

FEDERAL AVIATION ADMINISTRATION

Comments on Governor Circuit and Possible Radio Frequency Broadcast effects



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Executive Summary

The investigation here is based on circuit diagrams provided and manufacturer specifications of components. No actual testing has been performed. The analysis is at an engineering level and is not intended to represent a complete picture of the operation of the governor circuit.

1. High power broadcast AM radio transmitters are likely able to affect the governor circuit resulting in governor control that reduces the engine speed irrespective of the set input. This condition would not be experienced with the governor switch off or if the throttle control was held to overcome the controlling torque of the governor. The RF energy is demodulated by the circuit resulting in a signal that artificially increases the signal frequency representing the engine speed.
2. The current switched through the contacts appears to be very low compared with the currents normally associated with that required to keep the contacts clear from oxidation and contaminants. This is likely to lead to pulses being missed and result in an increase in engine speed as a result. Failure of the points to open circuit would result in the governor circuit driving the throttle towards overspeed. This may be overcome in the same way as above.

Introduction

This discussion is intended to inform a possible reason for observed undesired operation of a governor circuit in the near vicinity of high power broadcast radio stations. Several reports near High Frequency (2 to 30MHz), High power (exceeding 50 KW EIRP) and amplitude modulated radio stations have been received. The purpose of this discussion is not to propose a solution to the issue but to provide guidance on the most probable cause. It is hoped that an informed decision is enabled to engineer any required improvements in RF immunity to the circuitry as a by those skilled in the art of protection of electronics from radiated emissions.

General Circuit Description

The circuit is analogue and constructed from common of the shelf components. The input signal is derived from a pair of dry contacts in one of the two magnetos and this signal is also applied to the tachometer circuit. The two contacts are connected back to the control assembly via a screened twisted pair. Unfortunately the input circuitry is not designed in such a way as to take advantage of the twisted pairs ability to offer rejection of an external radiated signal. That is one of the twisted pair is connected to ground at the control assembly and the other to is connected to Pin H on the assembly. Pin H is connected to an input point via a decoupling feedthrough capacitor C 20 1000P and diode D12. R86 4K75 on the assembly connects the input point to

plus 12V. R87 4K75 connects the input point to the cathode of zener diode D13 with anode connected to ground. Capacitor C31 .047m is connected across D13. The cathode of D13 is connected to pin 1 of IC1 LM2917N Frequency to Voltage converter input. The resulting voltage output represents the engine speed. This voltage is compared with preset reference voltages to generate an error signal that drives an H bridge PWM circuit to cause a motor via a friction clutch to increase or decrease the engine speed to maintain within a desired rpm range.

This circuit is operation and providing control if

1. The governor switch is on
2. The pilot is not countering the torque applied by the motor as a correction

Wetting Current

The current through the contact points when closed can be calculated as $12/4750A = 2.5mA$

For dry contacts this is significantly below the minimum current normally associated with “wetting” the contacts.

This low current is likely to lead to poor reliability of the contacts due to oxidation and surface resistance and contaminants.

Also intermittent operation of these contacts will lead to a lower than actual engine speed being sensed resulting in attempts by the governor to overspeed the engine.

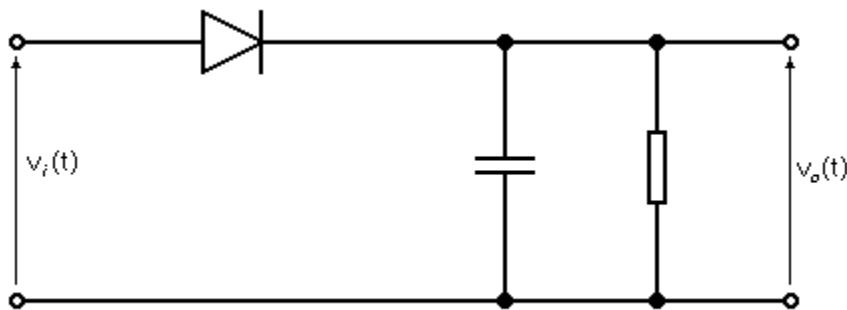
Circuit operation

Opening of the contact points results in the voltage at the D13 Cathode rising to 5.1V as D13 is forced into reverse conduction. When the contact points close this voltage along with the charge on C31 is reduced to 0.66V (from manufacturers data at a forward current of 2,5mA) the forward volt drop of diode D12. Repetition of this process produces a train of pulses whose frequency is proportional to engine speed and changes between 0.66V and 5.1V at pin 1 of IC1. This frequency train is then converted to a voltage by means of a charge pump. Resistors R3 and R4 set the voltage level at which the differential input of IC1 causes a change of state of the input amp and provides charge to the internal charge pump thereby causing an increase or decrease in the converted output voltage of IC1. This voltage is set to 2.4V (within the tolerance of the resistors that is not stated).

