Bipolar Junction Transistor Output Characteristics (BC457) with LabView (Technical Documentation)

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***Abstract*— To observe the output transfer characteristics of the BC546/547/548/549/550 NPN Epitaxial Silicon Transistor, a measurement system was created.**

Keywords—National Instruments USB-6001 (Low cost DAQ USB Device), Transistor BC547, Printed Circuit Board (PCB), National Instruments Software, NI LabVIEW©2020, DAQ module for automated collection of data.

I. INTRODUCTION

The Bipolar Junction Transistor (BJT) is a fundamental semiconductor device widely used in electronic circuits for amplification, switching, and signal modulation. The BC547, a general-purpose NPN transistor, is commonly employed in low-power applications due to its reliability and ease of use. Understanding the output characteristics of a BJT, such as the BC547, is crucial for designing and optimising electronic circuits. These characteristics, which describe the relationship between the collector current (I_C) and the collector-emitter voltage (V_{CE}) for different base currents (I_B), provide insights into the transistor's behaviour in various operating regions, including the active, saturation, and cutoff regions [1].

LabVIEW, a powerful graphical programming environment, offers a versatile platform for acquiring, analysing, and visualising data in real-time. By integrating LabVIEW with hardware interfaces, the output characteristics of the BC547 transistor can be efficiently measured and analysed. This approach not only simplifies the experimental setup but also enhances the accuracy and reproducibility of the results. In this study, we present a methodology for characterising the BC547 transistor using LabVIEW, highlighting its advantages in terms of automation, data processing, and visualisation [2].

II. HARDWARE DESCRITION

A. NI USB-6001

The NI USB-6001 is a compact, multifunctional data acquisition (DAQ) device manufactured by National Instruments (NI), designed for a low-cost measurement and automation applications. It offers 8 analog inputs, 2 analog outputs, 12 digital I/O lines, and a 32-bit counter, making it suitable for a wide range of laboratory and industrial tasks. With a maximum sampling rate of 20 kS/s and 14-bit resolution, the USB-6001 provides sufficient accuracy for many low-speed signal acquisition and control applications. Its plug-and-play functionality, powered entirely by the USB bus, ensures ease of use and portability. Additionally, the device is compatible with LabVIEW, enabling seamless integration for data acquisition, analysis, and visualisation. The USB-6001 is widely used in educational, research, and prototyping environments due to its affordability, reliability, and versatility [3].

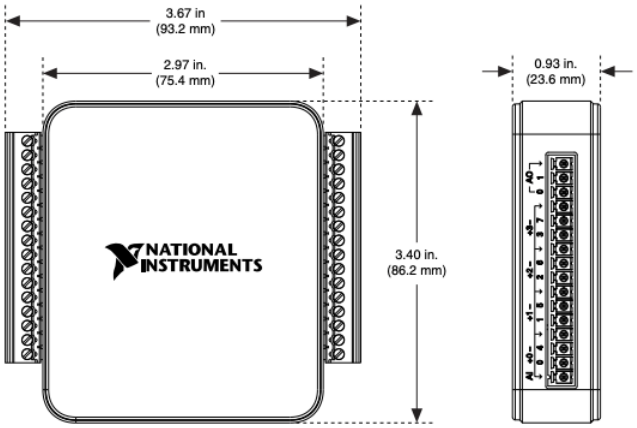


Figure 1: NI USB-6001 Dimensions [4].

Specifications for NI USB-6001:
The NI USB-6001 is a versatile data acquisition device with robust analog and digital capabilities. On the analog front, it features four differential and eight single-ended analog input channels and also providing flexibility for various signal measurement configurations [4].

Additionally, it includes two analog output channels with an operating voltage range of 0 to 5V, suitable for generating control signals in low-voltage applications [4].

