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应用指南 AN-3001

光耦合器输入驱动电路

光耦合器由一个光源和一个光敏检测器组成。在光耦合器或光子耦合对中，耦合依靠一个透明绝缘间隙一侧产生、另一侧检测到的光实现，两侧之间不存在电气连接（少量耦合电容除外）。在飞兆半导体光耦合器中，光是由红外发光二极管产生的，光检测器是一个驱动放大器（如晶体管）的硅二极管。硅材料的灵敏度在 LED 发射的波长处达到最大值，提供最大信号耦合。

由于光耦合器的输入是一个 LED，其输入特性都相同，与所采用的检测器类型无关。图 1 显示 LED 二极管的特性。正向偏置电流阈值出现在约 1 伏特处，电流成指数增加， I_F 的可用范围介于 1 mA 与 100 mA 之间，对应 V_F 的范围介于 1.2 与 1.3 伏特之间。正向偏置电阻的动态值与电流相关，如图中定义的 R_{DF} 和 DR 插图所示。在雪崩击穿前，反向漏电流处于毫微安范围内。

图 2 显示 LED 等效电路以及各组件的典型值。若需要电脑制模，可参考提供的二极管方程式，此外还提供了 IR LED 的方程式常数。注意，结电容非常大，并随应用的正向电压的增大而增大。图 3 绘制出该电容随应用电压的实际变化图。该大电容被驱动电阻控制，从而影响 LED 的脉冲响应。在结电流导致发光前，必须对电容进行充电。这种效应会在快速脉冲条件下，在应用电流和发光之间产生 10-20 毫微秒或更长的固有延迟。

LED 适用于正向偏置模式。由于电流在超过阈值后增速非常快，器件应始终在电流模式（而非电压模式）下驱动。实现电流驱动最简单的方式是提供一个串联限流电阻，如图 4 所示。这样， V_{APP} 和 V_F 之间的差值在目标 I_F 下通过电阻降低（根据其它标准确定）。硅二极管与 LED 反向并联安装。该二极管用于防止 LED 反向击穿，这是实现这种保护功能最简单的方法。在反向雪崩区域，必须防止 LED 过量耗散功率。少量反向电流不会伤害 LED，但是必须防止意外的浪涌电流。

LED 的正向电压有一个负温度系数 1.05 mV/°C，其变化如图 5 所示。

IR LED 的亮度作为正向电流 (I_F) 和时间的函数以指数形式缓慢降低。图 6 是根据 20,000 小时的实验数据绘制的光衰图。50% 的衰减量被认为是失效点。必须在光隔离器电路设计之初考虑衰减量，从而在设备的整个设计周期内允许降低，但仍符合电流传输比 (CTR) 的设计规格。此外，还显示 I_F 的驱动限制，用于延长器件的使用寿命。

在某些情况下，需要为 LED 采用一个高于二极管 V_F 1.1 V 标准电压的固定阈值。通过采用一个电阻对 LED 进行分流可实现这种阈值调整，电阻值由应用电压、串联电阻和所需阈值之间的比例决定。图 7 电路显示这些值之间的关系。计算将决定特定 I_{FT} 和 V_A 所需的电阻值。将多个 LED 串联起来共享同一个 I_F 也很合适。串联 V_F 为各个 V_F 的总和。串联中还可以使用齐纳二极管。

由于输入应用电压是可逆或可交替的，且需要检测输入的相位或极性，可采用双极输入电路，如图 8 所示。各个光耦合器可以控制不同功能，或进行并联，从而不受极性影响。注意，在此连接中，各个 LED 在反向偏置中保护彼此。

