Operating Conditions Dependence of the Junction Characteristics of Optocouplers

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Abstract

The present paper is a trial to shed further light on the dependence of the junction characteristics of the proposed optocoupler type 4N25 on the operating conditions; the applied voltage and signal frequency. For the input light emitting diode and output phototransistor, their forward and reverse (C–V) characteristics were investigated and plotted at different applied bias voltage- and frequency- levels. In this concern, the diffusion- and transition- capacitances, impedance, quality- and dissipation- factors, and the phase angle were investigated. Concerning the light emitting diode, at frequency value of 200 kHz, as an example, the diffusion capacitance value increases exponentially from 0.166 nF, up to 4.71 nF, measured at forward bias voltages of 0.01 Volt and 1.20 Volts, respectively. Also, at an applied forward bias voltage of 1.0 Volts, the diffusion capacitance increases from 1.76 nF up to 2.84 nF, measured at frequency levels of 50 kHz and 300 kHz, respectively. Considering the transition capacitance, and at signal frequency of 200 kHz, its value was shown to be decreased rapidly from 178.36 pF down to 30.42 pF whenever measured at 0.01 Volt and 0.30 Volt, respectively. But for higher bias voltages, the decreasing rate was shown to be negligible. On the other hand, at applied bias voltage of 1.0 Volt, its value was shown to be decreased from 28.76 pF down to 17.59 pF, measured at frequency levels of 50 kHz and 300 kHz. For the phototransistor, its emitter junction capacitance increased exponentially as a function of the emitter-base bias voltage, where at frequency of 200 kHz, as an example, its value increased from 0.581 nF up to 3.048 nF, measured at 0.01 Volt and 0.80 Volt, respectively. On the other hand, the collector junction capacitance was shown to be decayed rapidly as a function of the applied reverse bias voltage. Where its value decreased from 1.29 nF down to 0.012 nF, measured at 0.01 Volt and 0.90 Volt, at frequency of 200 kHz, as an example. Finally, it is proved that for both capacitances, their values are a direct decreasing functions of the operating frequency, where at applied bias voltage of 0.8 Volt, a values of 7.6878 nF and 0.05338 nF were decreased down to 1.811 nF and 0.0254 nF, respectively, with increasing the frequency from 50 kHz up to 300 kHz.

1. Introduction
1.1 Description of the Optocouplers

An opto-coupler (opto-electronic coupler) is essentially a photo-transistor/photo-diode and a Light Emitting Diode (LED) combined in one package, emerging optocoupler (Reed, et

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al., 1998, Yao, et al., 2007, Chin Wey, et al., 2013, Lei Tian, et al., 2014 and Chouthai, et al., 2013). The input of an optocoupler consists of an infra-red LED die; while, its output consists

of a detector die which typically is a photo bipolar NPN transistor. The input and output dice are separated by an electrically insulated material which is transparent to infrared light. The input and output components and their light transmitting medium are encased in molded plastic, metal can or ceramic enclosure. In this concern, the optocouplers of the type 4N25 were investigated throughout the study, where, Fig. (1) shows their circuit description and pin out (Eugene, et al., 2009). The 4N25 comes in a 6-pin dual inline package (DIP) and contains a gallium-arsenide light emitting diode and a silicon bipolar phototransistor coupled vertically meaning that the LED is directly on top of the phototransistor.
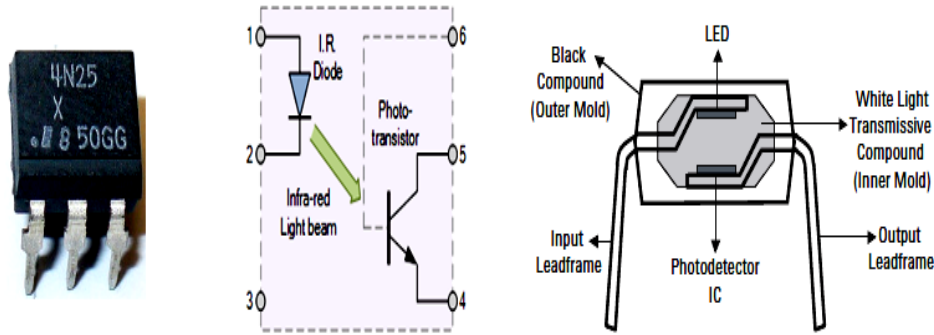
Fig. (1): The 4N25 optocoupler and its pin diagram.

1.2 Operating Principles of the Optocoupler

Optocouplers operate on the principle that light can be emitted, transmitted, and absorbed by a semiconductor to communicate signals optically (Reed, et al., 2004). The optical signal electrically isolates the microelectronic circuits on either side of the optocoupler (Fig. 2). From which, when the current flows in the LED, it emits infrared light, goes through the insulation material and detected by the collector base region of the phototransistor. Where an electron hole pairs is generates in the collector base region resulting in a photo current flowing into the base of the bipolar transistor. This photo current is multiplied by the current gain, beta, of the bipolar transistor to produce an output collector current. A current transfer ratio, CTR, of an optocoupler is defined as the ratio of the output collector current over the current flowing in the infrared LED (Eugene, et al., 2009).
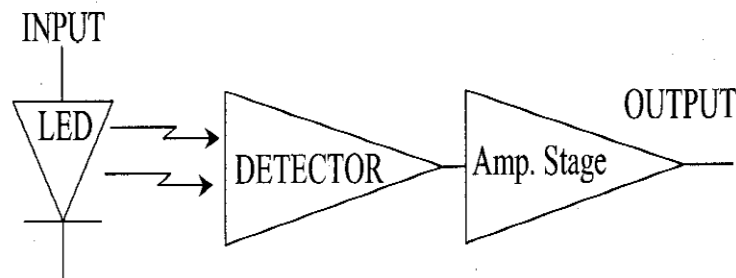
Fig. (2): Typical Optocoupler design.

