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Description

This invention relates generally to a current output oscillator circuit and, more particularly, to an integrated circuit current output oscillator which is simple, relatively insensitive to temperature and which occupies a small amount of semiconductor area.

Relaxation type oscillator circuits which are responsive to voltage trip points and which generate an oscillating output voltage signal are well-known. The conventional method of producing an oscillating current is to first generate an oscillating voltage and then perform a voltage-to-current conversion. A problem associated with this approach, however, may require excessive semiconductor area and may result in the introduction of additional error during the conversion process.

A circuit in accordance with the prior art portion of claim 1 is disclosed in EP—A—0013207.

The present invention provides an improved oscillator circuit in which said second means comprises:

- a first transistor having a base coupled to said capacitor, and having a collector and an emitter;
- a first resistor coupled between the emitter of said first transistor and a first supply voltage terminal; and

- a current mirror circuit having an input coupled to the collector of said first transistor and having a first output for generating an oscillating output current and having a second output for generating said control current, said current mirror circuit adapted to be coupled to a second supply voltage terminal.

The above and other objects, features and advantages of the present invention will be more clearly understood from the following detailed description taken in conjunction with the accompanying drawing which is a schematic diagram of the inventive current output oscillator circuit.

Referring to the drawing, a first current source I_C is coupled between a first voltage terminal (V_+) and a first terminal of capacitor C which may be internal or external to the integrated circuit chip. The other terminal of capacitor C is coupled to a second voltage supply terminal (e.g. ground). A first transistor Q_1 has a base coupled to node 4 which is the junction between current source I_C and capacitor C and has a collector coupled to the input of current mirror 2. The emitter of transistor Q_1 is coupled via resistor R_3 to the second voltage terminal. A second transistor Q_2 has its base and collector terminals adapted to receive a reference current I_{REF} . The emitter of transistor Q_2 is coupled via resistor R_2 to the second supply voltage terminal. A third transistor Q_3 has a base terminal coupled to the base of transistor Q_2 , an emitter coupled via resistor R_1 to the second supply voltage terminal and has a collector coupled to output 6 of current mirror circuit 2. A fourth transistor Q_4 has at least one emitter coupled to the emitter of transistor Q_3 , a base coupled to the collector of transistor Q_3 , and a collector coupled to node 4. The oscillating cur-

rent output appears at output 8 of current mirror 2. While current mirror 2 is shown only as a block having an input 10, outputs 6 and 8, and a power supply input 12, such circuits are well-known in the art and a further discussion is not deemed necessary.

The oscillator is of the relaxation type; i.e. the output current rises to a peak level and then is rapidly reset (relaxed) to an initial level. Let us first assume that transistor Q_4 is off and that current source I_C (which may be nothing more than a resistor to V_+) is supplying current to capacitor C . The voltage across capacitor C (and therefore on the base of transistor Q_1) begins to rise. This develops a voltage across resistor R_3 which in turn causes a collector current to flow in transistor Q_1 . Since the collector of transistor Q_1 is coupled to input 10 of current mirror 2, the current is mirrored to output terminals 6 and 8 of current mirror 2 which correspond to a control current (I_{CNT}) and the output current of the circuit I_{OUT} respectively. Thus, as the voltage across capacitor C rises, so does the output current I_{OUT} and control current I_{CNT} .

Transistors Q_2 and Q_3 control the trip point of the circuit. Since at first, the voltage across capacitor C is very low, the reference current I_{REF} is greater than the control current I_{CNT} . With I_{CNT} very small, transistor Q_3 is in saturation and transistor Q_4 is off. Thus, the output current I_{OUT} and the control current I_{CNT} will continue to rise as capacitor C is charged at a rate determined by the values of I_C and C ; i.e. $dv/dt = I_C/C$.

When the voltage across capacitor C is sufficient to cause the control current I_{CNT} to exceed the collector current of transistor Q_3 , transistor Q_4 will turn on. Since transistors Q_2 and Q_3 and resistors R_1 and R_2 comprise an NPN mirror circuit, Q_4 will turn on when the control current I_{CNT} equals the reference current I_{REF} as long as transistor Q_2 is identical to transistor Q_3 and R_1 equals R_2 . Of course, by varying emitter areas of transistors Q_2 and Q_3 and by properly scaling the resistor values, the switching point of Q_4 could occur when the control current I_{CNT} was in some other way proportionally related to the reference current I_{REF} .