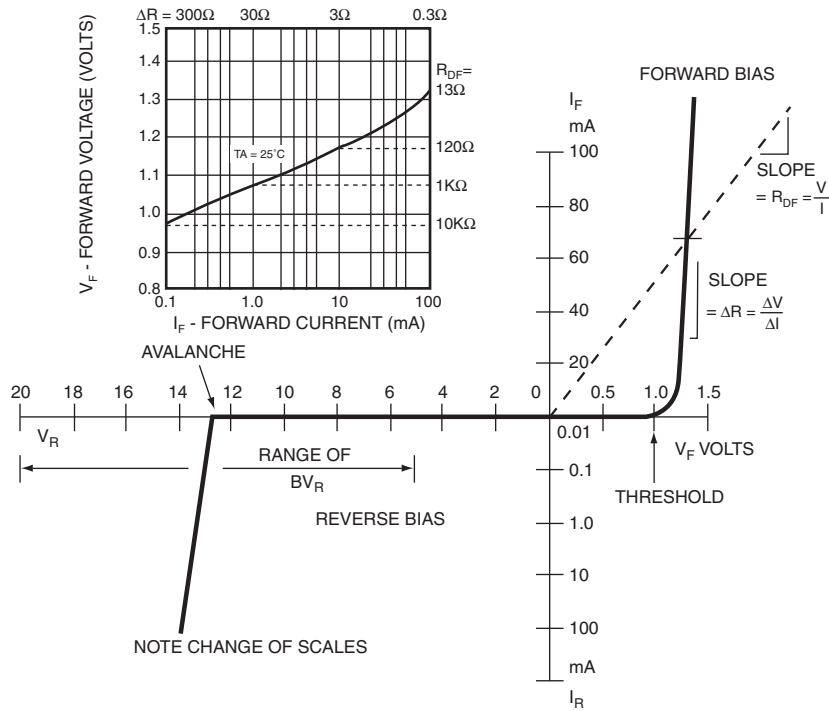
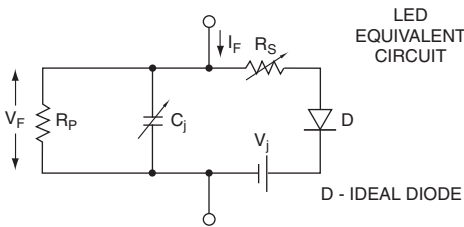


图 1. IR LED 的特性



V_F	-5	0	-	-	-	V
I_F	-	-	1	10	100	mA
C_j	55	100	300	500	-	pF
V_j	1.0	1.1	1.2	1.3	-	V
I_R	<10	0	-	-	-	nA
R_S	∞	30	3	0.3	-	Ω
R_P	>10 ⁹	-	-	-	-	Ω

$$I_F = I_{FT} \exp \frac{V_F - V_{FT}}{k}$$

$$V_F = V_{FT} + k \log \frac{I_F}{I_{FT}}$$

For IRLED (940nm)