1.3 Importance of Junction Characteristics Studies

Capacitance–voltage profiling is a technique for characterizing semiconductor materials and devices. The depletion region in the junction devices with its ionized charges inside behaves like a capacitor. So, by varying the voltage applied to the junction it is possible to vary the depletion width. The dependence of the depletion width upon the applied voltage provides information on the semiconductor's internal characteristics, such as its doping profile and electrically active defect densities. Measurements may be done at DC, or using both DC and a small-signal AC signal (the conductance method), or using a large-signal transient voltage. Besides, (C-V) measurements are widely used to characterize wide spectrum of semiconductor devices and technologies, including bipolar junction transistors, JFETs, III–V compound devices, photovoltaic cells, MEMS devices, organic thin-film transistor (TFT) displays, photodiodes, and carbon nano-tubes (CNTs). Finally, the junction capacitance may be used to measure doping concentration in the semiconductor side of a diode as well as determining the built-in potential and junction area of a device (Dutta, et al., 2013). In the present paper, both the diffusion- and transition- capacitances (C_D, and C_T), the impedance (Z), quality- and dissipation- factors (Q, D), and phase angle (Φ) of the input LED and output phototransistor of optocoupler were investigated.

2.0 Materials and Methods

During the course of the present paper a detailed study concerning the dependence of the junction characteristics of the input LED and output phototransistor of the proposed optocoupler type 4N25 on the operating voltage and frequency was carried out. In this concern, the following parameters: C_D, C_T, Z, Q, D and Φ were investigated and plotted as a function of the applied bias voltage ranging from 0.01 Volt up to 1.2 Volts (forward and reverse), with different frequency levels ranging from 50 kHz up to 300 kHz using a programmable automatic LCR meter type PM-6306, manufactured by Fluke.

3.0 Results and Discussions

3.1 (C-V) Characteristics of Input LED
3.1.1 Diffusion - and - Transition Capacitances

The diffusion -and transition -capacitances were given in Eqs. (1 and 2), respectively (Boylestad, et al., 1999 and Bogdan, et al., 2011):

$$C_{dif} = \frac{dQ}{dV} = \frac{d}{dV}\left[\tau I_o \exp\left(\frac{V}{\eta V_T} \right) \right] = \frac{\tau I_B}{\eta V_T} \quad \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots(1)$$

Where:
Q : total storage charge at the junction = $I_B \tau$,
τ : storage time,
I_B : diode base current, and
η : correction factor has a value between 1 and 2.

$$C_T = \frac{\varepsilon A}{W} \quad \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots(2)$$

Where:

A : junction area,

ε : dielectric permittivity of semiconductor material, and

W : thickness of the depletion layer.

Figure (3) shows the dependence of both the diffusion (C_D) - and transition (C_T) - capacitances on the applied bias voltage, plotted at different signal frequency levels. From which, it is clear that, both capacitances are functions of the applied voltage and the frequency. Considering, the diffusion capacitance (Fig. 3a), its value is a function of the diode current, storage time τ, and diode biasing current I_B, as given from Eq.1 (Bogdan, et al., 2011 and El - Ghanam and Abdel Basit, 2011). At frequency value of 200 kHz, as an example, the diffusion capacitance value increases exponentially from 0.166 nF, up to 4.71 nF, measured at the forward bias voltages of 0.01 Volt and 1.20 Volts, respectively. Also, at a certain value of the applied forward bias voltage of around 1.0 Volts, the diffusion capacitance increases from 1.76 nF up to 2.84 nF, measured at frequency levels of 50 kHz and 300 kHz, respectively. On the other hand, for the reverse-bias voltage (Fig. 3b), and at frequency of 200 kHz, as an example, C_T decreased rapidly from 178.36 pF down to 30.42 pF, measured at lower bias voltage less than 0.3 Volt. For higher voltage values, up to 1.2 Volts, its value was shown to be almost constant. The matter which is attributed to the existence of depletion region which behaves essentially like an insulator. Since the depletion width (w) will increase with increased reverse-bias potential, the resulting transition capacitance will decrease, as given from Eq.2 (Boylestad, et al., 1999). At a certain Value of a reverse applied voltage of 1.0 Volts, C_T decreased from 28.76 pF to 17.59 pF measured at frequency levels of 50 kHz and 300 kHz.
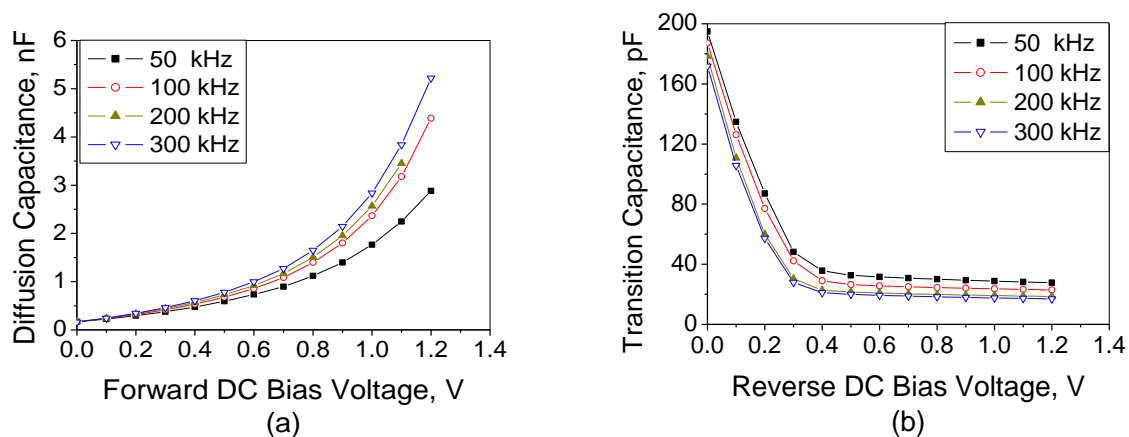