Since the emitter of transistor Q_4 is coupled to the emitter of transistor Q_3 , as Q_4 turns on harder the positive feedback will enhance the turning off of transistor Q_3 thus quickly turning transistor Q_3 off completely. Then, as transistor Q_4 goes into saturation, capacitor C will discharge through transistor Q_4 and resistor R_1 , with a time constant of approximately $R_1(C)$. By properly selecting the value of R_1 , the capacitor discharge time can be made very short compared to its charging time. Thus, the discharge time may be an insignificant factor in determining oscillator frequency.

The control current I_{CNT} and the output current will fall as the voltage across the capacitor C is reset since the voltage across resistor R_3 is also falling. It is important to note that the peak amplitude of the control current and of the output current is dependent only on the oscillator trip

point which is set by the reference current I_{REF} as described above. The peak output current is therefore directly proportional to I_{REF} and is independent of other oscillator components. The temperature coefficient of $I_{OUT(peak)}$ is also directly proportional to the temperature coefficient of I_{REF} .

Transistor switch Q4 will remain on as long as I_{CNT} provides adequate base current drive to Q4 and the capacitor discharge current through R1 is sufficient to bias transistor Q3 in the off state. Output current I_{OUT} , control current I_{CNT} and therefore the base current of transistor Q4 will drop to a very low value when the voltage at the base of transistor Q1 drops to a level which biases Q1 near a turn-off condition; i.e., $V_{BEQ1(low)}$. In addition, the discharge current through R1 decreases to a level which allows transistor Q3 to turn on quickly due to regenerative feedback through transistor Q4. With transistor Q3 on and in saturation, transistor Q4 is again off and the above described cycle will be repeated.

The peak voltage across capacitor C at the oscillator trip point is equal to the base emitter voltage across transistor Q1 when it is on plus the peak voltage across resistor R3; i.e., $V_{BEQ1(high)} + V_{R3(peak)}$. The voltage across resistor R1 (V_{R1}) is approximately equal to the collector current through transistor Q1 times the resistance of R3; i.e., $I_{CQ1}(R3)$. Since I_{CQ1} is directly proportional to the output current (I_{OUT}) through the action of current mirror circuit 2, $V_{R3(peak)}$ is directly proportional to I_{REF} ; i.e., $V_{R3} = k I_{REF} R3$ where k is a constant. As described in a preceding paragraph, the capacitor voltage after reset is $V_{BEQ1(low)}$. During one capacitor discharge cycle, the capacitor voltage (V_C) traverses a voltage range equivalent to

$$V_{BEQ1(high)} + V_{R3(peak)} - V_{BEQ1(low)}$$

From the well-known capacitor charging equation ($\Delta V/\Delta T = I/C$), the charging time is $\Delta T = \Delta V_C/(I_C/C)$ where I_C is the current through capacitor C.

Since the capacitor charging time represents the major portion of the oscillator output period, the oscillator frequency is $f = 1/\Delta T$. Generally, the magnitude of $V_{BEQ1(high)} - V_{BEQ1(low)}$ is much lower than $V_{R3(peak)}$. Thus, the frequency equation may be simplified to

$$f = I_C / k C I_{REF} R3$$

Furthermore, if I_C and I_{REF} are created by similar means, the equation may be further simplified to

$$f = 1 / C K R3$$

where

$$K = k I_{REF} / I_C$$

which may be made constant with respect to temperature. It can now be seen that the frequency of oscillation is primarily dependent on the values of passive components R3 and C. The temperature coefficient of the frequency is then predictably dependent only on the temperature coefficient of components R3 and C.

Finally, for improved functionality, it would be possible to add, with minimal impact, an additional emitter to transistor Q4 which would be on only during the reset time of the capacitor voltage. Such an output signal could prove valuable in the control of associated circuit. Further, multiple oscillating output currents can be easily provided with additional current mirror outputs.

