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Using of The Coaxial Cable to Construct a Current Pulse Generator

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ABSTRACT

THIS PAPER describes the design and performance of a coaxial cable current pulse generator, which is capable of produsing a single,fast speed,output pulse with short time duration.A (300 v) dc power supply has been used to charge a coaxial cable of length (100 m) with present of a mercury-wetted relay (M.W.R.) as switch.The generator design is relatively simple,being easy to construct and inexpensive.The output pulse from the generator rises in less than twenty nanoseconds and has a width of one microsecond.The device is suitable for low power such as a current shunt tester constant current source and trigger generator.A compensated ribbon shunt type of (9.808 $m\Omega$) has been used in this work. .

ملخص البحث:

يصف هذا المنشور تصميم وآداء مولد نبضة تيار قابلو محوري ،القادر على انتاج نبضة اخراج مفردة وسريعة وبزمن بقاء قصير.تم استخدام مجهز قدرة مستمرة (300 V) لشحن قابلو محوري بطول (100 m) مع وجود المرحل المبلل بالزئبق كمفتاح. إن المولد بسيط التصميم نسبيا وسهل التركيب وزهيد الثمن .ترتفع النبضة الخارجة من المولد بزمن أقل من عشرين نانوثانية وعرضها بحدود واحد مايكروثانية . هذا الجهاز مناسب للقدرات القليلة مثل فاحص وصلة التيار ومجهز نبضة التيار الثابت ومولد القدح . استخدم في هذا
العمل وصلة تيار ذات نوع شريطي معدل (9.808 m Ω).

1. INTODUCTION

SHORT DURATION current pulses ,with fast rise time and good flat top,are required for many physics discharge experiments and applications [1].One of these applications is a current shunt tester and calibrator which has been studied and constructed in this paper.Many techniques has been studied and designed in last researches to generate this types of pulses [2-6]. This paper describes the design and performance of current pulse generator,which capable of producing fast output pulse by using a coaxial cable in stacked-arrengement.The design is relatively simple,being easy to constract and inexpensive.Although,in the present work this pulse generator is suitable for low power applications such as high current testing of small capacitance loads,trigger generators with low jitter and current shunt testing and calibration.

2. BASIC PRINCIBLE

2.1 **The**

Type	Ribbon shunt -compensated
Resistor value	9.808 $m\Omega$

Current Shunt

The resistance of the current shunt (R_{sh}) shown in Fig.(1) plays an important role in the discharge current measurements and rogowski coil calibration.This shunt was constructed in cylindrical shape from stainless steel foil of thickness (0.076 mm).This thickness was chosen to be much less than the skin depth to allow the use of this current shunt over a wider rang of frequency.The cylindrical foil was terminated by two soldered tightly-fitting brass connectors.The voltage drop along the cylindrical foil is sensed by connecting a coaxial cable across its end so that there was no flux linkage.The sensed voltage in such geometry was therefore taken as the product of the discharge current ($I(t)$) and (R_{sh}), $i.e.$,($I(t) * R_{sh}$).

Table (1) demonstrates the characteristics of the current shunt which has been used in this work.

