ELECTRICAL LOAD ANALYSIS

GFC 700 AFCS

DIAMOND DA 40

P/N 005-00336-05 Rev. 1

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1 INTRODUCTION

1.1 Purpose of Document

The purpose of this electrical load analysis (ELA) is to document changes to electrical loads following the modification for a supplemental type certificate (STC) to install the Garmin GFC 700 Automatic Flight Control System (AFCS). This ELA will show the following:

1) The total power consumption after the alteration does not exceed the capacity of the electrical power generation and distribution system of the aircraft under foreseeable operating conditions.
2) The aircraft systems can be supported by the alternator during normal operation, the ship's battery can support the load on the Essential bus with the loss of the alternator, and the emergency battery pack can support an attitude indicator and the flood lighting given the loss of all other sources of power.

2 APPLICABLE DOCUMENTS

Diamond Aircraft Industries, Document No. 6.01.01-E, "Aircraft Flight Manual: DA 40"

Diamond Aircraft Industries, Document No. DA4-9231-60-05, Schematic, G1000 GFC 700 Autopilot, Option

Diamond Aircraft Industries, Document No. 6.07.02 Ch O-067/23.1351, "Electrical Load Analysis"

Garmin International, Document No. 005-00149-07, Electrical Load Analysis, G1000, Diamond Model DA40

3 SUPPLEMENTAL TYPE CERTIFICATE (STC)

3.1 Autopilot Modification

The addition of the Garmin GFC700 AFCS STC installation with the existing G1000 system modifies electrical loads in the DA40 aircraft.

As a prerequisite of the Garmin GFC700 STC, DA40 provisions provided by Diamond Aircraft modify the DA40 aircraft to facilitate complete installation of the Garmin GFC 700 Autopilot System. Several of these provisions affect the existing Electrical Load Analysis performed for the Garmin G1000 installation in the DA40 aircraft (ref: 005-00149-07). These provisions include removing the existing optional Honeywell KAP 140 autopilot with directional gyro. The STC subsequently provides for installation of the GFC700 pitch, roll, and pitch trim servos. Another significant modification provided with the GFC700 provisions is relocation of the existing AUDIO circuit breaker (GMA1347); rebussing it from the Avionics Bus to the Essential Bus. The purpose of relocating the AUDIO CB is to provide electrical power to the GMA 1347 audio panel for the autopilot disconnect aural alert if the Avionics Bus fails or the Avionics Master Switch is turned off while the autopilot is engaged. The existing AFCS circuit breaker was retained and reused for this GFC700 STC installation.

3.2 Multifunction Display MFD Modification

The GFC700 STC removes the existing GDU 1040 Multifunction Display (MFD) and replaces it with a GDU 1042 (Figure 1). The GDU 1042 includes AFCS mode selection buttons for the autopilot and also has an internal 35 watt heater. The heater turns on at temperatures below 15º Celsius to warm the display. This ELA assumes maximum load with the heater turned on continuously.

Figure 1

GDU 1042 Multifunction Display

3.3 Applicable Regulations

This analysis will show compliance to the following regulations:

1) 14 CFR 23.1309 (c)(d)
2) 14 CFR 23.1351 (a)(g)
3) 14 CFR 23.1353 (h)

4 SYSTEM DESCRIPTION

The DA 40 is an alternator driven 28 Volt DC system, which can be sub-divided into:

- Power Generation
- Storage
- Distribution
- Load

Figure 2 depicts the DA40 Power Distribution System.

For the GFC700 STC with regard to power generation and storage, the existing aircraft alternator, main ship battery, and standby battery pack are retained without modification. In addition, the existing electrical power distribution system of the DA40 aircraft is retained without modification. Conversely, electrical system loads on the Essential bus and Main Avionics bus are modified to remove the existing optional Honeywell KAP 140 autopilot with directional gyro and rebus the existing GMA1347 electrical load. The results of these modifications are shown in Table 1, Table 2, and Table 4 of this analysis. The results of the modifications are within normal alternator power bus capacity and meet the requirement for battery capacity following an alternator system power failure.

A 70 amp alternator is mounted on the front of the engine in the DA40 aircraft. It is driven by a V-belt and charges the main aircraft battery. The alternator system is the primary source of electrical power on the aircraft. In the event of an alternator failure, the main ship battery provides the essential aircraft systems with electrical power. Given the provision of these two independent sources of electrical power, a complete failure of the electrical systems is extremely unlikely.