The above description is given by way of example only. Changes in form and details may be made by one skilled in the art without departing from the scope of the invention.

Claims

1. A circuit for generating an oscillating output current and including a capacitor, first means (I_C) coupled to said capacitor for charging said capacitor, second means (Q1, R3, 2) coupled to said first means and responsive to a voltage across said capacitor for generating a control current (I_{CNT}) proportional to said output current, and third means coupled to said second means and adapted to receive a reference current (I_{REF}) and to provide a discharge path (Q4, R1) to discharge said capacitor when said control current exceeds some predetermined value with respect to said reference current, said circuit characterized in that said second means comprises:

a first transistor (Q1) having a base coupled to said capacitor, and having a collector and an emitter;

a first resistor (R3) coupled between the emitter of said first transistor and a first supply voltage terminal; and

a current mirror circuit (2) having an input coupled to the collector of said first transistor and having a first output for generating an oscillating output current (I_{OUT}) and having a second output for generating said control current, said current mirror circuit adapted to be coupled to a second supply voltage terminal.

2. A circuit according to Claim 1 wherein said first means biases both said second and third means.

3. A circuit according to Claim 1 or 2 wherein said third means comprises:

a second transistor (Q2) having a collector coupled to its base, said collector being adapted to receive a reference current, and having an emitter;

a second resistor (R2) coupled between the emitter of said second transistor and said first supply voltage terminal;

a third transistor (Q3) having a base coupled to the base of said second transistor, a collector coupled to the second output of said current mirror circuit and having an emitter;

a third resistor (R1) coupled between the emitter of said third transistor and said first supply voltage terminal; and

a fourth transistor (Q4) having a base coupled to the collector of said third transistor, an emitter coupled to the emitter of said third transistor and a collector coupled to said capacitor, said fourth transistor turning on to discharge said capacitor

point which is set by the reference current I_{REF} as described above. The peak output current is therefore directly proportional to I_{REF} and is independent of other oscillator components. The temperature coefficient of $I_{OUT(peak)}$ is also directly proportional to the temperature coefficient of I_{REF} .

Transistor switch Q4 will remain on as long as I_{CNT} provides adequate base current drive to Q4 and the capacitor discharge current through R1 is sufficient to bias transistor Q3 in the off state. Output current I_{OUT} , control current I_{CNT} and therefore the base current of transistor Q4 will drop to a very low value when the voltage at the base of transistor Q1 drops to a level which biases Q1 near a turn-off condition; i.e., $V_{BEQ1(low)}$. In addition, the discharge current through R1 decreases to a level which allows transistor Q3 to turn on quickly due to regenerative feedback through transistor Q4. With transistor Q3 on and in saturation, transistor Q4 is again off and the above described cycle will be repeated.

The peak voltage across capacitor C at the oscillator trip point is equal to the base emitter voltage across transistor Q1 when it is on plus the peak voltage across resistor R3; i.e., $V_{BEQ1(high)} + V_{R3(peak)}$. The voltage across resistor R1 (V_{R1}) is approximately equal to the collector current through transistor Q1 times the resistance of R3; i.e. $I_{CQ1}(R3)$. Since I_{CQ1} is directly proportional to the output current (I_{OUT}) through the action of current mirror circuit 2, $V_{R3(peak)}$ is directly proportional to I_{REF} ; i.e. $V_{R3} = kI_{REF}R3$ where k is a constant. As described in a preceding paragraph, the capacitor voltage after reset is $V_{BEQ1(low)}$. During one capacitor discharge cycle, the capacitor voltage (V_C) traverses a voltage range equivalent to

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Since the capacitor charging time represents the major portion of the oscillator output period, the oscillator frequency is $f = 1/\Delta T$. Generally, the magnitude of $V_{BEQ1(high)} - V_{BEQ1(low)}$ is much lower than $V_{R3(peak)}$. Thus, the frequency equation may be simplified to

$$f = I_C/kC I_{REF} R3$$

Furthermore, if I_C and I_{REF} are created by similar means, the equation may be further simplified to

$$f = 1/CKR3$$

where

$$K = kI_{REF}/I_C$$

which may be made constant with respect to temperature. It can now be seen that the frequency of oscillation is primarily dependent on the values of passive components R3 and C. The temperature coefficient of the frequency is then predictably dependent only on the temperature coefficient of components R3 and C.