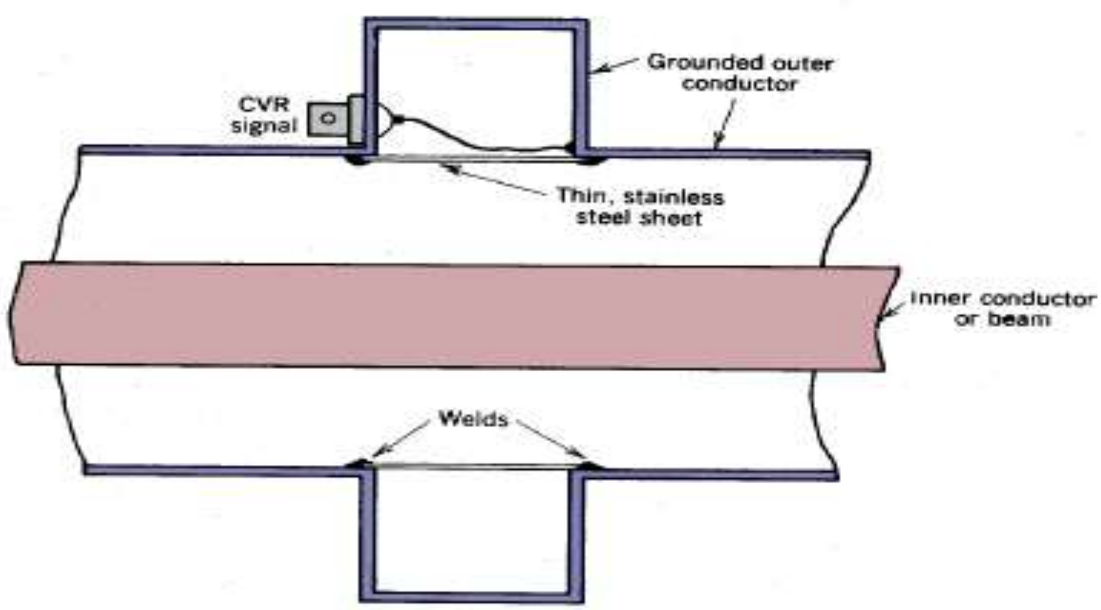


Fig. (1) Low-Inductance Current Shunt.

Table (1) The Characteristics of Present Current Shunt**.**

Response time	$\|T\| \le 12ns$
Rise time	$t_r \cong 8ns$
Frequency rang	$F(3dB) \cong 20MH_z$

2.2 The Coaxial Cable

Fig.(2) illustrate the coaxial cable which consists of an inner and outer conductor insulated from each other.Each conductor carries a desiered signal current (source to load or return).The outer conductor of a coaxial cable is not a true shield in that it is also the signal return.Atrue shield insulated from the signal carrying conductors and protects the enclosed coaxial conductors.However,the outer conductor of a coaxial cable is an electrostatic shield and thus protects against capacitive interferance [7].Two of the measurable parameters associated with the coaxial cable are[8]:

$$Z_o = \sqrt{L_o / C_o} \qquad (1)$$

and

$$U_o = \frac{1}{\sqrt{L_o C_o}} \qquad (2)$$

where

Z_o = characteristic impedance,

U_o = speed of transmission,

L_o = is the series inductance per unit length,

and

C_o = is the parallel capacitance per unit length

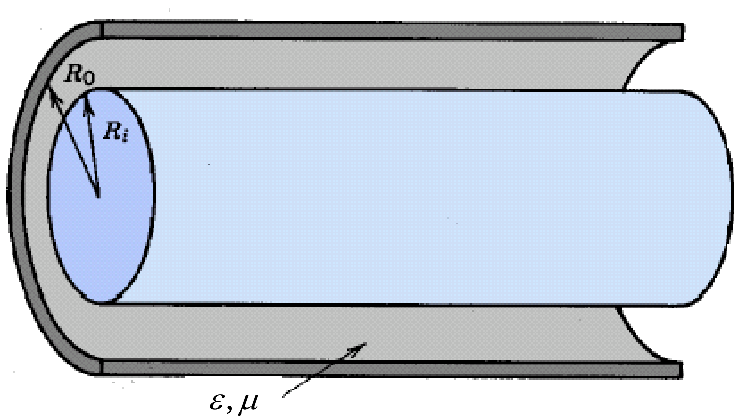


Fig.(2) The Coaxial Cable**.**

As coaxial cable is widely used in many applications,its principle is well-understood and available in literatures [1,7,8-11].Fig(3a) shows a sectional view of a line divided into differential elements of length Δx .Each element has a capacitance between the center and outer conductors proportional to the length of the element.If C_o is the capacitance per unit length,the capacitance of an element is $C_o\Delta x$ .Magnetic fields are produced by current flow along the center conductor.Each differential element also has a series inductance, $L_o\Delta x$,where L_o is the inductance per unit length.The circuit model of Fig.(3b) can be applied as model of the coaxial cable .The quantities C_o and L_o for cylindrical geometry are given by, [11]:

$$C_o = \frac{2\pi\varepsilon}{\ln(R_o / R_i)} \qquad (F/m)\ , \qquad (3)$$

$$L_o = (\mu / 2\pi)\ln(R_o / R_i) \qquad (\mathrm{H}/m). \qquad (4)$$

where

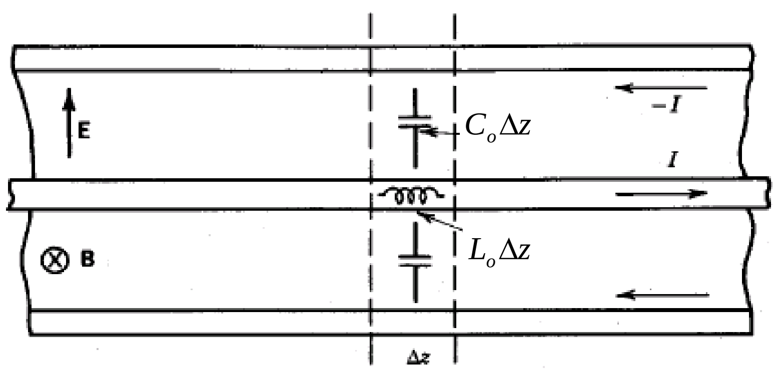
$\varepsilon =$ dielectric constant,

$\mu =$ magnetic permeability,

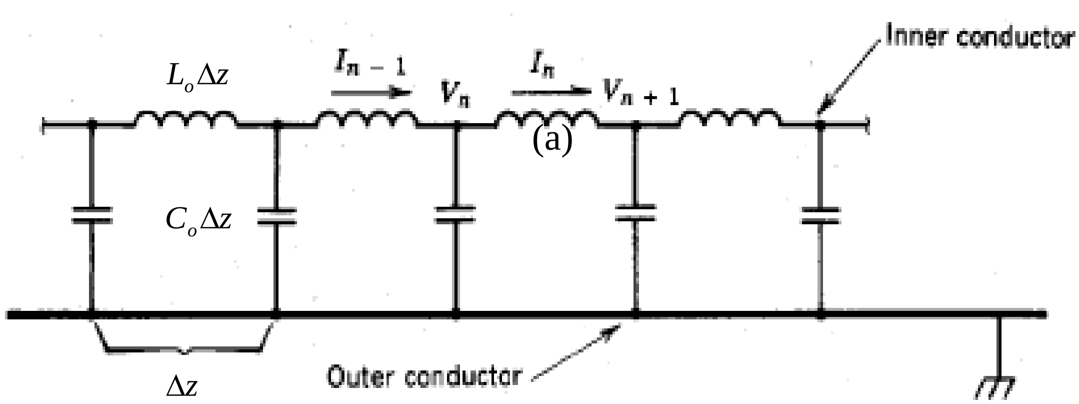
$R_o =$ outer conductor radius,

and

$R_i =$ inner conductor radius



(a)



(b)
Fig. (3) The Coaxial Cable . (a) Physical Basis Model ,
(b) Lumped Circuit .

For instant,the characteristic of the coaxial cable which has been used in this work are listed in Table (2).

Table (2) The Characteristics of Present Coaxial Cable.

Type	$RG\ 59\ B/U$
Diameter	$6.15\ mm$
Characteristic impedance	$75\ \Omega$
Capacitance per meter	$68\ pF$
Length	$100\,m$
Max. voltage	$6\ kv$

3. LAYOUT AND CONSTRUCTION

3.1 General

Apractical way of getting high current rectangular pulses of width few microsecond is with help a pulse-forming line (PFL), [1].A (PFL) can be an actual transmission line (or set of lines or cables),but is quite often just another set of capacitors and inductors arrenged in a specific way (then becoming a pulse forming network or PFN) to further tailor or shape the pulse for better matching to the final source stage.This PFL/PFN stage is also often termed ,because of its function,a pulse conditioning or a pulse modulation stage [12].The PFL has the capability of providing a flat top rectangular pulse with fast rise time.A fast closing switch is necessary for achieving fast rise time and spark gap,thyratron,thyristor and mercury wetted relay switches have turned out to be the most appropriate.

A simple PFL generator is shown in Fig.(4).The coaxial cable is charged from a dc power supply through an appropriate load.If the cable is charged to a voltage (V) and discharged through a resistance (R_L),a current proportional to the voltage and inversely proportional to the sum of the load resistance (R_L) and cable impedance (Z_o) flows through (R_L).The pulse current is sustained by a voltage wave ($V - R_L * I$) which travels into the cable with a velocity proportional to the coaxial cable length and inversely proportional to the square root of the product of ($L_o * C_o$).The wave will reflect at the far end of the cable,then return after time (T), [9].The pulse width, T ,is twice the time taken by electromagnetic wave to travel the length of coaxial cable (ℓ) in dielectric medium filled between the coaxial conductors.Mathematically,it can be defined as [1] :

$$T = 2(\ell / U_o) \qquad (5)$$

Because of a small series resistance and inductance of a practical coaxial cable the load current will reduced slightly,(this is the drop between the leading edge and trailing edge of the waveform).