This voltage is then compared against preset references to generate an error signal that is then applied to a PWM H bridge amplifier and a DC motor to provide a Governor control Torque.

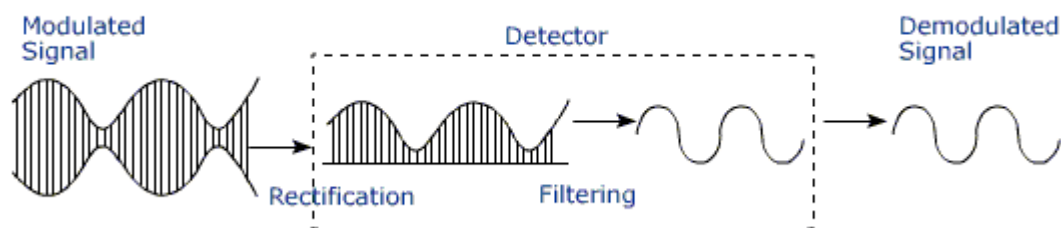
Accidental Demodulation

For any circuit demodulation of an amplitude modulated signal is possible if a Double Sideband Amplitude Modulated carrier is applied to the circuit and encounters a non linear element in the circuit. The simplest way to consider this is the basic circuit shown below.



The RF input voltage $V_i(t)$ is applied to the diode. The diode provides half wave rectification of the signal and the Capacitor shown “smooths” the rectified RF signal thus recovering the modulating signal $V_o(t)$. The resistor at the output is shown as this slowly discharges the capacitor to avoid the capacitor charging up to the peak voltage.

The waveforms are shown below, the rectifier being the diode and the filtering being the resistor capacitor.



Erroneous operation

With a high Amplitude modulated RF field impacting the wiring there are two states to consider.

1. With the contact breaker points closed
2. With the contact breaker points open

A partial diagram of the governor control is included below. Components indicated with an 18 in a triangle are not installed. The input wiring is twisted pair with one of the pair grounded with an overall braid. The braid gives some attenuation to RF but is only effective against E fields (Electric) up to a certain level. The twisted pair does not significantly contribute to the reduction of RF ingress as currently configured. No protection from H field (Magnetic) is provided for the system so RF could couple via simple transformer effect into the wiring harness. Capacitor C20 is a 1000pF feedthrough that acts as a simple first order RF filter. This gives some order of reduction but will be ineffective against medium to strong fields and much less effective at lower RF frequencies. At lower frequencies (600KHz MW) the coupling of RF is more difficult and transmitters tend to be below 50KW. The risk is still finite at these lower frequencies.

1. Contact breaker closed

With the contact points closed diode D12 is pushed into forward conduction and passes around 2.5mA. The voltage at Pin 1 of IC1 is approximately 0.66V. RF present on the input wiring is then connected to the anode of D13 as D12 is in conduction. D13 provides half wave rectification to the RF signal and the envelope is then “smoothed” by capacitor D31. These components forming the basis of a rudimentary AM demodulator.

The resulting signal applied to pin 1 of IC1 is 0.66Vdc with a superimposed demodulated audio frequency representing the modulation from the broadcast station.

IC1 is able to convert this frequency to affect its DC output providing the signal exceeds the preset threshold and is 10KHz (approximately) or less. Frequencies that are well within the audio transmitted signal.