Finally, for improved functionality, it would be possible to add, with minimal impact, an additional emitter to transistor Q4 which would be on only during the reset time of the capacitor voltage. Such an output signal could prove valuable in the control of associated circuit. Further, multiple oscillating output currents can be easily provided with additional current mirror outputs.

The above description is given by way of example only. Changes in form and details may be made by one skilled in the art without departing from the scope of the invention.

Claims

1. A circuit for generating an oscillating output current and including a capacitor, first means (I_C) coupled to said capacitor for charging said capacitor, second means (Q1, R3, 2) coupled to said first means and responsive to a voltage across said capacitor for generating a control current (I_{CNT}) proportional to said output current, and third means coupled to said second means and adapted to receive a reference current (I_{REF}) and to provide a discharge path (Q4, R1) to discharge said capacitor when said control current exceeds some predetermined value with respect to said reference current, said circuit characterized in that said second means comprises:

a first transistor (Q1) having a base coupled to said capacitor, and having a collector and an emitter;

a first resistor (R3) coupled between the emitter of said first transistor and a first supply voltage terminal; and

a current mirror circuit (2) having an input coupled to the collector of said first transistor and having a first output for generating an oscillating output current (I_{OUT}) and having a second output for generating said control current, said current mirror circuit adapted to be coupled to a second supply voltage terminal.

2. A circuit according to Claim 1 wherein said first means biases both said second and third means.

3. A circuit according to Claim 1 or 2 wherein said third means comprises:

a second transistor (Q2) having a collector coupled to its base, said collector being adapted to receive a reference current, and having an emitter;

a second resistor (R2) coupled between the emitter of said second transistor and said first supply voltage terminal;

a third transistor (Q3) having a base coupled to the base of said second transistor, a collector coupled to the second output of said current mirror circuit and having an emitter;

a third resistor (R1) coupled between the emitter of said third transistor and said first supply voltage terminal; and

a fourth transistor (Q4) having a base coupled to the collector of said third transistor, an emitter coupled to the emitter of said third transistor and a collector coupled to said capacitor, said fourth transistor turning on to discharge said capacitor



through said third resistor when said control current exceeds the collector current of said third transistor.

Patentansprüche

1. Schaltung zum Erzeugen eines oszillierenden Ausgangsstroms und enthaltend einen Kondensator, eine erste Einrichtung (1c), die mit dem Kondensator verbunden ist, um den Kondensator zu laden, eine zweite Einrichtung (Q1, R3, 2), die mit der ersten Einrichtung verbunden ist und auf eine Spannung über den genannten Kondensator anspricht, um einen Steuerstrom (I_{cnt}) zu erzeugen, der proportional dem Ausgangsstrom ist, und eine dritte Einrichtung, die mit der zweiten Einrichtung verbunden ist und dazu eingerichtet ist, einen Bezugsstrom (I_{ref}) zu erhalten, um einen Entladungsweg (Q4, R1) zu bilden, um den genannten Kondensator zu entladen, wenn der Steuerstrom einen gewissen vorbestimmten Wert in bezug auf den Bezugsstrom überschreitet, wobei die Schaltung dadurch gekennzeichnet ist, daß die zweite Einrichtung enthält:

einen ersten Transistor (Q1) dessen Basis mit dem genannten Kondensator verbunden ist, und der einen Kollektor und einen Emmitter aufweist;

einen ersten Widerstand (R3), der zwischen den Emmitter des ersten Transistors und einen ersten Spannungszuführanschluß geschaltet ist; und

eine Stromspiegelschaltung (2), die einen mit dem Kollektor des ersten Transistors verbundenen Eingang und einen ersten Ausgang zum Erzeugen eines oszillierenden Ausgangsstrom (I_{out}) aufweist und einen zweiten Ausgang zum Erzeugen des genannten Steuerstroms hat, wobei die genannte Stromspiegelschaltung dazu eingerichtet ist, mit einem zweiten Spannungszuführanschluß verbunden zu werden.