Fig. (3): Dependence of the diffusion (a) - and transition (b) - capacitances on the applied voltage, plotted at different signal frequency values.

3.1.2 Impedance

It is well known that the impedance of a circuit is defined as the ratio of the phasor voltage and the phasor current (Kim, et al., 2011). In this concern, considering the input LED, the dependence of its impedance on bias voltage in either the forward - or reverse - bias voltages were investigated and plotted at wide signal frequency band ranging from values of 50 kHz up to 300 kHz (Fig. 4). For the forward bias conditions, the impedance was proved to be function, only, on the forward bias voltage rather than the signal frequency (Fig. 4a), where its value decreases from 1.50 kΩ, measured at bias voltage 0.01 Volt, down to 0.02 kΩ,

measured at bias Voltage of 1.20 Volts (at f =200 kHz, as an example). On the other hand, the reverse impedance (Fig. 4b) was shown to be function of both the applied reverse bias and frequency. For low reverse bias voltages value, up to around 0.30 Volts, the impedance was shown to be with weak dependence of the applied bias, while its value is independent of the frequency. For intermediate bias voltages, from 0.3 Volt up to around 0.7 Volt a rapid increase on the impedance value was observed, depending on the applied signal frequency. Finally, for higher bias voltages, a saturation or semi-saturation on the impedance value was recorded.
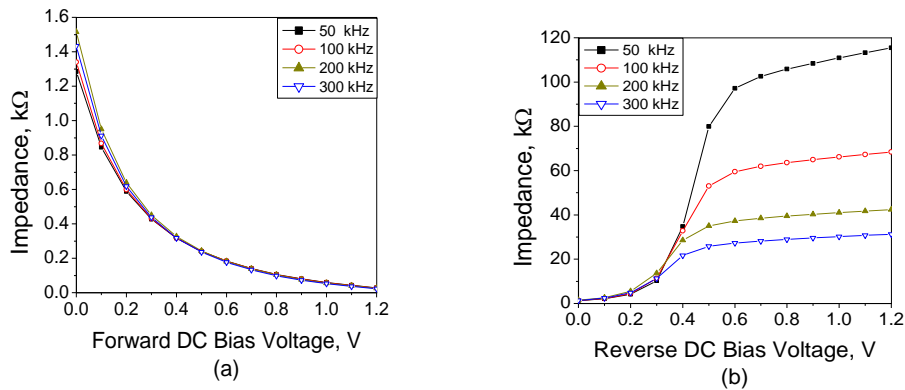

Fig. (4): Dependence of LED impedance on (a) forward-bias voltage and (b) reverse-bias voltage, plotted at different signal frequencies.

3.1.3 Quality Factors

Another important parameter of a capacitance diode is the quality factor (Q), which also called figure of merit, the value which should be high (Godse, et al., 2008). The quality factor of a reactive element either capacitor or inductor is the ratio of energy stored and returned by the element to the energy dissipated in the device resistance. Also, Q of a resonator can be defined as the ratio of the energy stored in a system to the energy dissipated per radian of the vibration cycle. Finally, Q can be expressed as (Hopcroft, et al., 2007):

$$Q = 2\pi \frac{E_{stored}}{E_{dissipated/cycle}}$$ …………………………………..……(3)

At high frequency levels, Q of a parallel capacitance diode could be expressed as (El - Ghanam and Abdel Basit, 2011):

$$Q = 2\pi f C R$$ ……………………………………………………(4)

Where:
f : frequency of the applied voltage,
C : equivalent parallel capacity, and
R : equivalent parallel resistance.

As deduced from Equ. (4), Q factor of a capacitance diode varies with the reverse bias; this is because the diode capacitance decreases as the reverse voltage is increased; Q is also