Power is stored in the 11 amp-hour lead acid main ship battery, which is mounted in the right-hand side of the engine compartment. The battery is connected to the airplane electrical system at the Essential bus. The battery switch on the instrument panel provides connection of this power source to the aircraft's electrical system.

In addition, a non-rechargeable dry battery pack is installed as a further source of power for the attitude indicator (artificial horizon) and the flood lighting (an electroluminescent panel). When the EMERGENCY switch is set to ON, these systems are supplied with power for 1.24 hours, independent of all other electrical loads. During each 100 hour inspection, this battery is checked for proper functioning. Every 2 years or after use (broken seal on the switch) the battery cells must be replaced.

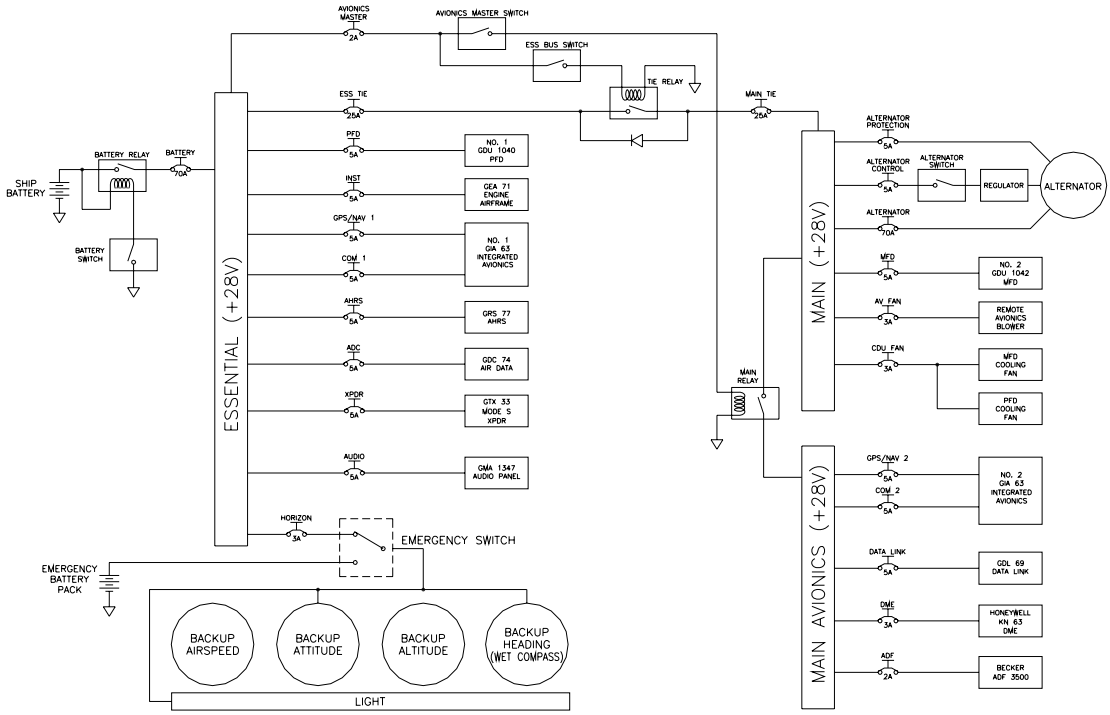

Figure 2

Power Distribution Schematic

5 ELECTRICAL LOAD ANALYSIS

The following pages give an overview of the power requirements of the electrical system in the plane. The goal is to demonstrate that the aircraft complies with the following statements:

1. The alternator output is adequate for IFR operation in accordance with § 23.1351(a)(1) and (a)(2)(i).
2. Both the ship battery and emergency battery pack are capable of supplying power to the essential load for at least 0.5 hours in accordance with §§ 23.1309 (c), (c)(1), (c)(2)(iii), (c)(3), (d), (e), and 23.1353 (h) through the following:
   a. The ship battery capacity is adequate for 0.62 hours of IFR operation for the systems on the Essential bus in case of an alternator failure.
   b. The emergency battery capacity is sufficient for 2.7 hours of emergency operation in case of an alternator failure and a total discharge of the ship battery. The emergency battery pack powers an attitude indicator and the flood lighting in accordance with § 23.1311 (a)(5).