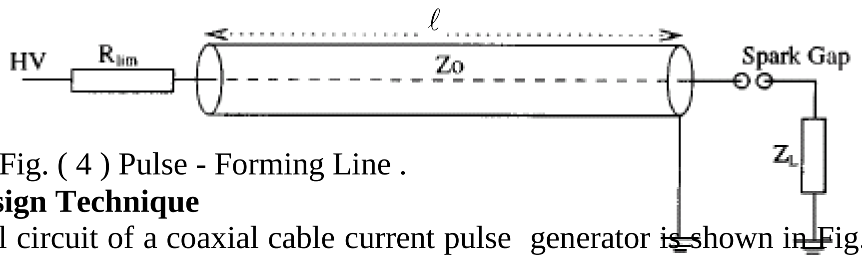


Fig. (4) Pulse - Forming Line .

3.2 Generator Design Technique

The practical circuit of a coaxial cable current pulse generator is shown in Fig.(5).The center conductor of a line of length ($100\ m$) is charged by a dc power supply to ($300\ V$).The dc supply is connected through acurrent resistor ($R_{Lim} = 100k\Omega$).The other end of the coaxial cable is connected through a mecury-wetted relay switch ($50H_Z$) to the current shunt ($R_{sh} = 9.808\ m\Omega$).When the switch is closed, $t = 0$,the charged cable dumps its energy into the load (R_{sh}) and a current pulse will be generated with amplitued of

$$I = V/(Z_o + R_{sh}) \cong V/Z_o \cong 300/75 \cong 4\text{A} \qquad (6)$$

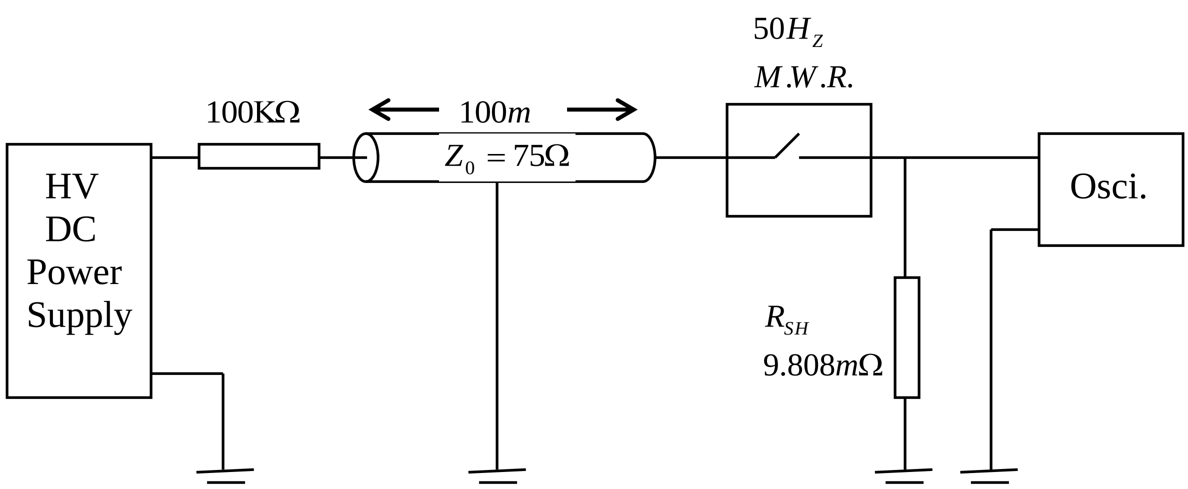


Fig. (5) The Coaxial Current Pulse Generator .