dependent on frequency. As shown in (Fig. 5), Q factor plotted as a function of forward and reverse bias voltage at different signal frequency levels. For forward bias voltage (Fig. 5a), Q factor decreased from 0.334 down to 0.158 measured at bias voltage value of 0.01 Volt and 1.2 Volts, at signal frequency of 200 kHz, as an example. On the other hand, for reverse bias voltage (Fig. 5b) increase from 0.01 Volt up to 0.6 Volt, Q factor increase from 0.368 up to 2.65, at F=200 kHz, as an Example, as the bias voltage increased up to 1.2 Volts, the Q factor almost constant. At a certain value of voltage (1.0 volts), as an example, Q factor of both forward and reverse bias voltage increased from 0.043 and 2.5656 up to 0.297 and 3.12, respectively, measured at a signal frequency value of 50 kHz and 300 kHz.
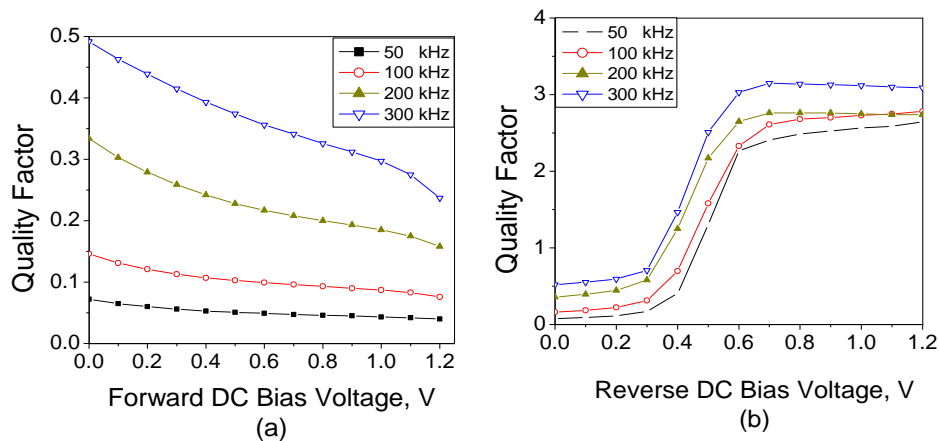

Fig. (5): Dependence of LED quality factor on (a) forward-bias voltage and (b) reverse-bias voltage, plotted at different signal frequency values.

3.1.4 Dissipation Factor

In principle, the dissipation factor (D) is simply the reciprocal of the Q factor, which in general could be expressed as (Rodahl, et al., 1995):

$$D = \frac{1}{Q} = \frac{E_{dissipated/ cycle}}{2\pi\, E_{stored}}$$ ……………………………………… (5)

An ideal capacitor stores energy without dissipating any power. However, due to equivalent resistances (R_{eq}), some power will be dissipated. So, one important characteristics of a capacitance diode the dissipation factor (D), which is expressed as (Dyer, 2001):

$$D = \tan\delta = \frac{R_{eq}}{X_{eq}}$$ ……………………………………………..…(6)

Where:
δ : angle of loss, and
X_{eq}: equivalent reactance

For the capacitor, D is related to the parallel resistance, R by:

$$D = \frac{1}{Q} = \frac{1}{2\pi f C R}$$ …………………………..…………..…................. (7)

From which, it is clearly shown that D is a direct function of both the applied voltage and signal frequency. A typical D curve of LED of optocoupler type 4N25 in the forward - and reverse - bias voltages, plotted at different signal frequency levels is depicted in Fig. (6). For forward bias voltage (Fig. 6a), D factor increased from 2.93 up to 5.92 measured at bias voltage value of 0.01 Volt and 1.2 Volts, at signal frequency of 200 kHz, as an example. At a certain value of voltage (1.0 volts), as an example, D factor of the forward bias voltage decreased from 21.5 down to 3.21, measured at a signal frequency value of 50 kHz and 300 kHz. On the other hand, for reverse bias voltage (Fig. 5b), from 0.01 Volt up to 0.5, D factor value was shown to be decrease from 2.8 down to 0.46, at F=200 kHz, as an Example, as the bias voltage increased up to 1.2 Volts, D factor almost constant. At lower bias voltage up to 0.5 Volt, D factor decreased as the signal frequency value increased, but for higher voltage up to 1.2 Volts, the D factor almost constant.
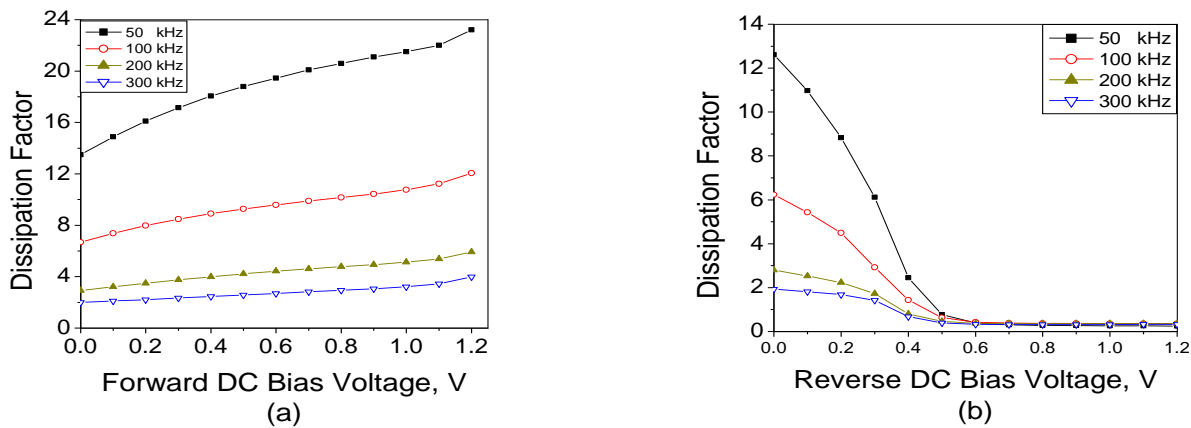

Fig. (6): Dependence of LED dissipation factor on forward (a)- and reverse (b)-bias voltages, plotted at different signal frequency values.