On the digital side, the device offers 12 digital I/O lines, divided into Port 0 (P0.0-P0.7) with 8 configurable lines and Port 1 (P1.0-P1.3) with 4 lines, supporting a high output voltage of up to 5.8V. It also provides an external voltage

output of +5V with a maximum output current of 200mA, enabling it to the power external sensors or peripherals [4]. Furthermore, USB-6001 includes a 32-bit event counter for precise timing and counting applications. The device is equipped with a USB 2.0 full-speed interface (12 Mb/s), ensuring fast and reliable data transfer between the DAQ and the host computer [4].

Device Pinout of NI USB-6001:

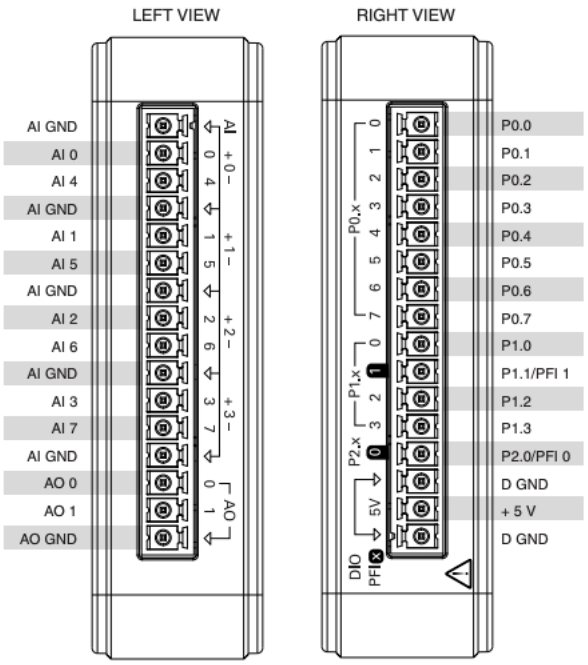


Figure 2: Device Pinout [4].

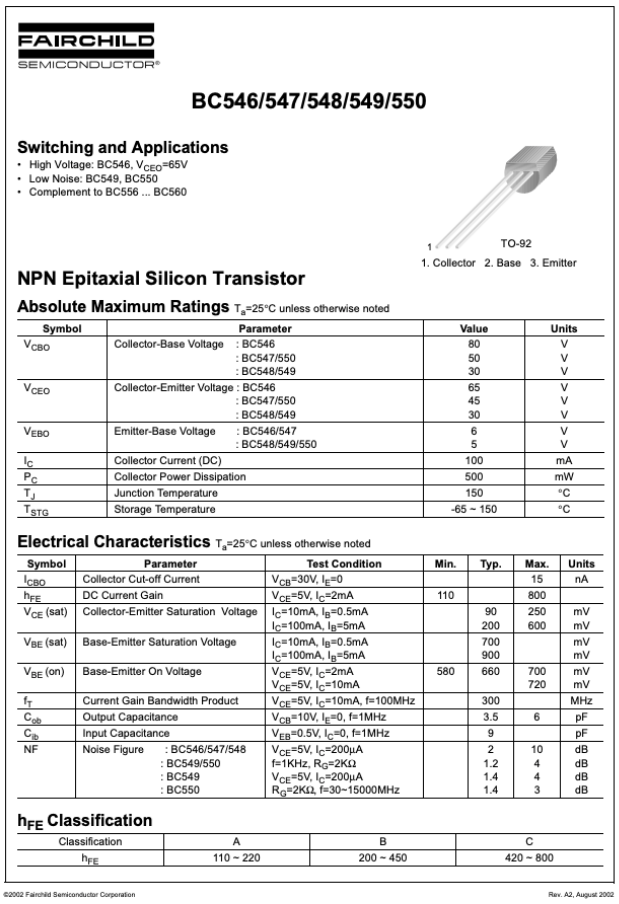
B. TRANSISTOR BC547

The BC547, being an NPN transistor, operates such that when its base pin is grounded, the collector and emitter remain open (reverse-biased), effectively blocking current flow. However, when a signal is applied to the base pin, the collector and emitter become closed (forward biased), allowing current to flow [5].