Fig.(6) shows the resultant output current pulse which has an amplitued of

$$V_o = V(R_{sh}/(Z_o + R_{sh})) \qquad (7)$$

$$= 300(9.808 * 10^{-3}/(75 + 9.808 * 10^{-3})) = 39\ mv$$

It is clear from Eq.(1) that the coaxial cable inductance per unit length equals to

$$L_o = Z_o^{\,2} * C_o \qquad (8)$$
$$= (75)^2 * 68 * 10^{-12} = 0.383 \;\; \mu\text{H}/m$$

Also the value of speed of transmission may be calculated from Eq.(2)

$$U_o = 1/\sqrt{0.383 * 10^{-3} * 68 * 10^{-12}} = 196.5 * 10^6 \;\; m/s$$

The pulse width may be obtained from Eq.(5)

$$T = 2(100/196.5 * 10^{-6}) = 1 \;\; \mu s$$

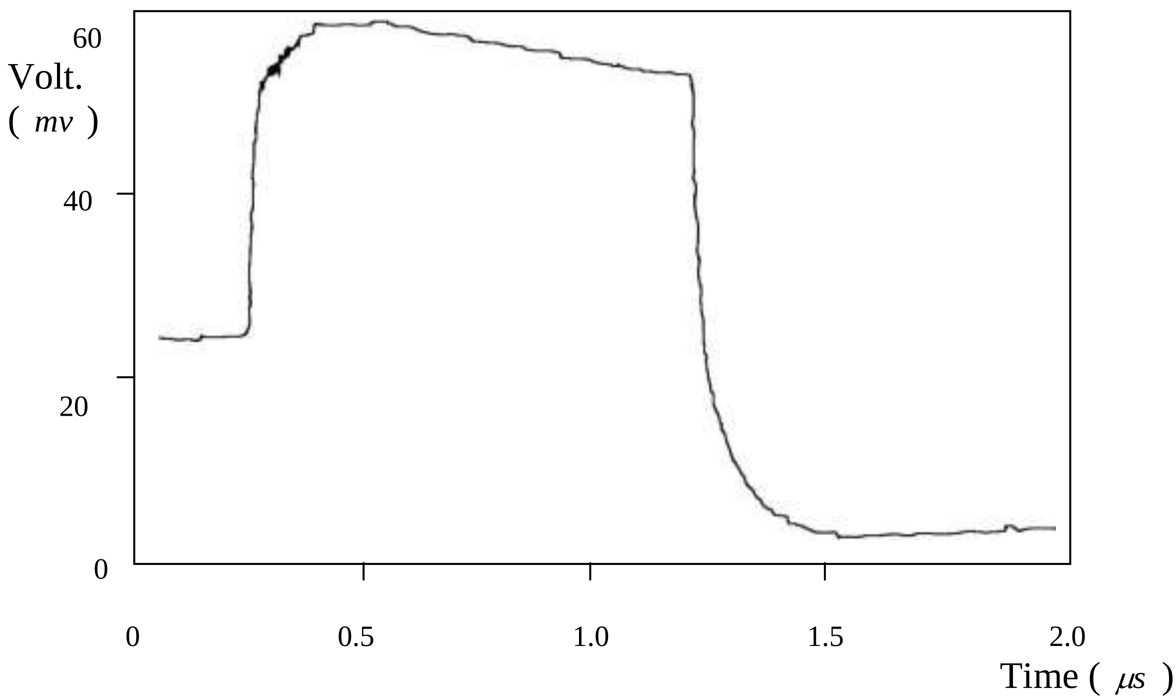


Fig. (6) The Output Current Pulse.

Because of a mismatch at both ends of source and load the reflections may take place for considerable time.The shape of the load waveform will depend on relative magnituedes of load and source impedances with respect to the characteristic impedance of the coaxial cable.When a reflected wave returns to the source the reflection coefficient is

$$K_s = \frac{Z_s - Z_o}{Z_s + Z_o} = 0.998 \qquad (9)$$

where

K_s = source end reflection coefficient,

Z_s = sourse end impedance $= 100\text{K}\Omega$, and

$Z_o = 75 \ \Omega$

The fraction of the propagating signal that reflects back toward the source is called, K_L far-end reflection coefficient.

$$K_L = \frac{Z_L - Z_o}{Z_L + Z_o} = -0.999 \qquad (10)$$

where

$Z_L =$ load impedance = 9.808 $m\Omega$

Because of a poorly terminated coaxial cable the signal will be reflected back and forth several time befor it settles down.For each round trip the pulse reduced by a factor $K_s K_L$ .It has been seen that the product $K_s K_L$ is large,so, the cable will require several round trips to stabilize. The time required for one complet round trip is equal to the cable length times its propagation delay

$$T_s = \ell\sqrt{L_o C_o} = 100\sqrt{0.383*10^{-6}*68*10^{-12}} = 5 \ \mu s \qquad (11)$$