$$V_{FTH} = 0.98V$$

$$I_{FTH} = 0.10mA$$

$$K = 0.360$$

$$R_S = \frac{0.03V}{I_F(A)}$$

图 2. 等效电路方程式

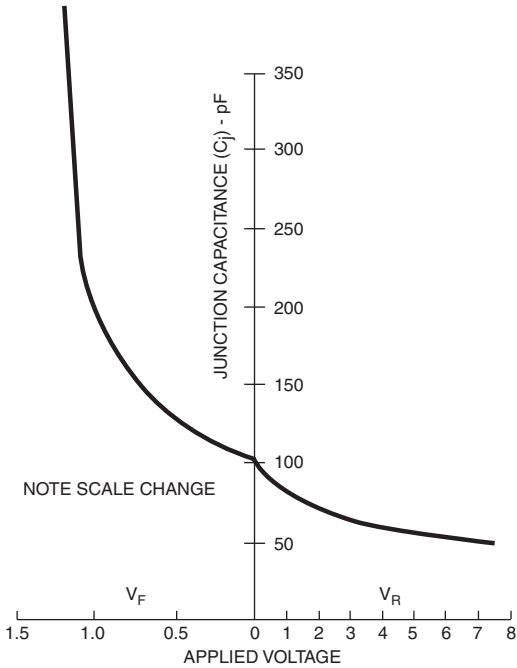


图 3. 结电容与电压的相关性

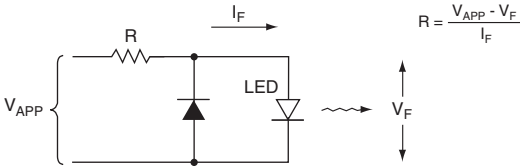


图 4. 典型 LED 驱动电路

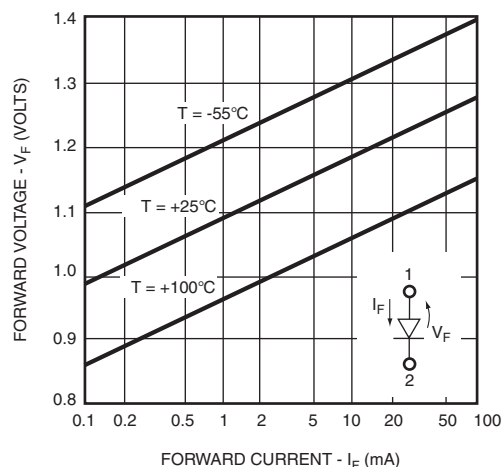


图 5. IR 正向电压与正向电流和温度

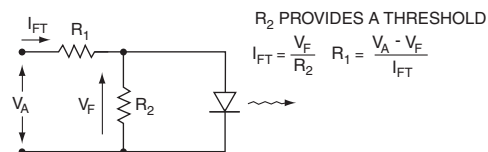


图 7. LED 阈值调整

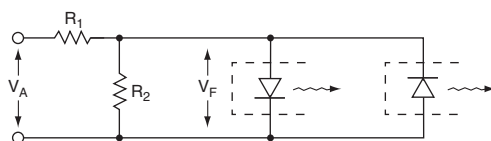


图 8. 双极输入选择

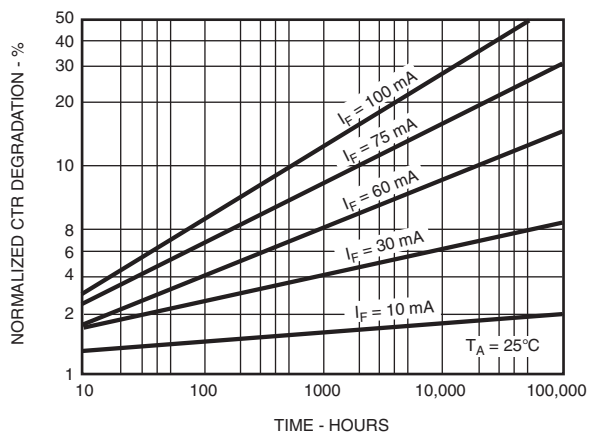


图 6. 亮度衰减与正向电流和时间

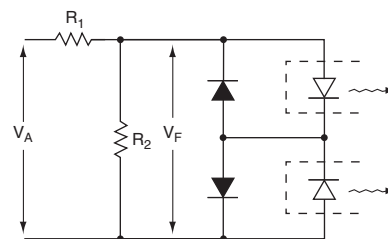


图 9. 高阈值双极输入

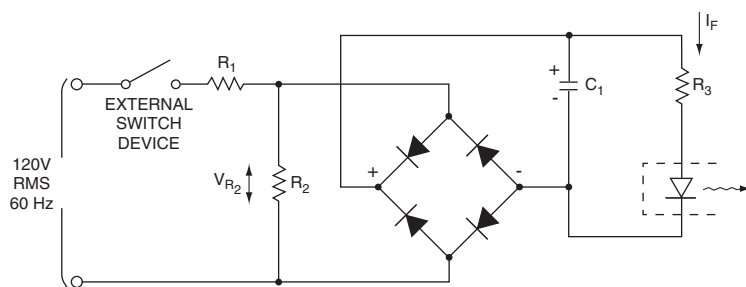


图 10. LED 驱动电路的交流输入

图 9 显示获取高抗噪能力高阈值的另一种方法，其中，各个 LED 与反向并联二极管反向串联，从而传导极性相反的电流。在该电路中， V_F 是串联 LED 和硅二极管的正向总压降。电阻用于实现标准阈值和限流功能。硅二