The transistor's current gain (β) ranges from 110 to 800, which determines its amplification capability. Due to its design limitations, the BC547 cannot drive loads requiring more than 100 mA, as the maximum current allowed through the collector pin is restricted to this value [5].

To bias the transistor for output characteristics, a base current (I_B) must be supplied, typically limited to a maximum of 5 mA to avoid damage. When the transistor is fully biased, it enters the Saturation Region, allowing a maximum current of 100 mA to flow between the collector and emitter. In this region, the typical voltage across the base-emitter junction (V_{BE}) is approximately 900 mV, while the collector-emitter voltage (V_{CE}) is around 200 mV [5].

Conversely, when the base current is removed, the transistor enters the Cut-off Region, effectively turning off, with the base-emitter voltage (V_{BE}) typically measuring around 660 mV [5].


BC546/547/548/549/550

FAIRCHILD SEMICONDUCTOR®

BC546/547/548/549/550

Switching and Applications
- High Voltage: BC546, V_{CEO}=65V
- Low Noise: BC549, BC550
- Complement to BC556 ... BC560

TO-92
1. Collector 2. Base 3. Emitter

NPN Epitaxial Silicon Transistor

Absolute Maximum Ratings T_a=25°C unless otherwise noted

Symbol	Parameter		Value	Units
V_{CBO}	Collector-Base Voltage	: BC546	80	V
		: BC547/550	50	V
		: BC548/549	30	V
V_{CEO}	Collector-Emitter Voltage	: BC546	65	V
		: BC547/550	45	V
		: BC548/549	30	V
V_{EBO}	Emitter-Base Voltage	: BC546/547	6	V
		: BC548/549/550	5	V
I_C	Collector Current (DC)		100	mA
P_C	Collector Power Dissipation		500	mW
T_J	Junction Temperature		150	°C
T_{STG}	Storage Temperature		-65 ~ 150	°C

Electrical Characteristics T_a=25°C unless otherwise noted

Symbol	Parameter	Test Condition	Min.	Typ.	Max.	Units
I_{CBO}	Collector Cut-off Current	V_{CB}=30V, I_E=0			15	nA
h_{FE}	DC Current Gain	V_{CE}=5V, I_C=2mA	110		800	
V_{CE} (sat)	Collector-Emitter Saturation Voltage	I_C=10mA, I_B=0.5mA		90	250	mV
		I_C=100mA, I_B=5mA		200	600	mV
V_{BE} (sat)	Base-Emitter Saturation Voltage	I_C=10mA, I_B=0.5mA		700		mV
		I_C=100mA, I_B=5mA		900		mV
V_{BE} (on)	Base-Emitter On Voltage	V_{CE}=5V, I_C=2mA	580	660	700	mV
		V_{CE}=5V, I_C=10mA			720	mV
f_T	Current Gain Bandwidth Product	V_{CE}=5V, I_C=10mA, f=100MHz		300		MHz
C_{ob}	Output Capacitance	V_{CB}=10V, I_E=0, f=1MHz		3.5	6	pF
C_{ib}	Input Capacitance	V_{EB}=0.5V, I_C=0, f=1MHz		9		pF
NF	Noise Figure : BC546/547/548	V_{CE}=5V, I_C=200μA		2	10	dB
	: BC549/550	f=1KHz, R_G=2KΩ		1.2	4	dB
	: BC549	V_{CE}=5V, I_C=200μA		1.4	4	dB
	: BC550	R_G=2KΩ, f=30~15000MHz		1.4	3	dB