2. Schaltung nach Anspruch 1, bei der die erste Einrichtung sowohl die zweite als auch die dritte Einrichtung vorspannt.

3. Schaltung nach Anspruch 1 oder 2, bei der die dritte Einrichtung enthält:

einen zweiten Transistor (Q2), dessen Kollektor mit seiner Basis verbunden ist, wobei der Kollektor dazu eingerichtet ist, einen Bezugsstrom aufzunehmen, und mit einem Emmitter;

einen zweiten Widerstand (R2), der zwischen den Emmitter des zweiten Transistors und den ersten Spannungszuführanschluß geschaltet ist;

einen dritten Transistor (Q3), dessen Basis mit der Basis des zweiten Transistors verbunden ist und dessen Kollektor mit dem zweiten Ausgang der Stromspiegelschaltung verbunden ist und der einen Emmitter hat;

einen dritten Widerstand (R1), der zwischen den Emmitter des dritten Transistors und den ersten Spannungszuführanschluß geschaltet ist; und

einen vierten Transistor (Q4), dessen Basis mit dem Kollektor des dritten Transistors verbunden ist, dessen Emmitter mit dem Emmitter des dritten Transistors verbunden ist und dessen Kollektor mit dem genannten Kondensator verbunden ist,

wobei der vierte Transistor einschaltet, um den genannten Kondensator über den dritten Widerstand zu entladen, wenn der genannte Steuerstrom den Kollektorstrom des dritten Transistors übersteigt.

Revendications

1. Circuit pour engendrer un courant de sortie d'oscillation et incluant un condensateur, un premier moyen (1c) couplé au condensateur pour charger le condensateur, un deuxième moyen (Q1, R3, 2) couplé au premier moyen et sensible à une tension dans le condensateur pour engendrer un courant de commande (I_{cnt}) proportionnel au courant de sortie, et un troisième moyen couplé au deuxième moyen et agencé pour recevoir un courant de référence (I_{ref}) et pour fournir un chemin de décharge (Q4, R1) pour décharger le condensateur quand le courant de commande dépasse une certaine valeur prédéterminée par rapport au courant de référence, le circuit étant caractérisé en ce que le deuxième moyen comprend:

un premier transistor (Q1) ayant une base couplée au condensateur, et comportant un collecteur et un émetteur;

une première résistance (R3) couplée entre l'émetteur du premier transistor et une première borne de tension d'alimentation; et

un circuit à courant en rapport géométrique ou miroir de courant (2) dont une entrée est couplée au collecteur du premier transistor et dont une première sortie sert à engendrer un courant de sortie d'oscillation (I_{out}) et dont une seconde sortie sert à engendrer le courant de commande, le circuit à courant en rapport géométrique étant agencé pour être couplé à une seconde borne de tension d'alimentation.

2. Circuit selon la revendication 1, dans lequel le premier moyen polarise à la fois les deuxième et troisième moyens.

3. Circuit selon l'une quelconque des revendications 1 et 2, dans lequel le troisième moyen comprend:

un deuxième transistor (Q2) dont un collecteur est couplé à sa base, le collecteur étant agencé pour recevoir un courant de référence, et comportant un émetteur;

une deuxième résistance (R2) couplée entre l'émetteur du deuxième transistor et la première borne de tension d'alimentation;

un troisième transistor (Q3) dont une base est couplée à la base du deuxième transistor, dont un collecteur est couplé à la seconde sortie du circuit à courant en rapport géométrique et comportant un émetteur;

une troisième résistance (R1) couplée entre l'émetteur du troisième transistor et la première borne de tension d'alimentation; et

un quatrième transistor (Q4) dont une base est couplée au collecteur du troisième transistor, dont un émetteur est couplée à l'émetteur du troisième transistor et dont un collecteur est



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couplé au condensateur, le quatrième transistor étant rendu conducteur pour décharger le condensateur par l'intermédiaire de la troisième

résistance quand le courant de commande dépasse le courant de collecteur du troisième transistor.

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