3.1.5 Phase Angle

It is well known that with reactive elements there will be a phase shift between the current and voltage. For a pure capacitive load the current will lead the voltage by 90° and for a pure inductive load the current will lag the voltage by 90°. With a mixture of resistive and reactive loads the phase angle will be somewhere between +90° and -90°, either leading or lagging (El - Ghanam and Abdel Basit, 2011).In this concern, the nature of the variation of phase angles as a function of the both the forward and reverse bias voltage is shown in Fig. (7). For forward bias voltage (Fig.7a), the phase angle increased from -18.9° up to -9.6° measured at bias voltage value of 0.01 Volt and 1.2 Volts, at signal frequency of 200 kHz, as an example. On the other hand, for the case of the reverse biased voltage (Fig. 7b), as its value increases from 0.01Volt up to 0.6 Volt, the phase angle decreases from -19.9° down to -69.6°, at F=200 kHz, as an example. Further increase in the bias voltage up to 1.2 Volts, shows that the phase angle almost constant. At a certain value of voltage (1.0 volts), as an

example, the phase angle of both forward and reverse bias voltage increased from -2.7°and -67.2°up to -17.3° and -72.6°measured at a signal frequency value of 50 kHz and 300 kHz.
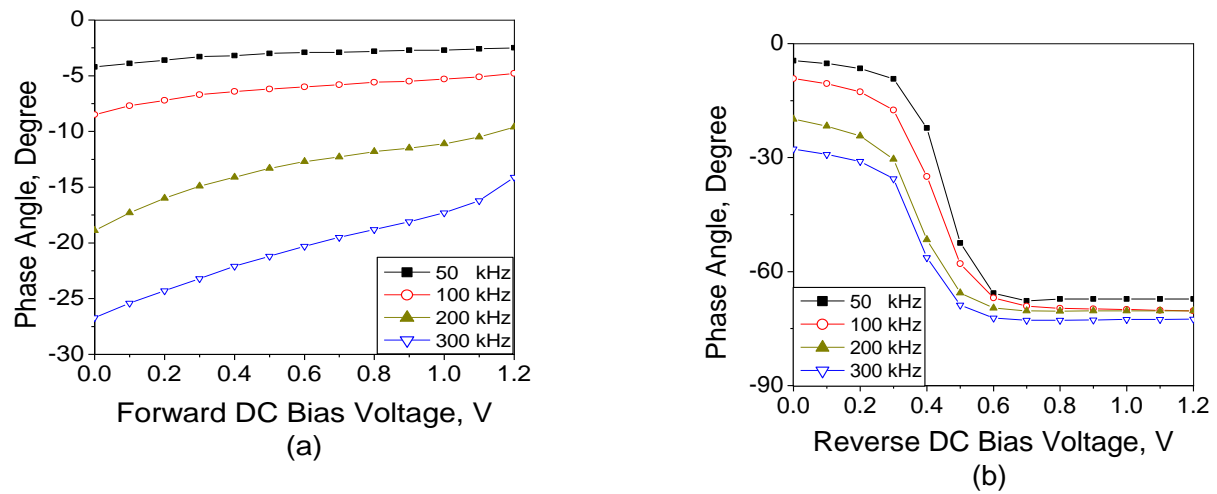

Fig. (7): Dependence of LED phase angle on forward (a)- and reverse (b)-bias voltages, plotted at different signal frequency values.

3.2 (C-V) Characteristics of Phototransistor
3.2.1 Emitter Diffusion -and Collector Transition -Capacitances

The capacitance–voltage relationships (C–V) of the emitter diffusion - and collector transition -capacitances of the phototransistor were studied at different frequency levels (Fig. 8). For the emitter junction, Fig. (8a) shows the forward emitter-base voltage dependence of the C_D, plotted as a function of different operating frequency values in the range from 100 kHz up to 300 kHz. It is clearly shown that, as an example, at frequency value of 200 kHz, C_D increases as a function of the emitter-base bias voltage, where a value of 0.581 nF, measured at 0.01 Volt, increases up to 3.048 nF, measured at 0.80 Volt. Considering the frequency, it is clearly shown from the same figure that, for the same bias-voltage values, C_D decreases as a function of frequency (El - Ghanam and Abdel Basit, 2011). Noting that C_D is independent of the junction area, but it depends mainly on the diode current (Eq. 1). On the other hand, for the collector-base junction, Fig. (8b) shows the (C-V) relationship, plotted at four different frequency levels of 50 kHz, 100 kHz, 200 kHz, and 300 kHz. It is clearly shown that the collector transition capacitance is a function of both the reverse voltage and frequency (Eq. 2). As an example, at 200 kHz, a capacitance value of around 1.2985 nF, measured at bias voltage (V_{CB}) of 0.01 Volt, decays rapidly as a function of the applied reverse voltage, where it reaches approximately a value of 0.01226 nF at V_{CB} value of 0.90 Volt. Considering the frequency, at a certain value of voltage of o.6 Volt, C_T decrease from 0.32 nF down to 0.11 nF as a frequency increased from 50 kHz up to 300 kHz.
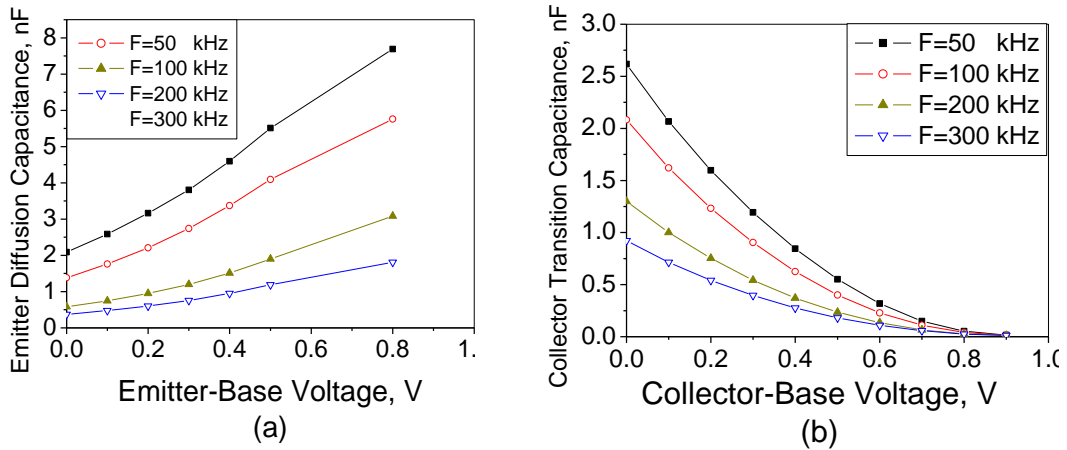
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Fig. (8): Dependence of the emitter diffusion (a)-and (b) collector transition -capacitances on bias voltage, plotted at different frequency values.