h_{FE} Classification

Classification	A	B	C
h_{FE}	110 ~ 220	200 ~ 450	420 ~ 800

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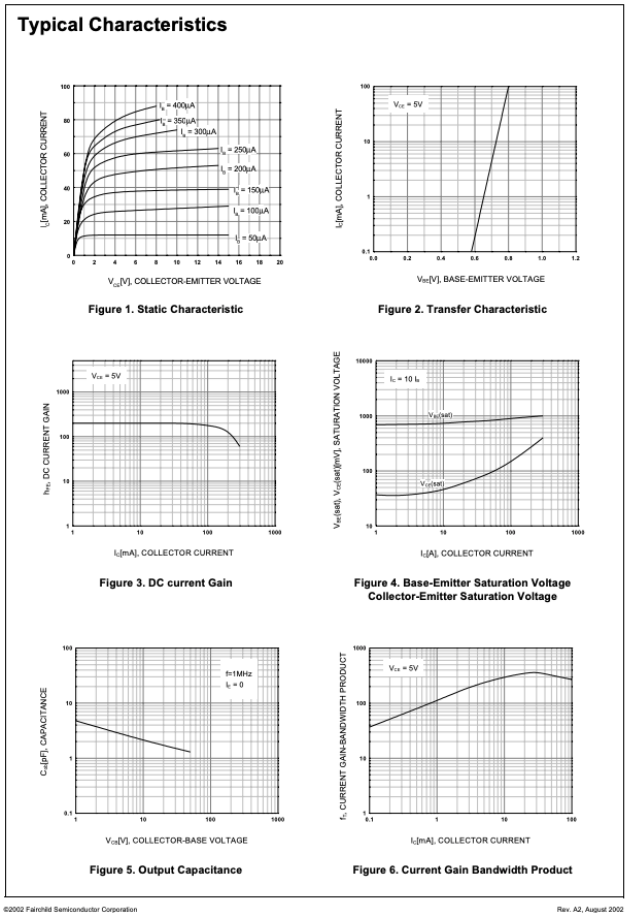
Figure 3: Switching and Applications of BC547 [5].

Typical Characteristics of BC547:


BC546/547/548/549/550

Typical Characteristics

Figure 1. Static Characteristic

Figure 2. Transfer Characteristic

Figure 3. DC current Gain

Figure 4. Base-Emitter Saturation Voltage Collector-Emitter Saturation Voltage

Figure 5. Output Capacitance

Figure 6. Current Gain Bandwidth Product

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Figure 4: Typical Characteristics of BC547 [5].

The BC547 Transistor has the following characteristics: Bi-Polar NPN Transistor; DC Current Gain (h_{FE}) of 800 at its highest; Continuous Collector Current (I_C) of 100mA; Emitter Base Voltage (V_{BE}) of 6V; Base Current (I_B) of 5mA at its maximum; and To-92 Package Availability [5].