Please note that the maximum known load values were used whenever possible.

5.1 Alternator Analysis

Table 1 depicts the maximum current draw on the DA 40 electrical system with the G1000 system installed in conjunction with the GFC700 AFCS installation under normal operating conditions. The maximum current draw from this table is then used in the analysis on the next page to depict the total load on the alternator when the output is de-rated 20% due to battery charging. All current values are in amps. The Duty Cycle Factor (DCF) is considered the percentage of time the unit will operate. The DCF is derived from the original Diamond Aircraft Industries' Original Electrical Load Analysis, Document No. 6.07.02 Ch O-067/23.1351.

LOAD	CURRENT DRAW	DCF	REQUIRED AMPS
No. 1 GDU1040	2.50	1.00	2.50
No. 1 GIA63 TX	4.30	0.10	0.43
No. 1 GIA63 RX	1.00	0.90	0.90
No. 1 GIA63 Other Functions	1.00	1.00	1.00
GRS77/GMU44	0.30	1.00	0.30
GDC74	0.60	1.00	0.60
GEA71	1.02	1.00	1.02
GMA1347	1.75	1.00	1.75
No. 2 GDU1042	2.50	1.00	2.50
No. 2 GIA63 TX	4.30	0.10	0.43
No. 2 GIA63 RX	1.00	0.90	0.90
No. 2 GIA63 Other Functions	1.00	1.00	1.00
GTX33	1.40	1.00	1.40
Attitude Indicator	0.55	1.00	0.55
Pitch Servo	1.00	0.50	0.50
Roll Servo	1.00	0.50	0.50
Trim Servo	1.00	0.50	0.50
Placards	0.09	0.10	0.01
Avionics Master Relay	0.10	1.00	0.10
Battery Relay	0.50	1.00	0.50
Ignition Relay	0.10	0.01	0.01
Strobe	3.40	1.00	3.40
Landing Light	1.20	0.10	0.12
Taxi Light	1.20	0.10	0.12
Instrument Light	1.19	0.20	0.24
Flood Light	0.50	0.01	0.01
Map Light	0.20	0.01	0.01
Position Light	3.40	0.20	0.68
Pitot Heat	5.80	0.20	1.16
Fuel Pump	2.20	0.10	0.22
Flaps	3.00	0.01	0.03
Alternator Protection	0.10	1.00	0.10
Alternator Control	2.50	1.00	2.50
Remote Avionics Blower	0.48	1.00	0.48
PFD Cooling Fan	0.08	1.00	0.08
MFD Cooling Fan	0.08	1.00	0.08
DME	0.54	1.00	0.54
ADF	1.10	1.00	1.10
GDL 69A	0.35	1.00	0.35
		TOTAL	**28.62**

Table 1, Load On Alternator (28V), All Systems On

5.1.1 Alternator Load Calculation

The following calculations show the total load on the alternator after the installation of the G1000 avionics system with the GFC700 AFCS. Note that the alternator is derated by 20% for battery charging. This alternator derating is part of the original Diamond Aircraft Industries' Original Electrical Load Analysis, Document No. 6.07.02 Ch O-067/23.1351.

Maximum Rated Alternator Output	70.0	amps
20% Reduction Factor for Battery Charging	x0.8	
Derated Output of alternator	**56.0**	**amps**

Updated Amps for IFR Flight (Table 1)	28.6	amps
Alternator Amps Available	÷56.0	amps
Percent of Max Alternator Load for IFR	**51.0**	**%**

The following calculations show the additional load on the alternator because of the G1000 avionics with GFC700 AFCS installation. This is a comparison to the original Diamond Aircraft Industries' Original Electrical Load Analysis, Document No. 6.07.02 Ch O-067/23.1351.

Updated Amps for IFR Flight (Table 1)	28.6	amps
Original Amp for IFR Flight	-23.0	amps
Change in Amps From Old Equipment to New Equipment	5.6	amps
Original Amp for IFR Flight	÷23.0	amps
Percent Change in Amps from Old Equipment to New Equipment	**+24.4**	**%**

In conclusion, the calculations above show that there is a 24.4% increase in required current for the G1000 avionics with GFC700 AFCS installations versus the original avionics installation. However, the GFC700 AFCS installation provides for a decrease of the total alternator load when compared to the KAP 140 autopilot installation.