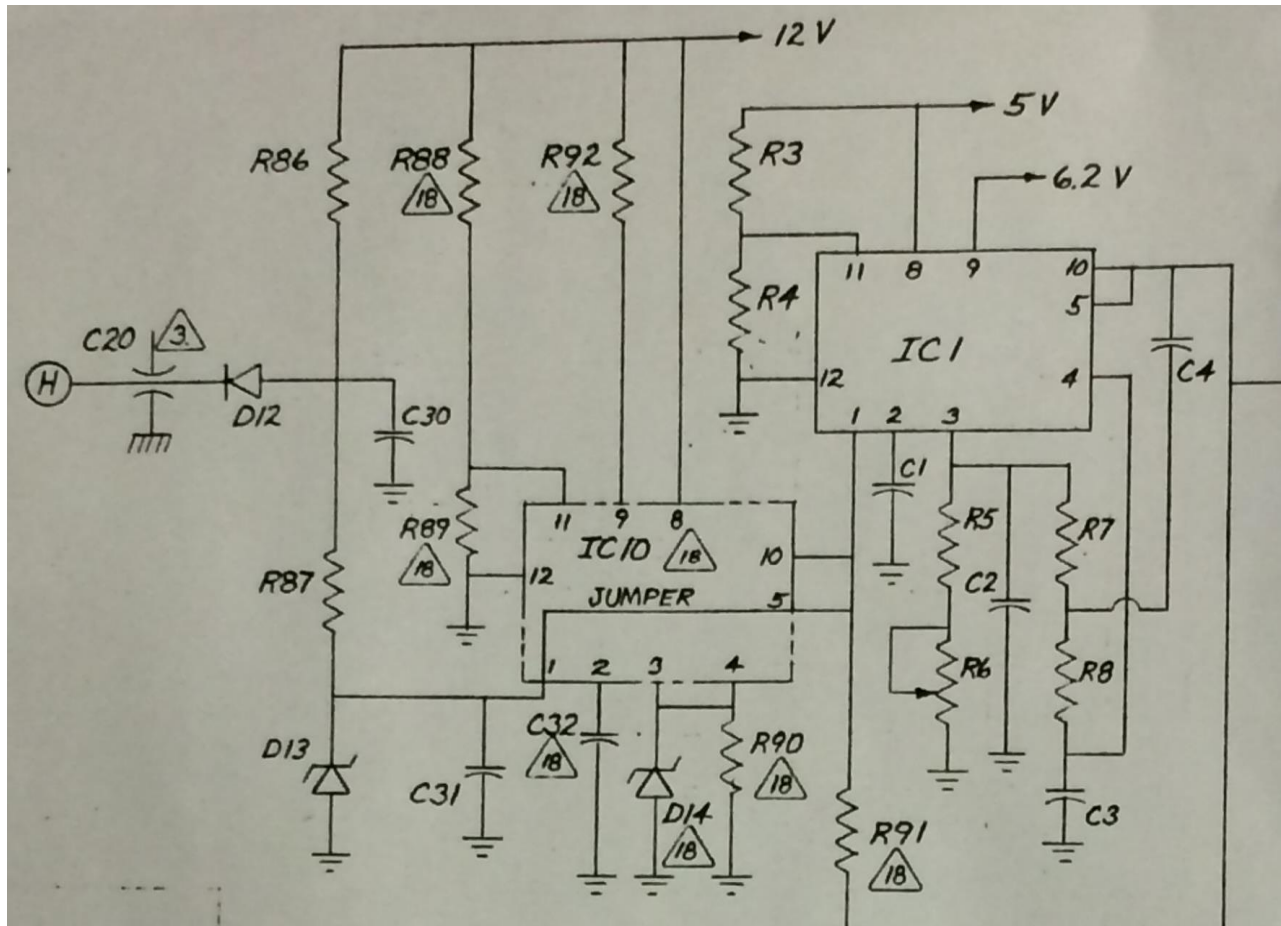
In order for input to pin 1 of IC1 to affect output it needs to exceed 2.4V (set by R3 and R4). Given that 0.66V already exists then 1.34V of demodulated RF is all that is required to affect this change. That would require an input RF current in excess of $1.34/R87 = 280 \mu A$. That level of current is well within that that could be expected to be induced into the wiring. The rising edge of the demodulated envelope results in a voltage level being applied to the charge pump. The falling edge of this envelope results in this being removed. If the normal expected frequency was 200Hz, a 2KHz demodulated envelope would indicate, erroneously, that the engine speed was 10 times higher than it actually was resulting in a governor control to drive the engine speed suddenly downward.

The effect of this is to provide extra pulses to IC1 that results in an output indicating the engine is running above the desired range. As a result engine speed is reduced unless countered as described elsewhere.

2. Contact breaker open

In this condition the voltage at the anode of D13 rises to 5.1V and the diode is reverse biased with a current of around 726 μ A.

This condition would require significantly more RF to affect the operation so is not examined here as condition 1. Will dominate and cause the effect.



The circuit above dated 1993 is an extract from the overall diagram showing the input circuitry being discussed. This represents about 1/3 of the components that make up the governor control circuit.