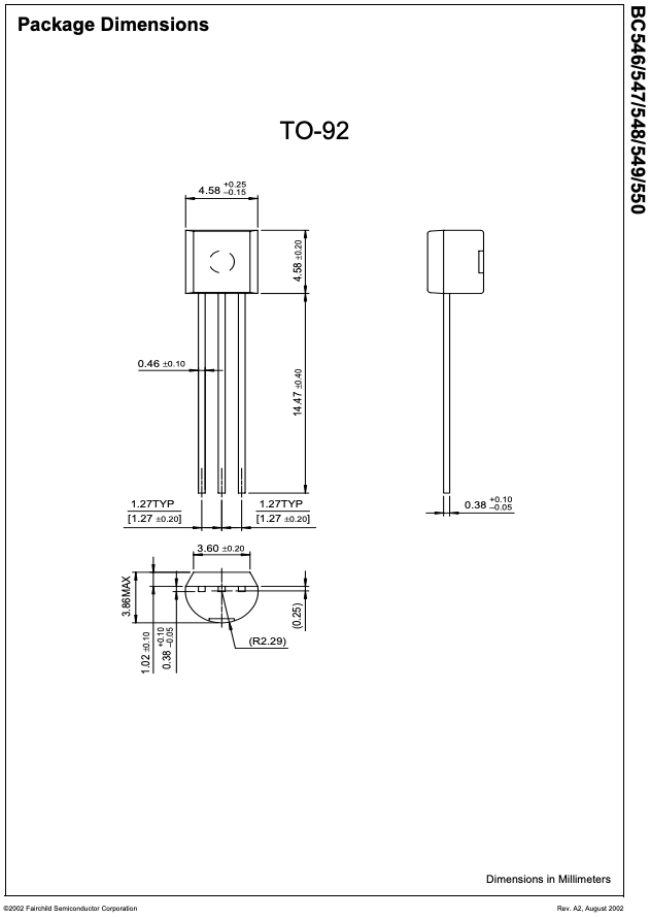

Figure 5: Package Dimenions of BC547 [5].

C. PRINTED CIRCUIT BOARD (PCB)

The PCB schematics are displayed in Figure (6 and 7). The two signals that the NI USB-6001 produces through the AO0 and AI2 interfaces are U_B and U_C. Two signals are sent to the transistor: one is sent to the base, and the other is amplified before being sent to the transistor's collector [6], [7].

A range of voltages are applied at these two working locations. When combined with computed current values, these voltages aid in the graphing of the transistor's transfer output characteristics [6], [7].

Additionally included in the schematic is a voltage protection circuit in case the operational 12 V_{DC} external voltage is exceeded. It also uses LM335 as a temperature sensor [7].

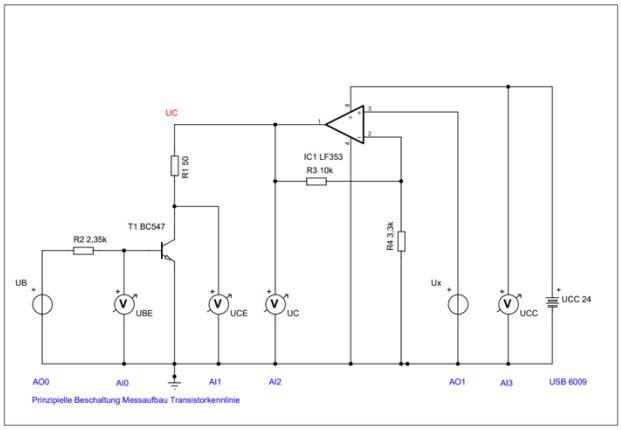

Figure 6: Basic Wiring Measurement Setup Transistor Characteristic [6].

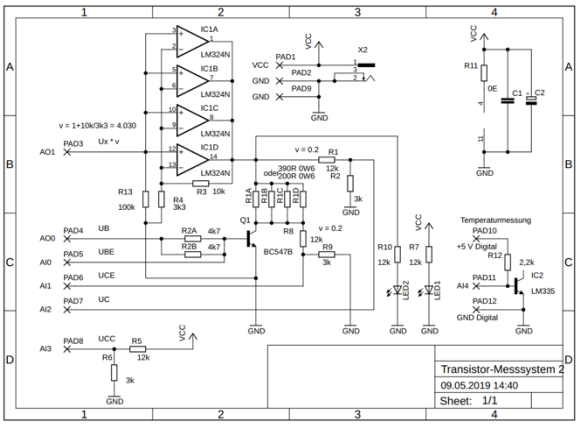

Figure 7: Transistor Measuring System [7].

D. DAQ Module to Acquire Data

The National Instruments DAQ module is responsible for data acquisition. Measurement of electrical or physical phenomena, such as voltage, current, temperature, pressure, or sound, using a PC is known as data acquisition (DAQ) [8].

A PC with programmable software (in our example, LabView), a variety of sensors, and DAQ measurement equipment make up a DAQ system. The DAQ uses signals from the experimental setup to function, digitizes the signals, analyzes the values it receives, stores the data, and displays it to the user [8].

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