5.1.2 Aircraft Battery Analysis

Table 2 below shows the total current draw of the electric system in the DA 40 including the G1000 components when the alternator fails and the aircraft is running off the ship battery. Only the systems on the Essential bus are powered. As a prerequisite of the Garmin GFC700 STC installation, aircraft provisions provide for the rebussing of the GMA1347 from the aircraft Main Avionics bus to the Essential bus. This load is included in Table 2. The result of this table is then used in the analysis on the next page to determine how long the ship battery can sustain this reduced configuration. Please note that this is the same ship battery as the one used in the original analysis.

LOAD	CURRENT DRAW	DCF	REQUIRED AMPS
No. 1 GDU1040	2.50	1.00	2.50
No. 1 GIA63 TX	4.30	0.10	0.43
No. 1 GIA63 RX	1.00	0.90	0.90
No. 1 GIA63 Other Functions	1.00	1.00	1.00
GRS77/GMU44	0.30	1.00	0.30
GDC74	0.60	1.00	0.60
GEA71	1.02	1.00	1.02
GTX33	1.40	1.00	1.40
Attitude Indicator	0.55	1.00	0.55
Battery Relay	0.50	1.00	0.50
Tie Relay	0.10	1.00	0.10
Landing Light	1.20	0.10	0.12
Flood Light	0.50	0.01	0.01
Pitot Heat	5.80	0.20	1.16
Flaps	3.00	0.01	0.03
GMA1347	1.75	1.00	1.75
		Total	**12.37**

Table 2, Load on Essential Bus

The following calculations show the total load on the battery after a failure of the alternator. This battery derating is part of the original Diamond Aircraft Industries' Original Electrical Load Analysis, Document No. 6.07.02 Ch O-067/23.1351.

Battery Amp Hours	11.0	amp-hours
Battery Available Factor	x0.7	
Battery Amp Hours Available	**7.7**	**amp-hours**
Amps Required for EMG Flight (from Table 2)	12.4	amps
Hours Electrical Power Required	x0.5	hours
Amp Hours Required for EMG Operation	**6.2**	**amp-hours**
Battery Amp Hours Available	7.7	amp-hours
Amp required for EMG flight(from Table 2)	÷12.4	amps
Hours Battery Power is Available	**0.62**	**hours**

The aircraft battery can supply the Essential bus for approximately 0.62 hours in case of an alternator failure.

Comparison to Diamond Aircraft Industries' Original Electrical Load Analysis, Document No. 6.07.02 Ch O-067/23.1351.

Updated Amps Required with Failure of Alternator (from Table 2)	12.4	amps
Original Amps Required with Failure of Alternator	-7.9	amps
Amps required from Old Equipment to New Equipment	**4.3**	**amps**
Original Amps Required with Failure of Alternator	÷7.9	amps
Change in Amps Required from Old Equipment to New Equipment	**57.0**	**%**
Updated Hours Battery Power is Available	0.62	hours
Original Hours Battery Power is Available	-0.9	hours
Change in hours Battery is available from Old to New Equipment	**-0.28**	**hours**
Original Hours Battery Power is Available	÷0.9	hours
Percent Change from Old to New Equipment	**-31.0**	**%**

5.2 Emergency Battery Analysis

Table 3 below shows the total current draw of the electric system in the DA 40 when the aircraft is running off the emergency batteries and only the attitude indicator and the flood lighting powered. A prerequisite for the GFC700 STC installation includes installation of the MCI Standby Attitude Indicator in the DA40. Table 3 below reflects this load. The result of this table is then used in analysis to determine how long the emergency power pack can sustain this configuration. Please note that this emergency power pack contains Lithium batteries and is installed on every DA40 aircraft with the G1000 / GFC700 installation. The values shown in Table 3 for the Flood Light were derived from Diamond Aircraft Industries' Original Electrical Load Analysis, Document No. 6.07.02 Ch O-067/23.1351.

LOAD	CURRENT DRAW	DCF	REQUIRED AMPS
Standby Attitude Indicator	0.55	1.00	0.55
Flood Light	0.50	1.00	0.50
		Total	**1.05**

Table 3, Emergency Battery Load

The following calculations show the amount of time the emergency battery can supply the standby instruments' power and lighting requirements. The conservative Amp-Hours value for this calculation was derived from Diamond Aircraft Industries' Electrical Load Analysis Report for the Lithium Emergency Power Pack, Document No. 6.07.02 Ch O-179/23.1351.