极管可以由其它光耦合器或可视信号指示灯中的 LED 取代。

AC 电源监控

在某些情况下，可能需要从 120 VRMS、60 Hz 或 400 Hz 电源驱动 LED。由于 LED 的响应时间以纳秒为单位，因此将严格遵循交流振幅，在每次输入过零时开关。若要光耦合器检测器提供恒定的交流输出至逻辑耦合，则需要对 LED 的输入进行整流和滤波。图 10 电路显示一个简单的滤波方案，能够为 LED 提供直流电流。在某些情况下，可以将滤波器设计在光耦合器的检测器侧，从而允许 LED 以线路频率施以脉冲。在图 10 电路中， C_1 值的选择旨在减小半个周期期间的 I_F 变化（低于检测器部分可以检测到的电流）。这种情况通常说明检测器正以饱和状态运行，因此将感应不到 I_F 的小幅变动。通过调整 R_1 、 R_2 和 R_3 的值能够优化滤波功能和 R_3C_1 时间常数等。关断速度可能是一个决定因素。可能需要更复杂的晶体管滤波，如图 11 所示，其中可以设计明确的时间延迟、上升时间和下降时间。在该电路中， C_1 和 R_3 的基本功能相同，如图 10 所示。晶体管为 R_4C_2 滤波网络提供高阻抗负载，一旦达到 V_F 值，将突然导通 LED 并将晶体管快速拉至饱和。关断瞬态包含 C_1 放电、通过 R_3 和 LED。

逻辑对逻辑接口

在采用光耦合器的逻辑对逻辑耦合中，可以使用一个简单的晶体管驱动电路，如图 12 所示。LED 通常为关断状态，只有在晶体管处于饱和状态时才会被通电。下面给出了设计方程式，用于计算串联限流电阻的值。晶体管关断时，只有少量集电极漏电流通过 LED。若光耦合器检测器能够检测到此小漏电流，可通过添加另一个 LED 并联电阻（显示为 R_1 ）使漏电流绕过 LED。 R_1 的值可以很大，对其进行计算从而保证漏电流不会超过图 5 中的阈值电压 V_F （~0.8 伏特）对应的电流。驱动晶体管可以是 TTL 或 DTL 集成电路的标准输出灌电流，0.2 伏特下的标称灌电流为 16 mA，饱和状态下可高达 50 mA。

若逻辑不能实现必要的灌电流 I_F ，可以采用辅助驱动晶体管来提升电流能力。图 13 电路显示如何连接一个 PNP 晶体管作为发射极跟随器或普通的集电极来获得电流增益。当栅极 (G_1) 输出较低时， Q_1 被导通，电流通过 LED。现在， R_1 的计算必须包含基极 - 发射极正向偏置压降 V_{BE} ，如图所示。