3.2.2 Impedance of Emitter -and Collector -base Junctions

Considering the junctions impedance, it is clearly shown that for both junctions, their impedances are a functions of their bias voltage values (Fig. 9). For the emitter-base junction, the impedance value was shown to be function of forward bias voltage, while it could be considered independent of signal frequency (Fig. 9a). On the other hand, for the collector-base junction, at low bias value range, from 0.01Volt up to 0.7 Volt, the impedance value was shown to be independent on both the reverse bias voltage and frequency. But, for higher bias voltage values, it is proved that its dependence is shown to be pronounced (Fig. 9b), where its value increased from 10.33 up to 64.53 as a reverse bias voltage increased up to 0.9 Volt, and decreased as a frequency increased.
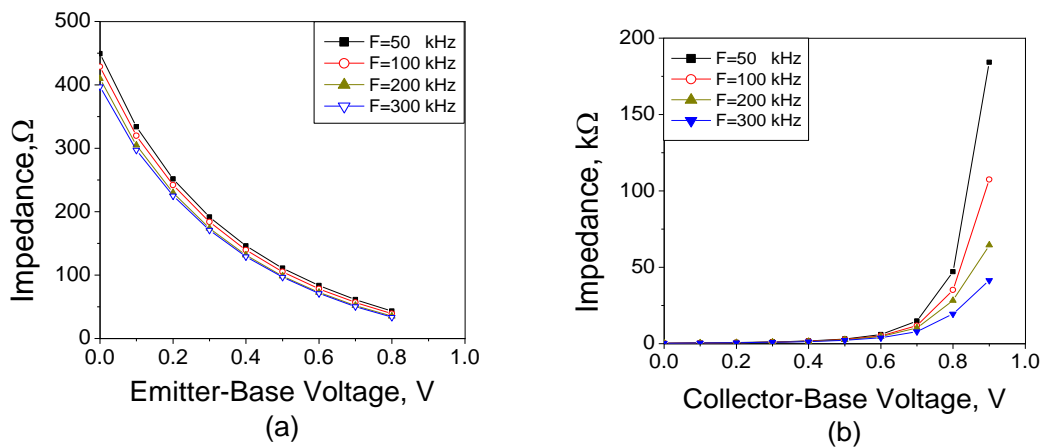

Fig. (9): Impedance-voltage relationships of phototransistor junctions plotted at different frequency values.

3.2.3 Quality Factor of Emitter -and Collector -Base-Junctions

As have been mentioned before, the quality factor is a figure of merit of the transistor, and can be expressed as the ratio of the inductive and capacitance reactance of the junction to its resistance. In this concern, Q dependence on the junction bias was experimentally measured for the output phototransistor. Fig. (10) shows the Q-factor plotted as a function of both forward emitter-base voltage (Fig. 10a) and the reverse collector-base voltage (Fig. 10b), respectively. The measurements were carried out at different frequency values ranging from 50 kHz up to 300 kHz. For the emitter–base junction, Q was shown to be decreased as the emitter-base forward voltage increased. Noting that for the forward emitter-base bias junction, Q was shown to be dependent on both the emitter bias voltage and signal frequency (Equ. 4). On the other hand, for the reverse collector-base mode, the quality factor shows lower dependence on the low bias voltage values up to 0.60 Volt. But, for higher bias voltage values, up to 0.90 Volt, Q shows, relatively, higher dependence on bias value. As an example, at frequency value of 200 kHz, Q was shown to increase from 0.987, measured at bias voltage of 0.40 Volt, up to 2.74, measured at bias voltage of 0.80 Volt.
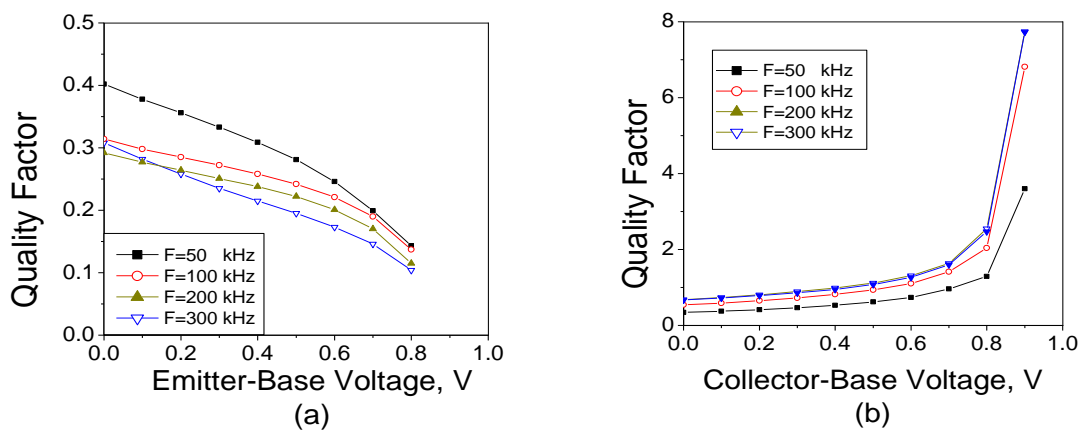