Emergency Battery Amp Hours Available	1.3	amp-hours
Amps Required for EMG Operation (from Table 3)	÷1.05	amps
Hours Emergency Battery Power is Available	**1.24**	**hours**

The emergency battery has sufficient capability to power the standby attitude indicator and standby instruments' lighting for the minimum 30 minute operational requirement subsequent to a total electrical system failure.

5.3 Avionics Bus Load Analysis

Table 4 below shows the total current draw of the Main Avionics bus in the DA 40. Refer to Figure 1 for power distribution. The results of this table are compared to the maximum amperage allowed by the Main Avionics Bus.

LOAD	CURRENT DRAW
No. 2 GDU1042	2.50
No. 2 GIA63 TX	4.30
No. 2 GIA63 RX	1.00
No. 2 GIA63 Other Functions	1.00
Pitch Servo	0.50
Roll Servo	0.50
Trim Servo	0.50
GDL69A	0.35
DME	0.54
ADF	1.10
Total	**12.29**

Table 4 –Main Avionics Bus Load

The maximum allowable current draw through the Main Avionics breaker is 25 amps.

Amps Available through Main Avionics Breaker	25.00 amps
Amps Required for Main Avionics Bus (Table 4 above)	-12.29 amps
Amperage Available for Additional Avionics	**12.71 amps**

The avionics bus has sufficient capability to power the additional equipment without overloading the 25 amp Main Avionics breaker. The maximum current required from equipment is 12.29 amps.

6 SUMMARY

The analysis above demonstrates the following statements to be true:

1. The alternator output is adequate for IFR operation in accordance with § 23.1351(a)(1) and (a)(2)(i).
2. Both the ship battery and emergency battery pack are capable of supplying power to the essential load for at least 0.5 hours in accordance with §§ 23.1309 (c), (c)(1), (c)(2)(iii), (c)(3), (d), (e), and 23.1353 (h) through the following:
    1. The ship battery capacity is adequate for 0.62 hours of IFR operation for the systems on the Essential bus in case of an alternator failure.
    2. The emergency battery capacity is sufficient for 2.7 hours of emergency operation in case of an alternator failure and a total discharge of the ship battery. The emergency battery pack powers an attitude indicator and the flood lighting in accordance with § 23.1311 (a)(5).
3. The DA 40 is an un-pressurized piston powered aircraft that does not require any special equipment (i.e. pressurization system controls, oxygen controls, etc.) to be powered at its maximum demonstrated altitude of 16,000 feet. This analysis shows that the aircraft battery can supply power to the essential avionics for at least 5 minutes when the aircraft is operating at its maximum demonstrated altitude, with critical fuel and the alternator fails. This analysis shows compliance to § 23.1351 (g)

    The following paragraph was taken from the NPRM comments that proposed paragraph (g) to 23.1351 via Amendment 23-43.

Conference proposal 456 recommended adding paragraph (g), essentially as proposed herein except the requirement would only be applicable for airplanes operated above 25,000 feet. The justification was that part 23 airplanes that operate at high altitudes above 25,000 feet depend upon electrical power for safe operation. Emergencies involving loss of normal electrical power at or above this altitude typically result in the loss of other systems, such as electric fuel pumps, pressurization system, warning system, navigation, communications, and instrumentation. The FAA developed special conditions for part 25 that initiated the requirement in this proposal and it was later adopted into part 25 by amendment 25.41, in 1977. Conference proposal 456 was essentially developed from the part 25 requirements except for the 25,000 foot applicability. When offered for comment at the conference, there were no objections on conference proposal 456. After further review, FAA has concluded that the proposal should not be limited to airplanes that operate above 25,000 feet since emergencies resulting in the loss of normal electrical power are critical for all airplanes. Five minutes is considered adequate time to cope with such an emergency so that pilot can operate the airplane safely and assess the reason for the loss of normal electrical power.

Critical fuel is not assessed when the DA 40 aircraft is operating at its maximum demonstrated altitude. The electrical system is simple enough for the pilot to troubleshoot, and there is more than adequate battery power left for the pilot to operate the aircraft at this altitude for five minutes independent of fuel status.

4. The Avionics bus has sufficient capability to power the additional equipment without overloading the 25 amp Main Avionics breaker. The maximum current required from equipment is 12.29 amps.