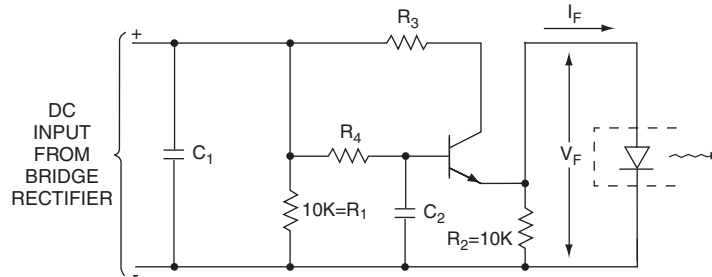


图 11. R-C- 晶体管滤波电路

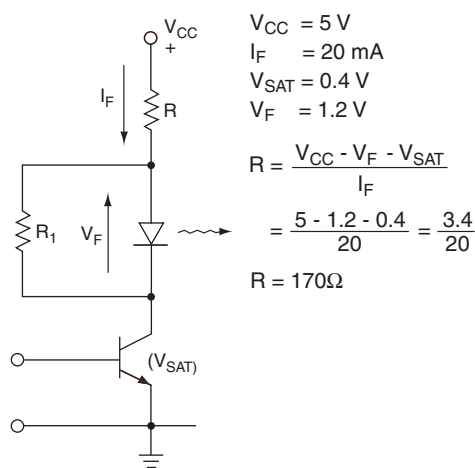


图 12. 晶体管驱动，通常为关断状态

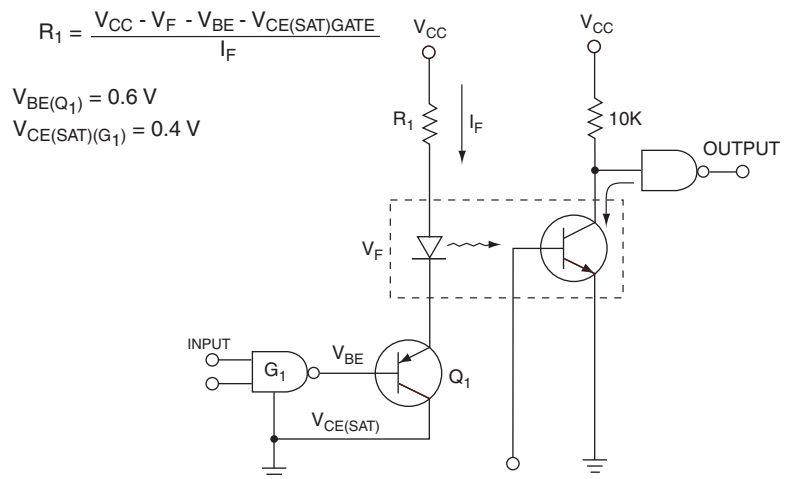


图 13. LED 串联升压器逻辑

当晶体管通常为导通状态时（如图 14 所示），需要使用低于阈值 V_F 的 V_{SAT} 对 LED 的 I_F 进行分流。典型开关晶体管的饱和电压低于 0.4 伏特（ $I_C = 20\text{ mA}$ 或更低）。确定串联电阻的值，从而在晶体管关断时提供所需的 I_F 。

若逻辑仍不能提供所需的灌电流 I_F ，可以采用一个升压晶体管，如图 15 所示。栅极输出较低时，晶体管 Q_1 会被导通，且 G_1 的 V_{CE} （饱和）和 Q_1 的 V_{BE} 之和将低于 LED 的阈值 V_F 。栅极输出较高时， Q_1 不导电且 LED 导通。可以正常计算 R_1 的值，但分路电流比 I_F 大。通常为导通或关闭状态的选择取决于光耦合器检测器部分的所需功能和电路的故障安全操作。

在很多应用中，需要将 LED 值脉冲驱动至超过器件的直流额定值。在这种情况下，“脉冲”被定义为在

LED、引线框和环境之间建立热平衡前出现并结束的导通 - 关断瞬态。这种平衡通常在一毫秒内出现。对于微秒范围内的脉冲，若占空比较低， I_F 可以被驱动超过直流额定值。图 16 中的图表显示过驱量、占空比和脉冲宽度之间的关系。过驱规范为器件数据表中列出的最大 I_{DC} 值。占空比较高、脉冲宽度较短时，平均功耗为限制性参数。对于较长的脉冲宽度，在占空比值较低时出现平衡温度，此时峰值功率为限制性参数。

占空比为 1% 或更低时，脉冲类似偶然出现的浪涌，允许采用其它额定值，如整流二极管中使用的 I^2t 。生命周期计算中应采用平均电流。在选择驱动条件时，必须考虑检测器的脉冲响应。

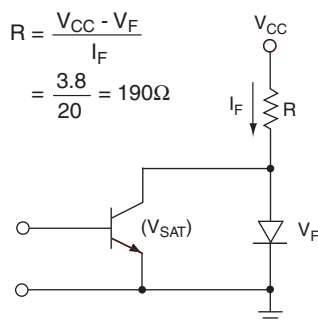


图 14. 晶体管驱动，通常为导通状态

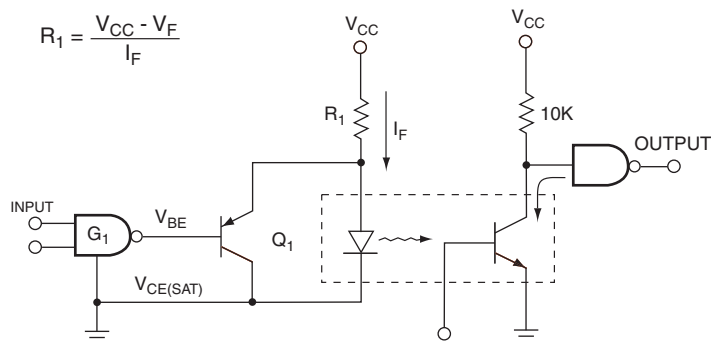


图 15. LED 并联升压器逻辑

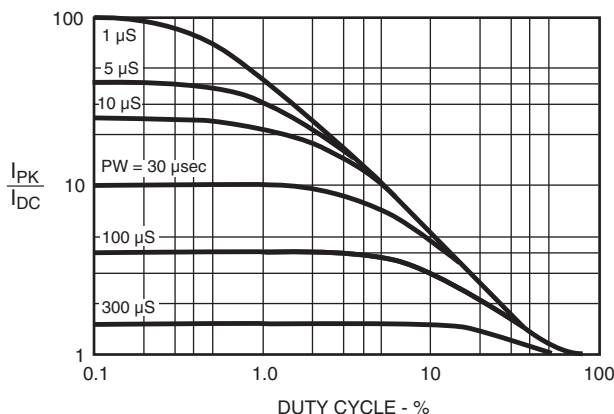


图 16. 最大峰值 I_F 脉冲，规范为最大 I_{DC}
(适用于脉冲宽度 (PW) 和占空比 (%))