Fig. (10): Quality factor dependence on forward emitter-base bias (a) and voltage reverse collector-base bias voltage (b), plotted at different frequency values.

3.2.4 Dissipation Factor of Emitter -and - Collector base-Junctions

The dissipation factor (D) dependence on bias voltage for both the collector-base and emitter-base junctions of the phototransistor were plotted at different frequency values (Fig. 11). For the emitter-base junction, the value of the dissipation factor was proved to be an increasing function of both forward voltage and frequency (Fig. 11a). On the other hand, for the reverse biased collector-base junction (Fig. 11b), it is clear that the value of D is a decreasing function of both the reverse voltage and frequency. As an example, for a signal of 200 kHz, a dissipation factor value of 1.498, measured at 0.01 Volt, decreases rapidly as a function of the applied reverse voltage value, where it reaches approximately a value of 0.101, measured at bias value of 0.79 Volt.
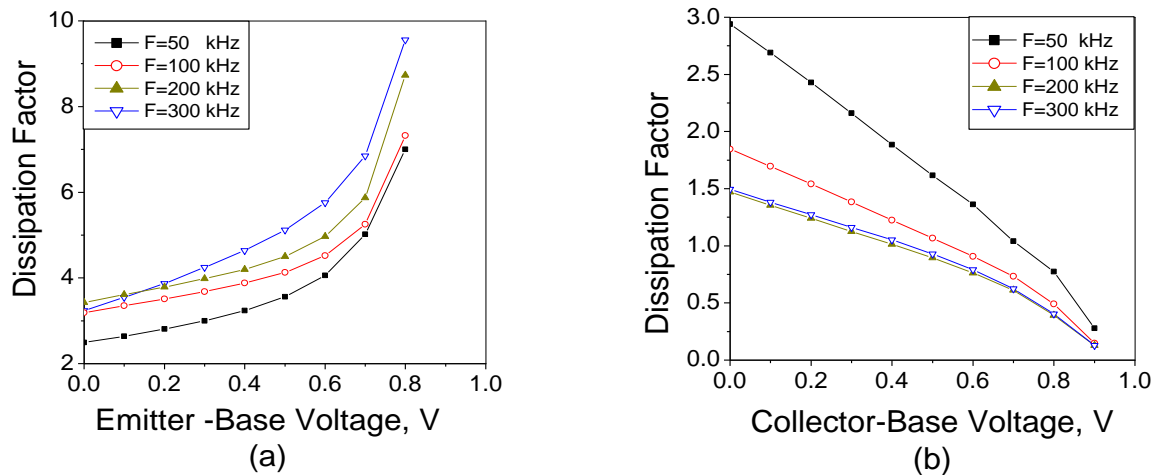
Fig. (11): Dependence of the dissipation factors on forward emitter-base bias voltage (a) and reverse collector-base bias voltage (b), plotted at different frequency values.

3.2.5 Phase Angle of Emitter -and Collector -Base-Junctions

The phase angle (Φ) is the angle between the current passing through the junction and the applied voltage, and is given by the ratio of the total reactance to the total ohmic resistance of the junction. In this concern, Fig. (12) shows the dependence of Φ on bias voltage for the forward emitter-base junction and the reverse collector-base junction, plotted at different frequency levels. For the emitter-base junction (Fig. 12a), Φ was plotted as a function of the forward bias voltage, where it is clearly shown that, it represents a decreasing function of both the forward bias voltage and signal frequency. At F=200 kHz, its value was shown to increase from -16.2°, measured at 0.01 Volt, up to -6.5°, measured at 0.80 Volt. On the other hand, for the reverse junction, it is clear that, for the bias voltage range from 0.01 Volt up to around 0.90 Volt, Φ was slightly increased, that is at 200 kHz, Φ value of -33.7°, measured at 0.01 Volt changes up to -84.2°, measured at applied value of 0.90 Volt. As well, Φ was shown to be direct increasing function of the signal frequency (Fig. 12b). Noting that, Φ is governed by the following equation (El - Ghanam and Abd el Basit, 2011):

