions, noise etc. effective time to time has been done. The details of the technique that have been used are given below.

1- High electron mobility transfer (HEMT) technique
2- Hetro junction bipolar transfer (HBT) technique
3- Slew rate technique
4- Series packing technique
5- Capacitor compensation technique

High electron mobility transfer (HEMT) technique- Generally HEMT is another name of FET, it is also known by the name of …….etc. While designing the FET, it is taken in to consideration's that in stead of the material GaAs used between two junctions Al GaAs are used. The main advantage of this experiment is that power consumptions, voltage and current gain, data transfer speed, bandwidth etc relatively improve designed from new materials, according to available literature survey using new materials gain increase more than 15db, power consumptions less than 330mW, and supply voltage less than 30Volt. HEMT are two types first pHEMT and second is mHEMT.

pHEMT – it is abbreviated from of pesodomorphic high electronic mobility transfer. In this technique AlGaAs-DinGaAs material is used in place GaAs. The main advantage of its use is that the gain and bandwidth both are better than devices made new material in comparison to devices made old materials.

mHEMT- it is abbreviated from of Metamorphic high electronic mobility transfer.in this technique we use a buffer layer in the place of GaAs, this technique also improve version of pHEM, used buffer layer material made by using material AlLnAs. The main advantage of the device made using this layer is high gain and low noise. GCPW (grounded coplanar waveguide technology has been used in its design. Noise figure 3.3db and 24 db gain.

HBT Technique- HBT is abbreviated from of Hetro-Junction Bipolar Transistor (HBT) technique. HBT is just modified form of BJT. BJT has been modified in such a way that extra capacitances can be created at the emitter based junctions. Due to which the amplifier designed with its help will be sufficient for the radio frequency operated devices. Transistor manufactured with HBT technology gave birth to a revolution in the field of radio communications. According to available literatures HBT technology used either single or combined with HEMT technology according to the requirement of electronic industries.

Slew rate technic- the rate of output voltage change with respect to per unit time is known as slew rate. Darlington amplifier design using slew rate technic measure the change in amplitude, change in output frequency etc. in this technique used CMOS nanotechnology like GPDK 180nm,90nm, &45nm.The main advantage of this technic reduces power consumptions and reduces low noise.

Series packing technique- In series packing technique many transistor using and create a resonator working for various quality of higher frequency. This technique use design Darlington amplifier for wide band with low noise amplifier for radio amd micro wavw frequency range. The main advantage of this technique provide stability against various parameter like input voltage, current gain temperature stability, etc. CMOS technology is best example of this technic.

Capacitor Compensation Technique- This technique design based on gain boosting on CMOS OPA and in biasing is based on capacitor compensations, so it called capacitor compensations technique. It is operated on in power supply rail to rail supply. The main advantage of this technique is flat gain with larger bandwidth for low power and low volage. This technique provided high speed closed loop bandwidth and power consumptions in mW.

A thorough survey of available literature-

In this study, the author has tried to know the technology, topology, bandwidth, power consumption, noise figures and the area used for the chip by studying the Darlington pair-based amplifier made in about 25 years. Another important aspect of this study is that for which bands of communication amplifiers currently designed from Darlington pairs can be used& how to control power consumption from what is currently known and make portable devices used longer.

S.N.	Year	Technology	technic	Stage	Bandwidth	Gain	Power consumptio	N.F.	Area

							ns		
1a	1989	Silicon Bipolar Monolithic			3.2GHz	9.3dB			
2b	1991		HBT	two	20GHz	3dB	60mW		
3c	1993	Complimentry tecnology	HBT		2GHz	7.5dB			
4	1995		HBT		1-8 GHz	17.5dB		2.5dB	
5	1996		HEMT&HBT		10GHz	10dB		1.5-2dB	
6	1998		HBT		86GHz	10dB			
7	2000				25.5GHz	10.95dB	40mW		
8	2004	feedback			500MHz-2.5GHz	-16dB			
9	2006	Feedback matched	PHEMT		1-3GHZ	15dB		3.3dB	
10	2007		HEMT		18.7GHz	14.7dB			
11	2009	0.018µm			17GHz	10dB	306mW		$0.67mm^2$
12	2010				30GHz	3dB			
13	2012		HBT & HEMT	Two		13.2dB	90mW		
14	2013	0.18 µm			26GHz	15.2dB	711mW		$1.41 \times 0.61\ mm^2$.
15	2014	0.25 µm GaAs pHEMT		Single	0.8-32.7	6	450mW		1.15
		0.25 µm GaAs pHEMT		Three	1.5-29.5	17.8	1370mW		2.9
16	2015		HBT	three	237MHz	47dB			
17	2016	Gpdk 90nm				20.5dB			

18	2017	0.18 µm			27GHz	3dB	94.3mW		
19	2018		HBT&HEMT		0.2-6GHz	24dB			**0.27 mm^2**
20	2020	0.18µm	pHEMT	two	16.7GHz	26dB			
21	2021	130nm	pHBT		70GHz	13.4dB	55mW		
22	2022				6GHz	15dB	55mW		0.22mm^2
23	2023	0.18um		Two	39GHz	11.52dB	25mW		

Conclusions- The contribution of Darlington Pair in the field of communication cannot be ignored. It is a different matter that nowadays a new mode of reducing power consumption is available, but no one can compete with an amplifier made of inverted pair in high-speed data transfer. If the power consumption is further controlled by using a new mode and the bandwidth is increased beyond GHz, then even today no one can compete with the dark ones.

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