LED 分流技术

有时，不希望输入电流全部通过 LED。要达到此目的，可以采用图 7 中推荐的旁通电阻来调整阈值。当完全打开或关闭输入电流时，这种方法非常适用，但若电流信息仅为恒定直流电平上的小幅变动时，旁通电阻同时旁通了 LED 需要的大部分信号。有两种方法可用来获取具有少量削减的信号。若信号变化迅速（如电话线路上的音频信号），可通过反馈电路取消检测器中的直流分量。若信号变化较慢，可以用动态分流电阻取代固定电阻。若采用恒流器件或电路与 LED 并联（如图 17 所

示），经过调整的直流分量会通过动态电阻，电流的任何变动都将导致终端电压的改变。因此，经过一系列变化的电流将通过并联 LED 电路。图 18 显示这个经过调整集中于 $I_L = 120 \text{ mA}$ ，且电路节点电压为 3.4 伏特的特定电路的性能。如电路所示，为方便起见，采用 CNY17-1 和 CNY17-4 的检测器部分。注意，在图 18 中，多数电流变化显示为 I_F 。直流电阻 (R_D) 和动态分流电阻 (R_d) 之间的比例为 50，表示通过固定电阻获得的信号传输增益。

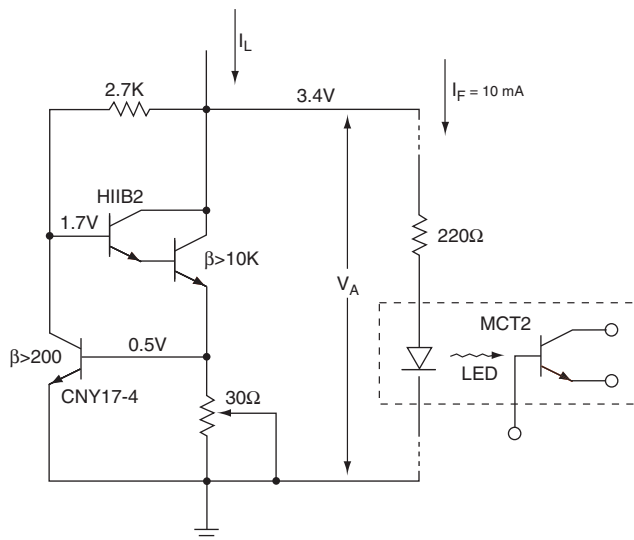


图 17. 恒定分流电阻

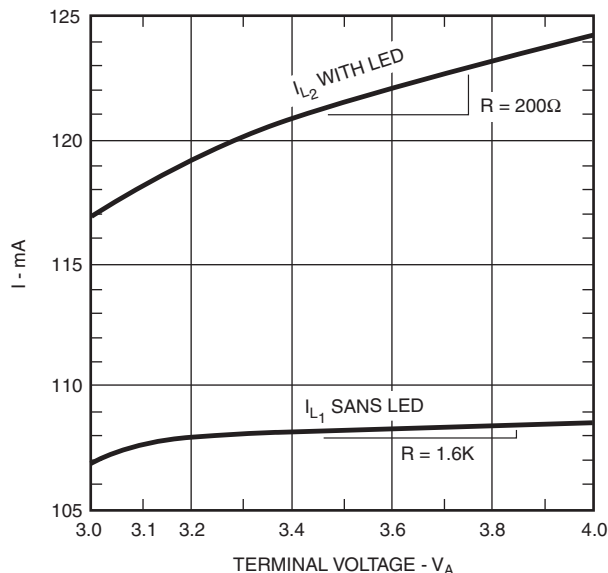


图 18. 分流电阻的性能

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