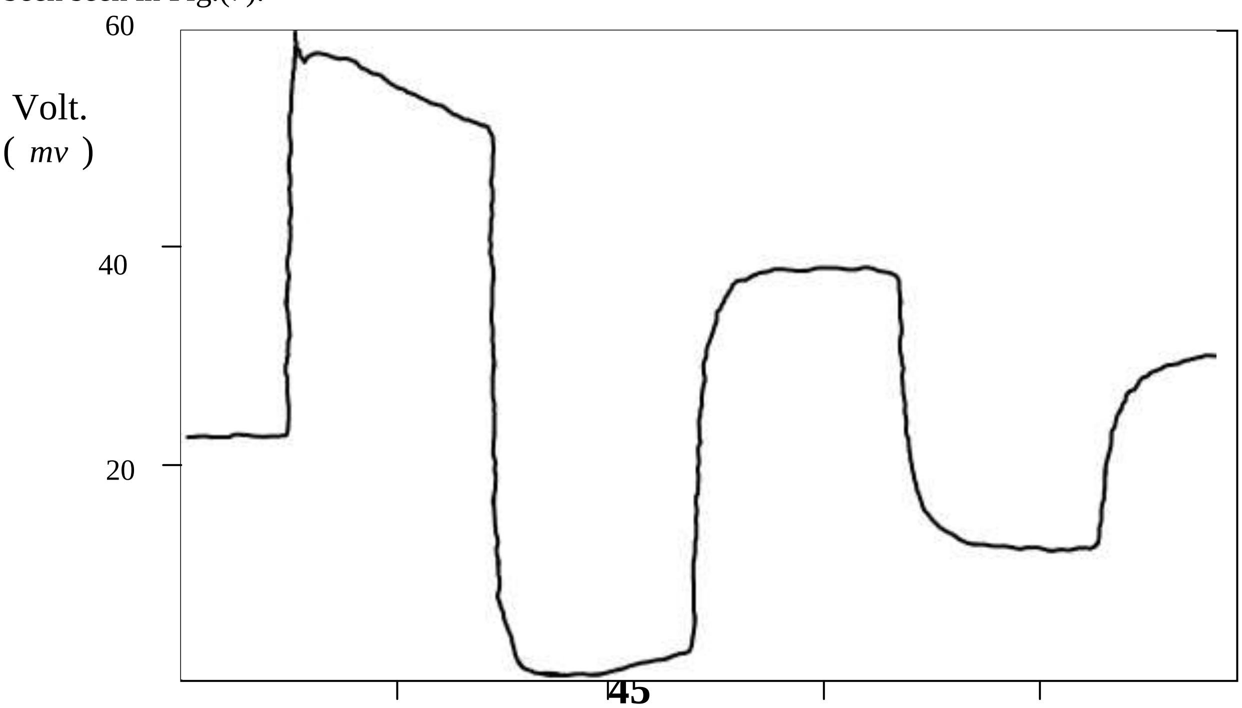
where

$T_s =$ settling time

Fig.(7) demonstrate the output current pulse and its reflected pulses with the settling time.It has been seen that a small difference between the amplitued of a specified and a reaized output current pulse,which was result from :

1- a non-zero resistance of practical coaxial cable,
2- series resistance and stray inductance of wires that has been used to connect the switch (mercury-wetted relay) with the current shunt and the coaxial cable,
3- the resistance of the oscilloscope probe and its termination resistor,and
4- un acuracy of charging dc voltage and the tolarence in cable impedance.

It is important to mentioned here that a stray series inductance resulting from the set-up connections cuases a small unwanted overshoot and ringing at the beginning of the pulse as it has been seen in Fig.(7).



0

0 1 2 3 4 5

Time (μs)

Fig. (7) The Output and Reflected Current Pulses .

4. CONCLUSIONS

We have presented here the design and construction of a coaxial high speed current pulse generator with sufficient rise time and good pulse width.The generator is low cost,pure resistive and easy to make.It has been used as a current shunt tester and can also be used for many other applications (e.g.,trigger generator).Higher values of a current may be produced by increasing the charging voltage,using a spark-gap as switch and using an other type of coaxial cable which has a lower value of characteristic impedance.The pulse width can be shortened by decreasing the length of a cable.Although extra car was taken in making the connections to minimize the stray inductance.So,a microstrip between one terminal of the current shunt and the copper blat strip with appropriate insulator (and dimentions) has been made to minimize the effect of such inductances.

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