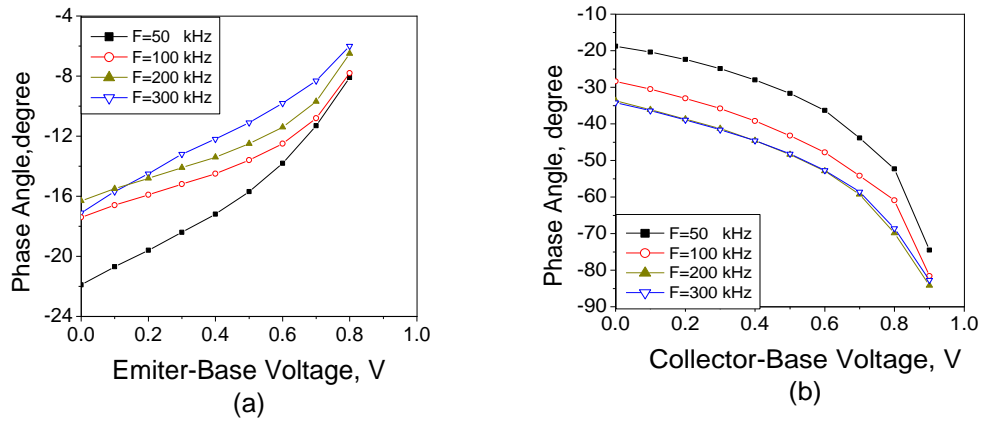$$\tan\theta = \frac{X_c}{R}$$ ……………………………………….…..…………..(8)

Fig. (12): Phase angle versus emitter-base bias voltage (a) and collector-base bias voltage (b), plotted at different signal frequency values.

4. Conclusion

In this paper, a detailed experimental study, and analysis of the junction capacitance characteristics (C-V) of the input LED and output phototransistor of the well known 4N25 optocupler were presented. From which, it is clearly shown that for both devices, and in turn the optocoupler itself, their capacitive characteristics are a direct functions of the operating conditions, from which are the biasing voltage and frequency.

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المخلص باللغة العربية

اعتماد خصائص وصلة نبائط المزدوج الضوئى على ظروف التشغيل

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يهدف هذا البحث إلى إلقاء المزيد من الضوء على إعتماد خصائص وصلة نبيطة المزدوج الضوئى المقترح طراز 4N25 على ظروف التشغيل من جهد مطبق وتردد الإشارة. وفي هذا الصدد فقد تم دراسة ورسم كافة الخصائص الكهربية للنبيطة الثنائيه الباعثة للضوء (دخل المزدوج الضوئى) ولنبيطة الترانزستور الضوئي (خرج المزدوج الضوئى) عند قيم مختلفه لكلا من الجهد المطبق ومستويات تردد الاشاره ومنها موا سعة الانتشا ر (C_D)، مواسعة الانتقال (C_T)، الاعاقه (Z)، معامل الجوده (Q)، معامل الفقد (D)، وزاوية فرق الطور (Φ) وذلك فى حالتى الانحياز الامامى والعكسى . فيما يتعلق بالنبيطة الثنائى الباعثة للضوء، فقد أظهرت النتائج انه عند ثبوت تردد الاشاره عند قيمه معينه تساوى 200 kHz، على سبيل المثال، فان مواسعة الانتشار تزداد كداله اسيه فى جهد الانحياز المطبق من 0.166 nF الى 4.71 nF مقاسه عند قيم للجهود تساوى Volt 0.01 و 1.20 Volts على التوالى. كما ثبت انة حال تطبيق قيمه معينه من الجهد تساوى حوالى 1.0 Volts، على سبيل المثال، فقد تم تسجيل ازدياد فى قيمتها من 1.76 nF الى 2.84 nF مع زياده تودد الاشاره من 50 kHz الى 300 kHz . وعلى الجانب الاخر وعند ثبوت تردد الاشاره عند قيمه معينه تساوى 200 kHz، على سبيل المثال، فان قيم مواسعة الانتقال تقل سريعا من 178.36 pF مقاسه عند جهد يساوى 0.01 Volt الى 30.42 pF مقاسه عند جهد يساوى 0.3 Volt . كما ثبت انة حال تطبيق جهد انحياز اعلى، فأن الانخفاض فى قيمة المواسعة يكاد يكون غير ملحوظ. كما تم تسجيل انة عند قيمه معينه من الجهد يساوى 1.0 Volt،على سبيل المثال، فان قيمة مواسعة الانتقال تقل من 28.76 pF الى 17.59 pF مع زياده تودد الاشاره من 50 kHz الى 300 kHz. اما بالنسبه الى نبيطة الترانزستور الضوئي، فقد ثبت ان قيمه مواسعة وصلة الباعث تزداد كدالة اسية مع الجهود المطبقة على وصلة الباعث- القاعده، حيث ان قيمتف عند تردد معين يساوى 200 kHz ، على سبيل المثال ، تزداد قيمتها من 0.581nF الى 3.048 nF مقاسة عند قيم للجهود تساوى 0.01 Volt و 0.80 Volt على التوالى. على الجه ة الاخرى، فإن قيمتها تضمحل سريعا كدالة فى جهد الانحياز العكسى المطبق ، حيث تقل قيمته من 1.29 nF الى 0.012 nF مقاسة عند قيم للجهود تساوى 0.01 Volt و 0.8 Volt على التوالى. اما بالنسبة الى اعتماد المواسعتين السابقتين على تردد الاشارة، فإنه عند قيمة معينة من الجهود المطبقه تساوى 0.8 Volt لوحظ ان قيمتهما تقل من 7.7 nFو 0.053 nF الى 1.8 nFو 0.03 nF على التوالى مع زيادة تردد الإشاره من 50 kHz الى 300 kHz.